GENIV PRODUCT USER MANUAL

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Version AB
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Siemens Energy & Automation, Inc.

Large Drives A

For the support representative nearest you, please call Siemens main office at 724.339.9500.

Version History

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Safety Precautions and Warnings

The GenIV is designed with considerable thought to personal safety. However, as with any piece of high power equipment, there are numerous internal connections that present potentially lethal voltages. In addition, some internal components are thermally hot to the touch. Follow the warnings below when working in or near the GenIV System.

Danger - Electrical Hazards!

- **Always** follow the proper lock-out/tag-out procedures before beginning any maintenance or trouble-shooting work on the drive.
- **Always** follow standard safety precautions and local codes during installation of external wiring. Protective separation must be kept between extra low voltage (ELV) wiring and any other wiring as specified in IEC61800-5-1.
- **Always** work with one hand, wear insulated or rubber safety shoes, and wear safety glasses. Also, always work with another person present.
- **Always** use extreme caution when handling or measuring components that are inside the enclosure. Be careful to prevent meter leads from shorting together or from touching other terminals.
- **Use** only instrumentation (e.g., meters, oscilloscopes, etc.) intended for high voltage measurements (that is, isolation is provided inside the instrument, not provided by isolating the chassis ground of the instrument).
- **Never** assume that switching off the input disconnect will remove all voltage from internal components. Voltage is still present on the terminals of the input disconnect. Also, there may be voltages present that are applied from other external sources.
- **Never** touch anything within the GenIV cabinets until verifying that it is neither thermally hot nor electrically alive.
- **Never** remove safety shields (marked with a HIGH VOLTAGE sign) or attempt to measure points beneath the shields.
- **Never** run the drive with cabinet doors open. The only exception is the control cabinet which contains extra low voltages (ELV).
- **Never** connect any grounded (i.e., non-isolated) meters or oscilloscopes to the GenIV system.
- **Never** connect or disconnect any meters, wiring, or printed circuit boards while the drive is energized.
- **Never** defeat the instrument's grounding.
- **Only** qualified individuals should install, operate, troubleshoot, and maintain this drive. A qualified individual is "one familiar with the construction and operation of the equipment and the hazards involved."
- **Hazardous voltages** may still exist within the GenIV cabinets even when the disconnect switch is open (off) and the supply power is shut off.
- When a system is configured with drive bypass switchgear (e.g., contactors between line and motor, and drive and motor), these switches should be interlocked so that the line voltage is **never applied** to the drive output if the medium input voltage is removed from the drive.

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Warning!
- **Always** comply with local codes and requirements if disposal of failed components is necessary (for example, CPU battery, capacitors, etc.).
- **Always** ensure the use of an even and flat truck bed to transport the GenIV drive system. Before unloading, be sure that the concrete pad is level for storage and permanent positioning.
- **Always** confirm proper tonnage ratings of cranes, cables, and hooks when lifting the drive system. Dropping the cabinet or lowering it too quickly could damage the unit.
- **Never** disconnect control power while medium voltage is energized. This could cause severe system overheating and/or damage.
- **Never** store flammable material in, on, or near the drive enclosure. This includes equipment drawings and manuals.
- **Never** use fork trucks to lift cabinets that are not equipped with lifting tubes. Be sure that the fork truck tines fit the lifting tubes properly and are the appropriate length.

ESD Sensitive Equipment!
- Always be aware of electrostatic discharge (ESD) when working near or touching components inside the GenIV cabinet. The printed circuit boards contain components that are sensitive to static electricity. Handling and servicing of components that are sensitive to ESD should be done only by qualified personnel and only after reading and understanding proper ESD techniques. The following ESD guidelines should be followed. Following these rules can greatly reduce the possibility of ESD damage to PC board components.
- Always transport static sensitive equipment in antistatic bags.
- Always use a soldering iron that has a grounded tip. Also, use either a metallic vacuum-style plunger or copper braid when desoldering.
- Make certain that anyone handling the GenIV printed circuit boards is wearing a properly grounded static strap. The wrist strap should be connected to ground through a 1 megohm resistor. Grounding kits are available commercially through most electronic wholesalers.
- Static charge buildup can be removed from a conductive object by touching the object to a properly grounded piece of metal.
- When handling a PC board, always hold the card by its edges.
- Do not slide printed circuit boards across any surface (e.g., a table or work bench). If possible, perform PCB maintenance at a workstation that has a conductive covering that is grounded through a 1 megohm resistor. If a conductive tabletop cover is unavailable, a clean steel or aluminum tabletop is an excellent substitute.
- Avoid plastic, Styrofoam™, vinyl and other non-conductive materials. They are excellent static generators and do not give up their charge easily.
- When returning components to Siemens LD A, always use static-safe packing. This limits any further component damage due to ESD.

Additional safety precautions and warnings appear throughout this manual. These important messages should be followed to reduce the risk of personal injury or equipment damage.

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About This Manual

Separation of Manuals

This manual is one component of a series of manuals intended for use with the Robicon Perfect Harmony series of Medium Voltage (MV) Pulse Width Modulated (PWM) Variable Frequency Drives (VFD). Each part in this series is for use by individuals having unique job functions and qualifications. The manuals in this series are listed below:

- The *GenIV Product User Manual* (A5E01454341C)

- *GenIV Commissioning and Maintenance Manual* (A5E01454341D)

- *NXG ToolSuite Software User Manual* (A1A902291)

- *NXG Communications Manual* (A1A902399)

- *NXG Control Manual* (A1A19001588)

The *GenIV Product User Manual* (A5E01454341C) defines the configuration and capabilities of the Perfect Harmony family of Medium Voltage Variable Frequency Drives and specifically addresses the GenIV configuration.

The *GenIV Commissioning and Maintenance Manual* (A5E01454341D) provides a detailed description of how the system is transported, installed, and maintained at the customer's site.

The *NXG ToolSuite Software User Manual* (A1A902291) provides a detailed description of ToolSuite, a PC-based application that integrates various software tools used for NXG based Drives. The NXG ToolSuite is a high-level GUI that runs on a PC that is equipped with the Microsoft Windows operating system. The NXG control and the PC running the NXG ToolSuite communicate using Ethernet and TCP/IP protocol.

The *NXG Communications Manual* (A1A902399) describes the NXG control communication board, which enables network communication via a variety of protocols and enables modem connection.

The *NXG Control Manual* (A1A19001588) describes the NXG control system. The Harmony family of drives is a collection of MV drives with different power topologies and cooling methods. The unifying factor with the drives is the NXG control system - a second generation control for the Harmony line.

All manuals contain a readers' comments form. Please complete these forms and return them to us. Monitoring your feedback allows us to continue to exceed your expectations and provide complete, effective, easy-to-use product documentation.

Reference Tools

Many steps have been taken to promote the use of this manual as a reference tool. Reference tools include the following:

- A thorough table of contents for locating particular sections or subsections

- Chapter number thumb nails in the outer margins for easy location of chapters

- Special text styles are applied to easily differentiate between chapters, sections, subsections, regular text, parameter names, software flags and variables, and test points

- A comprehensive index

If you have any comments or suggestions to improve the organization or increase the usability of this manual, please complete the Readers' Comments Form located at the end of this manual and return it to Siemens LD A Document Control.

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Conventions Used in this Manual

The following conventions are used throughout this manual:

- The terms "Perfect Harmony," "VFD," "variable frequency drive," and "drive" are used interchangeably throughout this manual.

> **Note:** Hand icons in the left margin alert readers to important operational or application information that may have special significance. The associated text is enclosed in a border for high visibility.

> **Attention!** Attention icons in the left margin alert readers to important safety and operational precautions. These notes warn readers of potential problems that could cause equipment damage or personal injury. The associated text is enclosed in a border for high visibility.

> **Caution - Electrical Hazard!** Electrical hazard icons in the outer margins alert readers to important safety and operational precautions. These notes warn readers of dangerous voltages, potential safety hazards, or shock risks that could be life threatening. The associated text is enclosed in a border for high visibility.

> **ESD Warning!** These icons in the left margin alert readers to static sensitive devices. Proper electrostatic discharge precautions should be taken before proceeding or handling the equipment.

- Chapter numbers are highlighted in the outer margins to facilitate referencing (see margin)
- Test points and terminal block designations are shown in uppercase, boldface (e.g., **TB1A**)

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1   Overview

The Robicon Perfect Harmony series of Medium Voltage (MV) Pulse Width Modulated (PWM), Variable Frequency Motor Drives (VFD) are designed and manufactured by Siemens LD A, New Kensington, PA, USA with additional manufacturing facilities in Europe, Asia, and South America. The Harmony VFD is intended for use with standard medium-voltage three-phase AC induction, synchronous, wound rotor, permanent magnet, or super conducting motors. When any of these types of motor is connected to a utility supply at a fixed frequency (i.e., 60 or 50 Hz), the motor runs at a single speed. The Harmony series of drives allows variable speed motor operation without sacrificing any of the desirable properties of the motor.

1.1 Purpose

This manual defines the configuration and capabilities of the Perfect Harmony family of Medium Voltage Variable Frequency Drives and specifically addresses the GenIV configuration. Detailed descriptions of the common features of the Harmony drive family are defined in the following manuals:

Companion Manuals:

- *GenIV Commissioning and Maintenance Manual* (A5E01454341D)

- *NXG ToolSuite Software User Manual* (A1A902291)

- *NXG Communications Manual* (A1A902399)

- *NXG Control Manual* (A1A19001588)

1.2 Introduction

The Perfect Harmony VFD is based on a patented (U.S. patent #5,625,545) multi-level output topology. Medium voltage levels are obtained by adding together the outputs of multiple low-voltage power cells. The low-voltage power cells are simplified variations of standard PWM motor drives for low-voltage service, which have been built in high volume for many years.

The Harmony series drives achieve this uncompromised performance by employing time-proven technology in a simple configuration. Figure 1-1 shows a typical power circuit topology for a 4160 Volt Perfect Harmony series drive, using 750 VAC power cells. In this configuration, each motor phase is driven by 3 power cells connected in series. The groups of power cells are wye connected with a floating neutral. Each cell is powered by an isolated secondary winding of an integral isolation transformer. The nine secondaries are each rated for 750 VAC at one ninth of the total power. The power cells and their associated transformer secondaries are insulated from each other and from ground for 5 kV class service or "according to the output voltage rating of the drive."
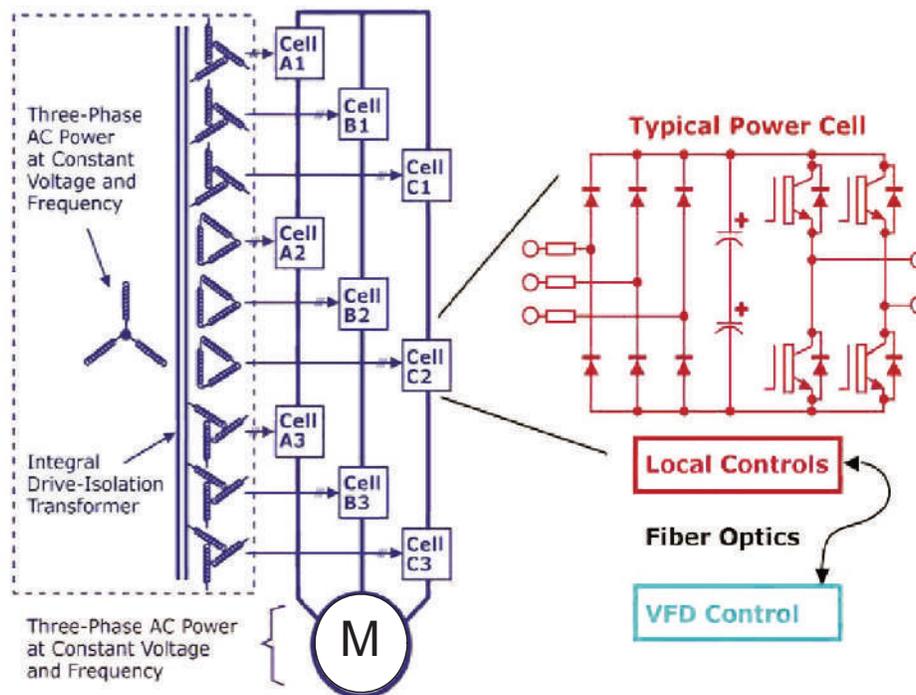
Figure 1-1: Harmony Topology

For higher output voltage capabilities, Figure 1-1 would be extended to have up to 8 power cells in series in each phase, with additional secondary windings (number of secondaries equals number of power cells) on the integral isolation transformer.

Each power cell is simply a static power converter. It is capable of receiving input power at 750 VAC, 3-phase, 50/60 Hz and delivering that power to a single-phase load at a variable frequency from 0.5 to the maximum rated output frequency of the drive.

1.2.1 Clean Power

Prior to the introduction of the Perfect Harmony Drive, other solutions with variable frequency output power conversion created unwanted line disturbance (refer to Figure 1-2, six-pulse and twelve-pulse input waveforms).

The Perfect Harmony drive system mitigates power quality issues by:

- Providing clean power input (low values of flicker, TIF, harmonic current distortion)
- Providing a high power factor
- Providing a nearly perfect sinusoidal output

The Perfect Harmony drive series meets the most stringent IEEE 519-1992 requirements for voltage and current harmonic distortion, even if the source capacity is no larger than the drive rating. This series protects other on-line equipment (such as computers, telephones, and lighting ballasts) from harmonic disturbances. Perfect Harmony also prevents "cross talk" with other variable speed drives. Clean power input eliminates the need for time-consuming harmonic/resonance analyses and costly harmonic filters. Figure 1-2 illustrates harmonic distortion waveforms for a typical 6-pulse, a typical 12-pulse, and the Perfect Harmony series drive.
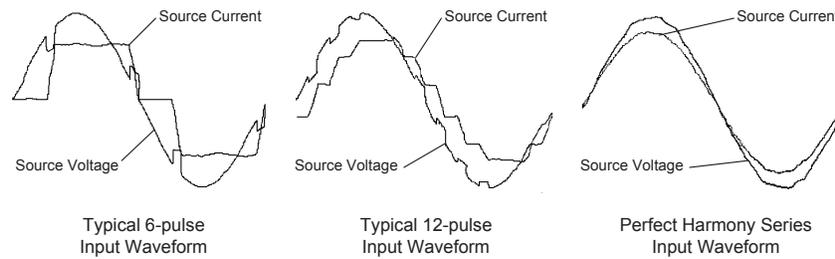
Figure 1-2: Harmonic Distortion Wave Form Comparisons (6-pulse, 12-pulse, and Perfect Harmony)

Total harmonic distortion of the source current is 25% for the 6-pulse, 8.8% for the 12-pulse, and 0.8% for the Perfect Harmony. The corresponding voltage distortions with a typical source impedance are 10%, 5.9%, and 1.2%, respectively.

> **Note:** The above comparisons were done using a typical 1000 Hp current source drive (6-pulse and 12-pulse modes), and a Perfect Harmony series drive operating from an 1100 kVA, 5.75% impedance source.

1.2.2   High Power Factor

Power factor is a measure of the fraction of current that produces real power to the load. Typically, power factor is given as a percentage. A high power factor VFD (e.g., 94%) makes much better use of its input line current demand in producing real power to the motor than a VFD operating at a low power factor (e.g., 30%). VFDs having a low operating power factor often generate square-wave-shaped line currents. This can lead to harmonics and other associated resonance problems.

The Perfect Harmony series draws nearly perfect sinusoidal input currents having a power factor that exceeds 94% throughout the entire output frequency range without the use of external power factor correction capacitors. This eliminates utility penalties for power factor and demand charges, and improves voltage regulation. In addition, feeders, breakers, and transformers are not overloaded with reactive power. Low speed applications specifically benefit from the Perfect Harmony series, since a high and stable power factor is maintained throughout the entire output range using standard induction motors. Figure 1-3 compares graphs of power factor versus percent speed for the Perfect Harmony series and a typical phase-controlled SCR drive.
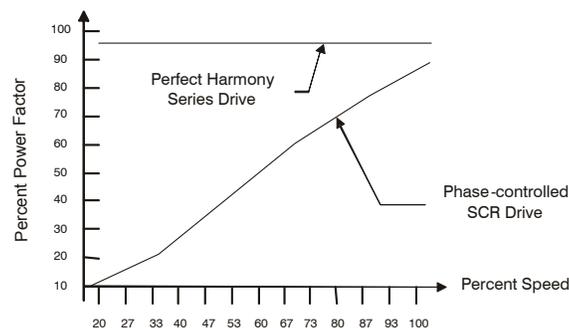
Figure 1-3: Comparison of Perfect Harmony and a Typical Phase-Controlled SCR Drive

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1.2.3 Nearly Perfect Sinusoidal Output Voltages

The design of the Perfect Harmony series of variable frequency drives inherently provides a sinusoidal output without the use of external output filters. This means that the drive provides a low-distortion output voltage waveform that generates no appreciable audible motor noise. In addition, there is no need to derate motors (the drive can be applied to new or existing 1.0 service factor motors). In fact, Perfect Harmony drives eliminate harmful VFD-induced harmonics that cause motor heating. Similarly, VFD-induced torque pulsations are eliminated (even at low speeds), thereby reducing the stress on mechanical equipment. Common mode voltage stress and dv/dt stress are also minimized. A typical graph of the output current from a Perfect Harmony drive is illustrated in Figure 1-4.

Figure 1-4: Nearly Sinusoidal Wave Form of the Output Current from a Perfect Harmony Drive

Unlike standard PWM Systems, the voltage applied to the motor leads is developed in many small steps instead of a few large steps. This provides two distinct advantages: the voltage stress on the motor leads is dramatically reduced, and the quality of the motor currents is dramatically increased.

The staircase multilevel Perfect Harmony inverter output can produce 2N+1 voltages (where N= # cells per phase) from line to neutral. The ability to generate many different voltage levels allows the Perfect Harmony to synthesize an accurate approximation of a sinusoidal output waveform.

1.3 Perfect Harmony Features

The features of the Perfect Harmony family of Medium Voltage drives are summarized as follows:

- Truly Scalable Technology with modular construction

    o Air Cooled: GenIV, GenIIIe, GenIII NBH

    o Liquid Cooled: WCIII, HV

- 200 to 40000 Hp (150 kW to 30 MW)

- Wide range of Motor Voltages Supported

    o 2300 VAC through 13800 VAC

- Low Harmonic Input

- High Efficiency and Power Factor

- Line Disturbance Immune

- Compatible with new or existing motors

- Power Cell Bypass with floating neutral point control

- Negligible Torsion

- Wide Range of Connectivity to industrial PLC Networks

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- Parallel drive control

- Multi-motor control

- Long cable compatible

- Synchronous line/load transfer capability

- Inherent input/output metering

- Coordinated input protection scheme

- Dual frequency braking

- ProToPS^{TM}

- Partial or fully regenerative (4Q)

1.3.1   Harmony VFD Family Features

The Harmony VFD families consist of four core design configurations, where they are functionally identical and share a common controller. These four design configurations are targeted at distinct output power configurations with little overlap between the frame sizes. These drive families are summarized as follows:

☞ | **Note:** The following ratings are subject to change.

GenIV:

(Refer to Table 4-1 for full GenIV product range)

- 200 to 3500 Hp (150 - 2600 kW)

- 2.3 to 6.9 kV Output

- 2.4 to 13.8 kVAC 50/60 Hz Input

- Air Cooled

- Power Cell Ratings:

  o 750 Volts
  o 40, 70, 100,140, 200, or 260 Arms

GenIIIe:

- 3000 to 9000 Hp (2.25 - 6.75 MW)

- 2.3 to 7.2 KV Output

- 2.4 to 13.8 kVAC 50/60 Hz Input

- Air Cooled

- Power Cell Ratings:

  o 690 Volts
  o 315, 375, 500, or 660 Arms

WCIII:

- 4000 to 10000 Hp (3 MW - 14.2 MW)

- 2.3 to 8.0 kV Output

- 2.4 to 13.8 kVAC 50/60 Hz Input

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- Water Cooled
- Power Cell Ratings

     o 750 Volts
     o 880 or 1250 Arms

HV:

- 10000 to 40000 Hp (7.5 MW to 30 MW)

- 7.2 to 13.8 kV Output

- 2.4 to 13.8 kVAC 50/60 Hz Input

- Water Cooled

- Power Cells

     o 1375 Volts

     o 500, 800, or 1400 Arms

1.3.2   VFD Scalability

The Perfect Harmony Power cells provide truly scalable technology that is provided by the wide range of output power configurations offered by the power cells, and the ability to connect up to 8 cells in series for each output phase. When connected in series, the current rating for each phase is simply equal to the output current rating of the cells; the output voltage rating is simply the sum of the output voltage ratings of the cells.

☞   **Note:** Cells of different power ratings should not be intermixed.

The Control system for the Harmony is identical regardless of the output ratings of the VFD, where the only configuration differences are the feedback sensor configurations and the number of cell communication channels required. The Control is based on a per unit implementation, where the user simply enters the nameplate ratings for the Motor and VFD. The controller automatically scales itself, based on these ratings. This results in a common control implementation and "touch and feel" for all drives, regardless of the power ratings.

1.3.3   VFD Output Ratings

Using the cell output voltage rating, the output capability of the VFD can be calculated based on the number of power cells connected in series in each of the 3 output phases, which establishes the Available System Output Capability, also known as "VAVAILABLE." This is also the maximum voltage that can be supported on the output terminals of the drive when energized.

The rated output voltage of the drive is then calculated as follows:

VAVAILABLE (Volts) = 1.78 * #Cells * CellV * Vin / Vrated * TransformerTapSetting
    Where: #Cells = Number series power cells per phase
           Vin   = Measured Line Input voltage (rms)
           Vrated = Rated VFD Input Voltage (rms)
           TransformerTapSetting: use 0.95 when +5% tap on input transformer is used
                                  1.00 when 0% tap is used
                                  1.05 when -5% tap is used

☞   **Note:** Overmodulation (O-M) is used for GenIV and WCIII product families to achieve output voltages that are 5% higher than VAVAILABLE.

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The VFD Rating is then calculated using VAVAILABLE and the rated cell current.

   VFD Rating (KVA) = 1.732 * VAVAILABLE * Power Cell Continuous Current Rating.

☞ | **Note:** The VFD integral isolation transformer and cell frame are chosen in agreement with the load ratings, i.e., site conditions, cable length, and motor nameplate data (power factor efficiency, frequency, and service factor).

1.3.4   Rectifier Configuration

Each Power Cell Input is configured as a 6-Pulse uncontrolled diode rectifier. The Input transformer includes a dedicated secondary winding for each power cell, where the transformer secondaries are arranged in a delta and extended delta configuration with varying degrees of phase shift. Typical Perfect Harmony VFD configurations consist of a minimum of 3 to a maximum of 8 series power cells per output phase.

Effective Rectifier Configuration is:

- 3 Cells/Phase = 18 Pulse
- 4 Cells/Phase = 24 Pulse
- 5 Cells/Phase = 30 Pulse
- 6 Cells/Phase = 36 Pulse
- 7 Cells/Phase = 42 Pulse
- 8 Cells/Phase = 48 Pulse

1.3.5   Power Cell Bypass Option

As an option, each power cell in the drive can be equipped with a bypass contactor. This contactor will be automatically energized by the VFD master control if the associated power cell malfunctions. Once the contactor is energized, the damaged cell is no longer electrically part of the inverter system, which allows the VFD to resume operation.

Since the cells in each phase of a Perfect Harmony Drive are in series, bypassing a cell has no effect on the current capability of the drive, but the output voltage capability will be reduced. Usually the required motor voltage is roughly proportional to speed, so that the maximum speed at which the drive can fulfill the application requirements will also be reduced. Therefore it is important to maximize the motor voltage available after one or more cells have been bypassed. The Harmony control system maximizes output voltage capability using a patented technique (US Patent 5,986,909) defined as "Neutral Point Shift," which is described in Section 5.13.1 of this document.

1.3.6   Transformer Winding Configuration

Each transformer secondary winding sees typical 6-Pulse Harmonics. The transformer secondaries are wound with varying phase angles, resulting in a multi-pulse reaction. The input transformer primary winding and the line sees between 18 to 48 Pulse Harmonics, as defined by the power cell configuration. This patented topology results in nearly sinusoidal current and a high, stable input power factor across the entire load range.

- Secondary Windings see Higher Harmonics
    - o Plurality of phase staggered delta or extended delta reduces current
- Primary Winding sees Low Harmonics
    - o Harmonics reflect multi-pulse secondary configuration

The Perfect Harmony transformers are applied to motor drives using the rule of 1 kVA per Hp (see below), resulting in a transformer utilization factor of 89%. The transformer is unusual in that the secondary windings carry six pulse currents, while the primary carries nearly perfect sine waves. The total VA of the secondary windings is greater than the VA of the primary windings.

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Rated Input Current (Amps) = [(kVA rating) x 802] ÷ [√3 x Rated Primary voltage x 0.96 x 0.94]

With following assumptions used for sizing purpose:

> Motor efficiency = 93%
> VFD efficiency at full load = 96%
> Input power factor = 94%
> Output power per Hp at shaft = 746 / 0.93 = 802

Reducing this equation results in:

> Rated Input Current (Amps) = [(kVA rating) ÷ (Rated primary voltage)] x 513.11

1.3.7   Control Overview

Perfect Harmony is a simple "synchronous" control. Basic operation is summarized as follows:

- Control sends message to each power cell control via dedicated fiber links

- Cell executes request by firing one switch pair:

  > o Plus DC voltage
  > o Minus DC voltage
  > o Zero voltage

- Cell control confirms switch pair fired

- Control confirms firing from:

  > o Output voltage divider
  > o Output Hall Effect current transducer

- No two cells ever switch at the same time

- Cell switching rate is low compared to effective switching frequency of VFD:

  > o Typically 600 Hz carrier frequency per pole, results in 1200 Hz switching frequency per cell

- VFD effective switching frequency is simply the cell switching frequency times the number of cells per phase

- Switching rate is constant over the entire output frequency range

- Default control is an open flux vector control:

  > o V/Hz and closed loop (i.e., encoder) control modes also available

1.4 Applications

- Oil and gas (including long cables)

- Municipal water

- Power Generation

- HVAC

- Cement

- Chemicals

- Research

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1.5 Evolution

Historic Milestones:

1994:   World's 1st fully integrated voltage source inverter (VSI) medium voltage motor drive using IGBTs that meet IEEE 519 for input current distortion and NEMA/IEC for motor HVF (without using output step-up transformers or line/load filters).

1995:   1st IGBT-based 6.6 kV drive without an output transformer.

1996:   1st IGBT-based drive above 10000 Hp (7500 kW).

1998:   Introduction of ProToPS^{TM} and 500th Perfect Harmony drive installed.

1999:   Introduction of process-transparent cell bypass ("fast bypass") capability and neutral point shift.

2000:   1st VSI drive to operate a medium voltage synchronous motor.

2001:   1000th Perfect harmony drive installed.

2002:   1500th Perfect Harmony drive installed.

2003:   1st High Voltage 13.8 kV drive capable of operating motors from 4000 to 90000 Hp connected directly to 13.8 kV source.

2004:   Built largest PWM drive, 80000 Hp.

2006:   Introduction of smallest footprint medium voltage VFD, GenIV "MicroHarmony."

1.6 Intellectual Property

The Perfect Harmony topology and features are protected by the following patents:

5,625,545	6,222,284	6,313,600
5,986,909	6,236,580	6,411,530
6,014,323	6,262,555	6,417,644
6,166,513	6,301,130	6,762,947

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CHAPTER

2   Theory

2.1 Introduction

The Harmony series drives provide variable speed operation by converting utility power at fixed frequency and fixed voltage to variable frequency, variable voltage power. This conversion is done electronically, without moving parts. Unlike older drive types, the Harmony series does not force the user to accept unpleasant by-products of this conversion process. Specifically:

- The Perfect Harmony series drives do not inject significant harmonic distortion into the plant's distribution system. No power filters are required. No interference to sensitive equipment or resonance problems with power factor capacitors will occur.

- The Perfect Harmony series drives present a high power factor to the utility, typically 94% or better throughout the speed range. No power factor correction is required.

- The Perfect Harmony series drives do not require any derating of the motor due to output harmonics. No additional motor heating is produced, versus operation directly from the utility.

- The Perfect Harmony series drives, when set up properly, do not produce torque pulsations, which can excite mechanical resonance.

- The Perfect Harmony series drives cause no noticeable increase in acoustic noise from the motor, versus operation directly from the utility.

- The Perfect Harmony series drives cause no appreciable additional stress to the motor insulation, versus operation directly from the utility.

- The Perfect Harmony series drives allow unrestricted use of rated motor torque throughout the speed range, subject only to the thermal limitations of the motor.

- The Perfect Harmony series drives are virtually silent in operation, if liquid-cooled, so that normal conversation is possible next to drives running at full power.

- The Perfect Harmony series drives are completely modular in construction, so that if necessary, a defective module can be replaced in minutes. Sophisticated microprocessor-based diagnostics pinpoint the location of any defects.

2.2 The Power Circuitry

> ☞ **Note:**
> The examples used in this section refer to drives having 750V cells. High-Voltage cell systems (1375V) and GenIIIe (690V) will have different values.

The Harmony series drives achieve this uncompromising performance by employing well-proven technology in a modular configuration. Medium voltage levels are obtained by adding together the outputs of multiple low-voltage power cells. The low voltage power cells are simplified variations of standard PWM motor drives for low-voltage service, which have been built in high volume for many years.

Figure 2-1 shows a typical power circuit topology for a 4160 Volt Perfect Harmony series drive, using 750 VAC cells. Each motor phase is driven by 3 power cells connected in series. The groups of power cells are wye connected with a floating neutral. Each cell is powered by an isolated secondary winding of an integral isolation transformer. The nine secondaries are each rated for 750 VAC at one ninth of the total power. The power cells and their secondaries are insulated from each other and from ground for full output voltage rating.

For higher output voltages, additional power cells and isolated transformer secondaries would be added as required.

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Each cell is a static power converter. It is capable of receiving input power at 750 VAC 3-phase, 50/60 Hz and delivering that power to a single-phase load at any voltage up to 750 VAC and at any frequency up to the rated maximum frequency defined in Chapter 3.

> ☞ **Note:** For output frequencies greater than 167 Hz, the VFD power cell current output may be de-rated due to switching losses. Consult the factory for information applicable to the specific application requirements.

With three 750 VAC power cells in series per phase, a Perfect Harmony series drive can produce as much as 2425 VAC line-to-neutral, or a maximum VAVAILABLE of 4200 Volts.

> ☞ **Note:** Over-modulation is used to allow 750 Volt cells to achieve nominal motor ratings (e.g., 4,160V with 9 cells).

It should be noted that it is possible to connect as many as eight power cells in series using the Harmony control. VAVAILABLE determines the maximum voltage that can be delivered from the VFD output. The actual voltage delivered is fully adjustable. As the Harmony VFD topology is based on multi-level output capabilities, the result is true adjusted voltage. The advantages of utilizing the VAVAILABLE capability of the VFD become apparent when the patented advanced cell bypass option is applied for high availability or redundant applications.

Other cell voltages are available, which will change the number of cells needed for a given output voltage. However, the basic principle is unchanged.

The power cells all receive commands from one central controller. These commands are passed to the cells over fiber optic cables to maintain electrical isolation.

The transformer secondaries that supply the power cells in each output phase are wound to obtain a small difference in phase angle between them. This cancels most of the harmonic currents drawn by the individual power cells, so that the primary currents are nearly sinusoidal. The power factor is always high - typically 95% at full load.

The schematic of a typical power cell is shown in Figure 2-2. In this example, a 3-phase diode rectifier, fed by the 750 VAC secondary, charges a DC capacitor bank to about 1012 VDC. The DC voltage feeds a single-phase H-bridge of IGBTs.

At any instant of time, each cell has only three possible output voltages. If Q1 and Q4 are on, the output will be +DC bus volts from T1 to T2. If Q2 and Q3 are on, the output will be –DC bus volts. Finally, if either Q1 and Q3 or Q2 and Q4 are on, the output will be 0 volts.

With 3 power cells per phase, the circuit can produce 7 distinct line-to-neutral voltage levels (±3036, ±2024, ±1012, or 0 volts). With N cells per phase, (N*2)+1 distinct voltage levels are available, where N is a maximum of 8. The ability to generate many different voltage levels allows the Harmony series drives to produce a very accurate approximation to a sinusoidal output waveform.

Figure 2-3 shows how these waveforms are generated for the case of 3 cells per phase. First, a reference signal is created for each phase. These signals are digital replicas of the ideal waveform to be approximated. In Figure 2-3, **RA** illustrates the reference signal for phase A. This reference signal is then compared with 3 triangular carrier signals. Figure 2-3 shows conditions when the output frequency is 60 Hz and the carrier frequency is 600 Hz, so that there are exactly 10 carrier cycles per reference cycle. The 3 carriers are identical except for successive phase shifts of 60 degrees (based on the number of cells per phase). Phase shift between carriers in each phase is computed based on the following equation:

> Carrier Phase Shift (same phase) = 180 degrees / # Cells per Phase

2
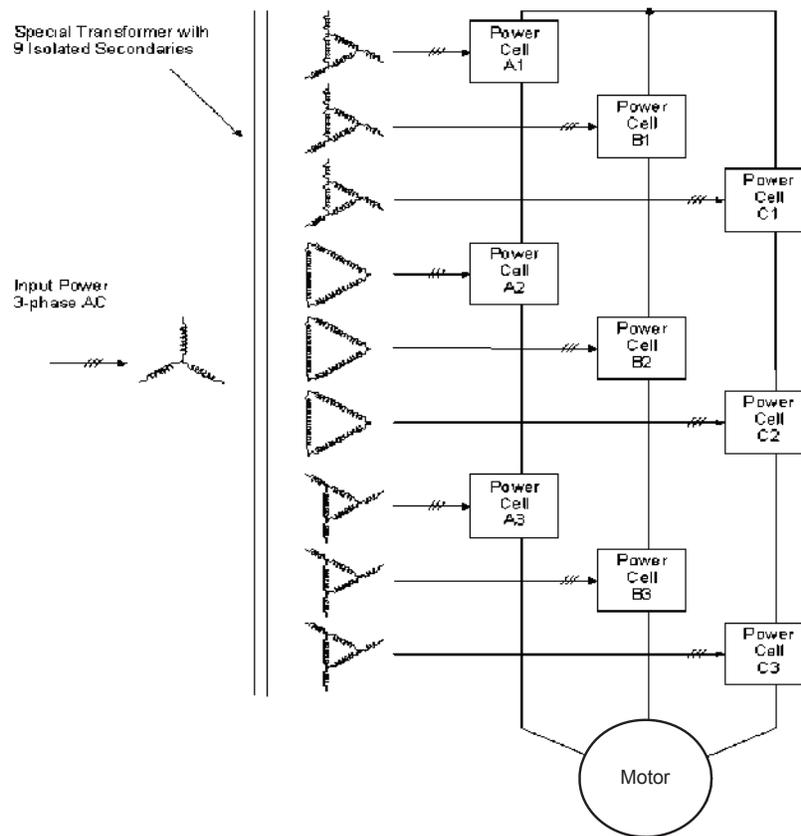
Figure 2-1: Topology of Perfect Harmony VFD (3 Cells)

Whenever the reference is greater than the first (unshifted) carrier, the signal **L1** is high; otherwise **L1** is low. **L1** is used to control the pair of transistors **Q1** and **Q2** in cell **A1** (see the left pair of transistors in Figure 2-2). Whenever the reference is greater than the inverse of the first carrier, the signal **R1** is low; otherwise **R1** is high. **R1** is used to control the pair of transistors **Q3** and **Q4** in cell **A1** (see the right pair of transistors in Figure 2-2).

The difference between **L1** and **R1** gives the output waveform of cell **A1**, shown in Figure 2-3 for Phase A as **A1**.

In a similar manner, the reference signal is compared with the second carrier (shifted 120 degrees) and its inverse to generate control signals **L2** and **R2** for the transistors in cell **A2**. The output waveform of cell **A2** is shown as **A2**.

2
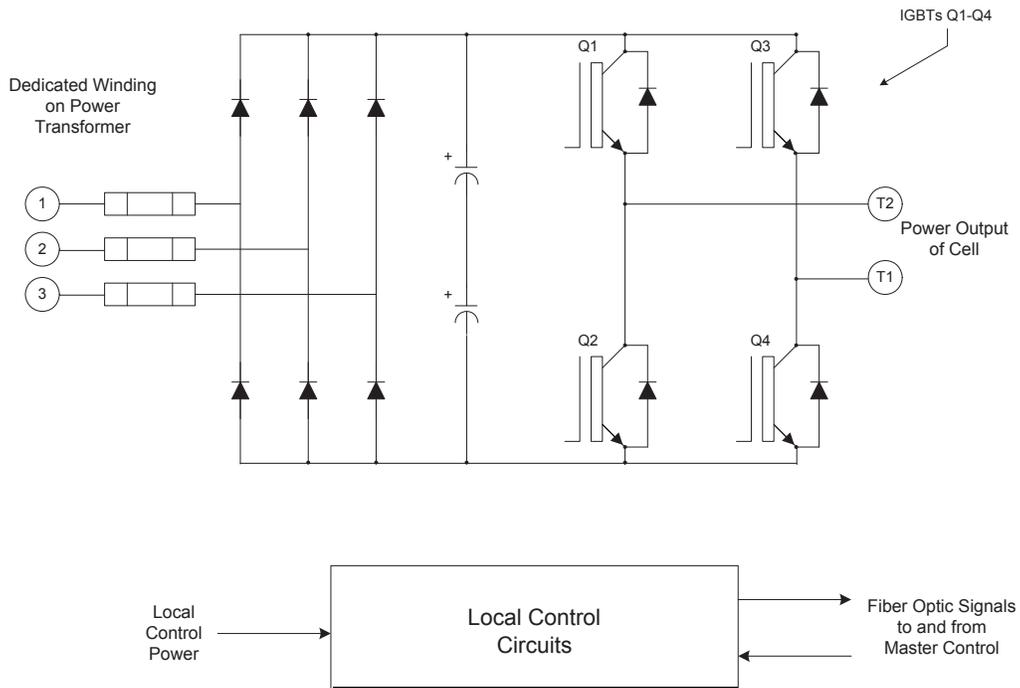
Figure 2-2: Schematic of a Typical Power Cell

Finally, the reference signal is compared with the third carrier (shifted 240 degrees) and its inverse to generate control signals **L3** and **R3** for the transistors in cell **A3**. The output waveform of cell **A3** is shown as **A3**.
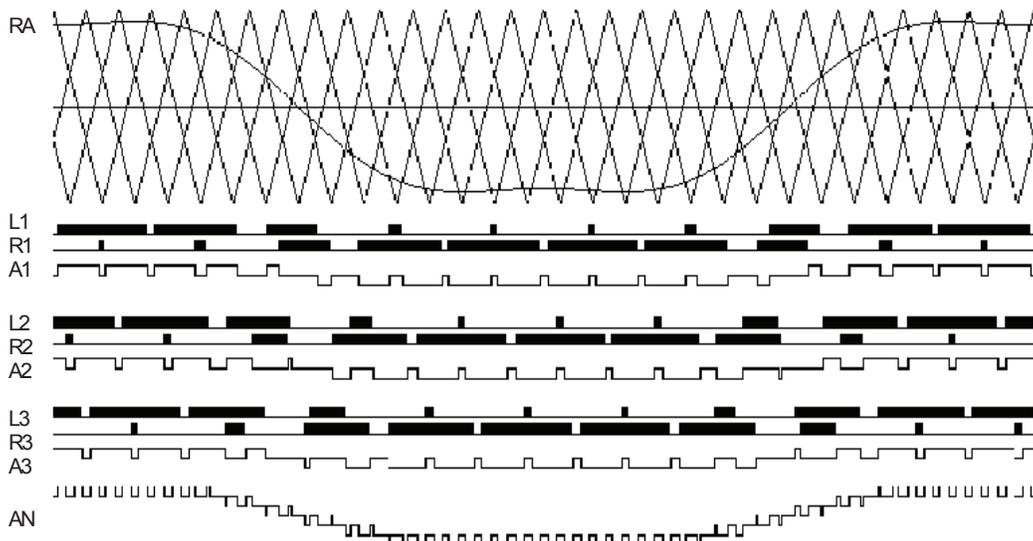
Figure 2-3: Waveforms for Phase A

The sum of the output voltages from cells **A1**, **A2** and **A3** produces the A-to-neutral output voltage of the drive, shown in Figure 2-3 as **AN**. There are 7 distinct voltage levels. Note that this voltage is defined between terminal **A** and the floating neutral inside the drive, not the motor neutral.
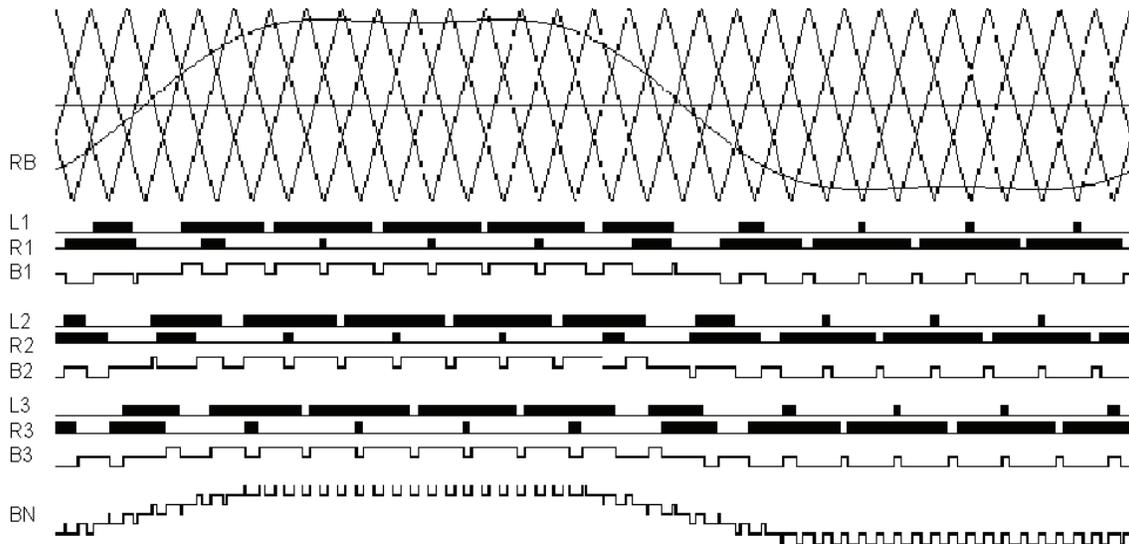
Figure 2-4: Waveforms for Phase B

Figure 2-4 shows the same signals for Phase B. The 3 carriers are identical to Figure 2-3, except each is shifted by 20 degrees from its Phase A equivalent (see following note). The reference **RB** is also identical to Figure 2-3, except that it is delayed by 120 degrees (at the reference frequency).

The sum of the output voltages from cells **B1**, **B2** and **B3** produces the B-to-neutral output voltage of the drive, shown in Figure 2-4 as **BN**.

Figure 2-5 repeats the two line-to-neutral voltages **AN** and **BN**. The numerical difference between **AN** and **BN** forms the line-to-line voltage impressed on the motor, and is shown in Figure 2-5 as **AB**.
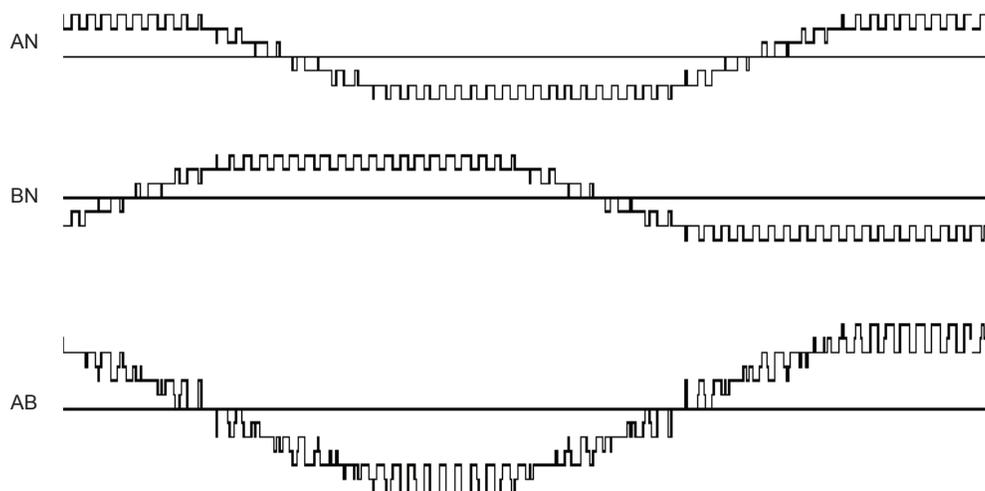
Figure 2-5: Waveforms for Line-to-Line Voltage

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> **Note:** The phase shift of the carrier signals between phases is determined by the number of cells in the system, the equation being Phase shift = 180 degrees / total number of cells. In this case (3 per phase or 9 cells total), the carrier signal phase shift phase to phase is (180 / 9) = 20 degrees. This shift of the carriers between phases reduces the number of devices that are switching at one time. The above is true if no cells are in bypass. If one or more cells are in bypass, the carrier signals are offset by 180 degrees / total remaining cells.
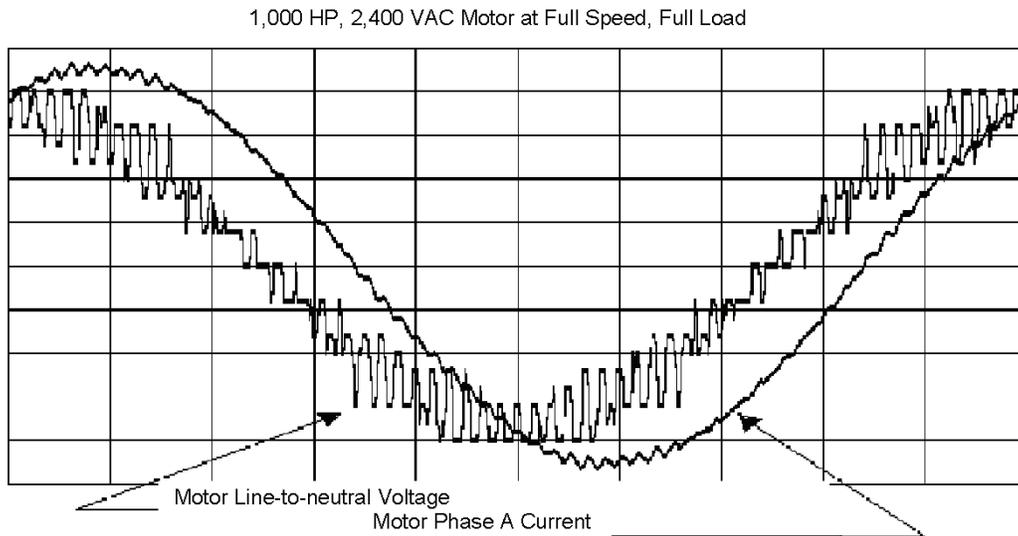
Figure 2-6: Harmony Output Waveforms, 2400 Volt Drive at Full Load

Figure 2-6 shows motor voltage and current waveforms for a 2400 VAC Harmony drive rated at 1000 Hp. The voltage shown is between phase A and the motor neutral (not the same as the drive neutral). The motor current is in phase A during full-load operation. Anyone familiar with such waveforms for other types of static drives will appreciate how accurately they approximate true sine waves. A quantitative measure of the waveform quality is its Total Harmonic Distortion, or THD. The THD of the motor currents with a Harmony series drive is typically less than 5 percent.

Figure 2-7 shows the input voltage and current waveforms for the same drive as shown in Figure 2-6, under the same conditions. The perfect sine wave in Figure 2-7 is the voltage into the special input transformer, measured between phase A and the neutral of the wye-connected primary. The other waveform is the current into phase A of the same winding.

The currents drawn from the power source by Harmony series drives are also good approximations to true sine waves, due to the harmonic cancellation obtained with the phase-shifted secondary windings of the transformer. The THD of the input currents with a Harmony series drive is typically less than 5 percent.

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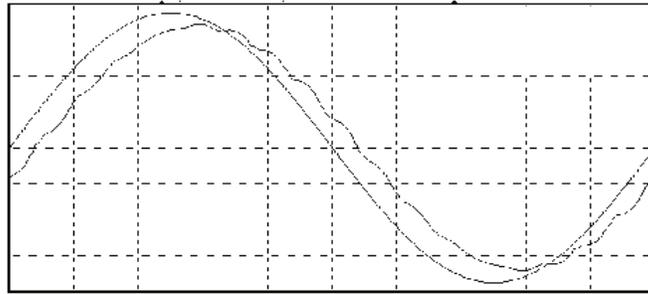
Figure 2-7: Harmony Input Waveforms for a Drive at Full Load

Note in Figure 2-7 that the input current lags behind the input voltage by less than 15 degrees at full load. This represents a power factor better than 96 percent. Harmony series drives always maintain a high power factor, typically better than 95 percent throughout the speed and load range.

> **Note**: The waveforms shown represent the <u>worst</u> case for a Harmony series drive when there are only 3 cells per phase. When the number of cells increases, as in 12 or 15 cell drives, the waveforms improve considerably.

Figure 2-8 shows the motor voltage and current for a 15 cell Harmony drive at full power, while Figure 2-9 shows the input voltage and current for the same drive and load.
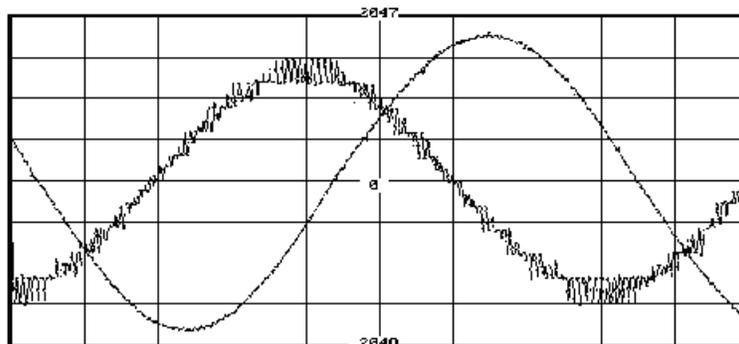
Figure 2-8: Motor A-B Voltage and Current in Phase C at Full Load for a Harmony Drive
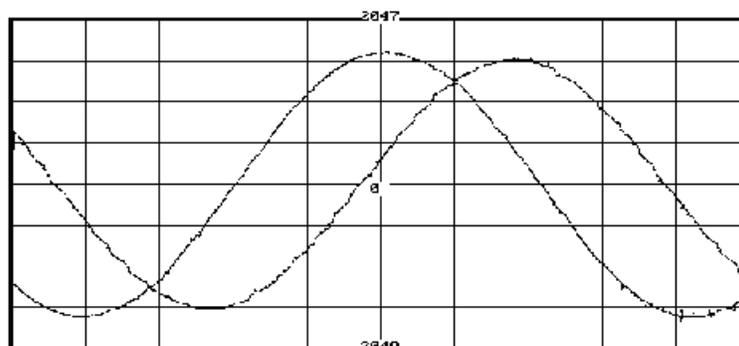
Figure 2-9: Input A-B Voltage and Current in Phase C at Full Load for a Harmony Drive

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2.3 The Control System

The block diagram in Figure 2-10 shows the implementation of the Harmony Control System. The Control System consists of the following functional blocks: Signal Interface and Conditioning, an A/D Converter, a Processor, a Digital Modulator, and Fiber Optic Interfaces.

The Signal Interface processes the feedback signals collected from the drive. These circuits scale and filter the feedback signals before passing them along to the A/D Converter. Provisions are included to interface to an ESTOP signal.

The function of the A/D Converter is to sample the input and output currents and voltages, and convert them to digital signals for the processor. The sample rate varies from 3 kHz to 6 kHz and is a function of the carrier frequency (which is also the IGBT switching frequency), and the number of "available" cells in the system. The Digital Modulator generates the signal for the A/D converters to start sampling. Once the A/D converters finish sampling, they provide an interrupt to the processor to begin its calculation cycle.

☞ **Note:** The A/D converter function includes provisions for encoder feedback monitoring.

The processor performs all of the functions for motor control and generates three-phase voltage commands for the digital modulator. In addition, it monitors the input voltages and currents to provide metering functions (such as power factor, input power, and harmonic calculation), input protection (excessive losses, excessive reactive current, under-voltage, and single-phasing), and input voltage magnitude, frequency, and phase angle for Synchronous Transfer.

The Digital Modulator contains registers that are used for communication with the Processor. For each phase voltage command, the processor writes two values to the modulator. The first for the present time instant and the second for a time instant that is extrapolated for half a sampling period. A voltage increment, or step corresponding to these values, and the direct number of steps between values, is also written to the modulator. These phase commands are written by the processor once every sampling period.

The modulator creates a set of timing signals that cause the control software to sample the feedback signals and run the control and monitoring algorithms. These timing signals are used to transmit information to the cells simultaneously, once every 9 to 11 microseconds. This time (is determined by the processor and) is based on the drive configuration, and is fixed for a particular configuration. In between every transmission period, the modulator performs interpolation, phase-shifted carrier generation, pulse-width modulation (PWM), and cell communication. The resulting PWM commands for each cell, along with the mode of operation, is assembled as a data packet that is transmitted to each cell through dedicated Fiber Optic Interfaces. In response to the transmitted data, the modulators receive a similar data packet from each of the cells. The return message from the cells contains status bits that are decoded by the modulator and conveyed to the processor.

Every transmission is checked for completeness and parity. If an error is detected, a link fault is generated. The data packet sent to the power cells provides operational mode and switching information. The local communication circuits in each power cell operate as slaves to the Modulator. The local control circuits on each power cell convert the information received to IGBT firing pulses.

The return packet echos the operational mode and cell status. Should an individual cell be bypassed, the modulator commands all power cells to disable their outputs with the next message to the cells. The worst case shut down of all power cells requires 2 transmission cycles or 22 μsec. maximum.

When advanced cell bypass is included with a drive, the modulator communicates with the bypass controller and monitors hardware faults such as IOC, ESTOP, and power supply faults. The Bypass Controller is configured to control the cell bypass (mechanical) contactors. After detection of a cell fault, the processor communicates with the Bypass Controller to bypass the faulted cells. In addition to bypassing cells, the Bypass Controller constantly checks the status of the contactors to verify if they are in their requested states.

The Fiber Optic Interface transfers data between the modulator and the cells over dedicated fiber optic channels. Each cell receives its firing commands and status signals through a full duplex fiber optic channel.

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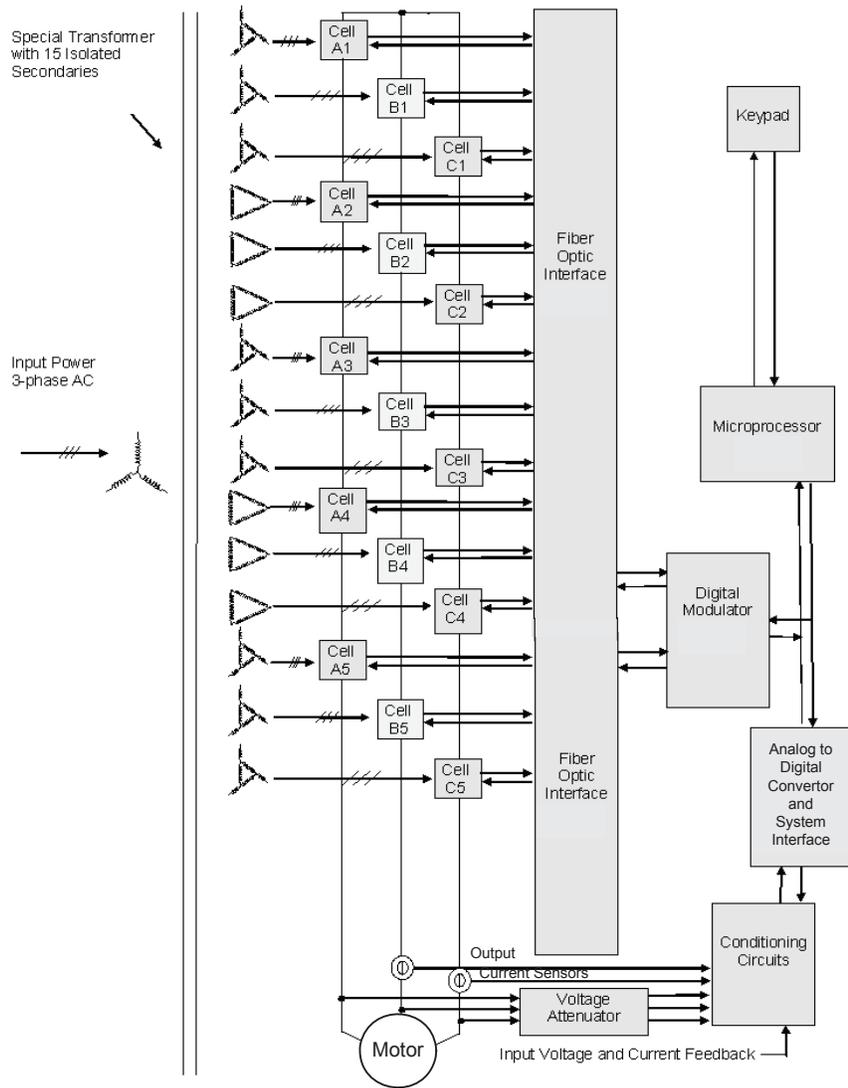
Figure 2-10: Block Diagram of Harmony Control Structure

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CHAPTER

3   GenIV Specifications

3

3.1 System Specifications

Parameter	Rating
Input Line Voltage	2.4, 3.0, 3.3, 4.16, 4.8, 6.0, 6.3, 6.6, 6.9, 7.2, 8.4, 10, 11, 12, 12.47, 13.2, or 13.8kV; 3 phase; +10% / -5%
Input Frequency	50 or 60Hz ±5%
Input Power Factor	> 0.94 above 10% load
Input Harmonics	<= 5% TDD with ambient THDv <= 2%
Efficiency	98% Transformer, 99% Converter, 96.5% Total VFD
Output Horsepower, Frame Sizes	200-1100 (9cell - Size 1), 1000-2250 (9cell - Size 2), 300-3500 (15 cell)
Output Voltage	4160V (9 cell), 6900V (15 cell)
Output HVF	< 0.03
Output dv/dt	< 3000 V/µS
Output Current	40, 70, 100, 140A Cell Frame Sizes
Overload Capacity	150% 1 minute / 10 minute (Ambient temperature $\leq$ 40°C)
Output Frequency & Drift[1]	0.5 - 330 Hz, ± 0.5%
Output Torque	10 - 167 Hz rated torque (2 Quadrant)
Design Life	20 years
Auxiliary Voltage	380 - 400 - 415V, 50 Hz; 460 - 480V, 60 Hz; 3-phase[3]
Enclosure Type	NEMA 1 Ventilated
Degree of Protection	IP 31
Ambient Temperature	0 - 40 °C (max. 45 °C with useful life derate[2])
Humidity	95% non-condensing
Altitude	0 - 3300 ft. without derating
Audible Noise	≤ 75db at 3 ft. from cabinet
Dust contamination	< 100 micron @ 6.5 mg/cu. ft.
Gas contamination	< 4 PPM reactive halides and sulfides
Cooling	Ventilated, forced air-cooled with integrated fans

1. For high speed projects (> 300 Hz), consult Siemens concerning trade sanctions.
2. Consult engineering for reduced life expectancy calculation.
3. Consult factory for availability of auxiliary voltages other than shown.

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3.2 Power Cell Specifications

Cell Frame	040	070	100	140	200	260
Output Nameplate Current	40A	70A	100A	140A	200A	260A
Input Voltage	750V ± 10%, 3 phase, 50/60 Hz					
Input Current	28A	48A	73A	96A	140A	182A
Overload Capacity (see Note) (* Ambient ≤ 40°C)	CL-1: 110% of nameplate 1 minute/10 minutes CL-2: 150% of nameplate 1 minute/10 minutes CL-3: 200% of nameplate 3 seconds/10 minutes					
Losses %	1.3	1.2	1.1	1.0	1.2	1.2
Discharge to 50 VDC, minutes.	0.84	1.68	2.53	3.37	4.51	6.02
Electrical Connections	Rear access blind connection via power plugs					
Weight (lbs.)	52	57.5	63	68.5	103	113
Envelope Width	13.42"				14.00"	
Envelope Depth	21.83"				25.88"	
Envelope Height	9.67"				13.12"	
Forced Air Cooling	> 180 CFM (225-250 typical for Cell Frames 40, 70, 100, and 140)				> 300 CFM (300-350 typical for Cell Frames 200 and 260)	

☞ **Note:** The GenIV drive generates acoustic noise levels above 70 dB. Phase 1 noise generation is less than or equal to 73 dB while Phase II generates noise levels at less than or equal to 75 dB.
No hearing protection is required.

☞ **Note:** At ambient temperatures ranging from 40 to 45°C, the 140A cell frame is limited to 150% 1 minute/10 minutes overload with a 130 Amp continuous rating.

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4   Product Description

4.1 Drive Family Description

GenIV is the fourth generation of forced air-cooled medium voltage, voltage source inverter drives offered in the patented Robicon Perfect Harmony topology. GenIV differentiates itself from prior generations in that:

- The 200 - 2250 Hp, 4160V frame uses a single enclosure (no shipping splits)

- At its inception, the 200-1100 Hp, 4160V drive is the smallest footprint MV AC drive in the world

- Nine Cell configuration for 4160V output (750V cell input, and O-M techniques)

- The 300 - 3500 Hp, 6600V frame consists of a transformer enclosure that is mated to a cell enclosure without shipping splits (2000 Hp or below) or 1 shipping split (above 2000 Hp)

- Transformer and cell sections have independent intake air cooling paths

- Electronically commutated (EC) brushless DC motor cooling blower

- NXGII control with integral I/O system and Eagle software

- Power cell connections are made with blind mate power plugs and locking latches (no fasteners)

The GenIV is a series of adjustable speed AC motor drives presently available in 4160V outputs, and loads ranging from 200 - 1100 Hp. Four power cell amperage types are available: 40, 70, 100, and 140. Drives in this product series provide an efficient, cost effective, and reliable method of adjusting the speed of an AC motor. The core unit contains a wide range of expandable features, enabling it to meet the demands of many types of industrial applications. Siemens GenIV (also known as MicroHarmony) may be purchased in one of three configurations.

- Core: These units contain a wide range of components that achieve common requirements for Medium Voltage drive performance:

    o Integral isolation transformer

    o NEMA 1 ventilated (IP31) enclosure

    o Multiple power and amperage frame sizes

    o Multiple input voltages and frequencies

    o ASA 61 gray enclosure paint

    o Keypad, E-Stop

    o Electronically commutated (EC) cooling blower

    o NEMA hole pattern medium voltage connections

- Pre-Engineered: These option packages allow customers to specify a variety of add-ons to the flexible Core unit without an increase in footprint (see list below):

    o Electrostatic transformer shield

    o Distribution class surge arresters

    o Mechanical cell bypass

    o Redundant blower (or N+1)

    o Blower cage with duct interface

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- o Encoder power supply for CLVC
- o EMC auxiliary voltage filter
- o MPM space heaters
- o Mechanical door key interlocks
- o Auxiliary voltage isolation transformers
- o Industry standard communications (single or dual networks)
- o Agency approval

- Custom: These selections are not readily available as pre-engineered options for the GenIV; however, our Siemens engineering staff has experience in designing these configurations in transition cabinets as an add-on to the drive line-up (see list below):

  - o Synchronous transfer output reactors
  - o Synchronous motor exciters and field supplies
  - o RTD scanners
  - o Motor encoders
  - o Switchgear and full/reduced voltage motor starters
  - o Power quality equipment
  - o Long cable filters
  - o Control power transformers
  - o Off-voltage auxiliary voltage transformers
  - o IP42 and NEMA 3R enclosures
  - o Customer specified enclosure paint colors
  - o Marine duty packages
  - o Expansion I/O and PLC capabilities
  - o Control houses
  - o Heat exchanger systems

> **DANGER!**
> Failure to observe the following may result in severe injury or death:
> PT and CT secondary circuits are capable of generating lethal voltages and currents with their primary circuit energized. Follow standard safety precautions while performing any installation or service work (i.e. removing PT fuses, shorting secondaries, etc.)

4.2 Cabinet Outlines

The cabinet configurations of the GenIV Perfect Harmony drives vary, depending upon the project requirements for input and output voltage, and output power and amperage. The GenIV, in its core configuration, consists of a single cabinet with multiple sections. Single cabinet units are shipped with their blower cage(s) removed. The various sections are described below:

- Transformer section
- Cell section
- Input/output section
- Control section
- Control wire way
- Blower #1 (and #2 with redundant option)

GenIV is offered in various core configurations, dependent upon the number of cells and power cell type amperage. Table 4-1 lists the core configurations:

Table 4-1: GenIV Core Configurations

Cells in Drive (without Redundancy)	Output Voltage Available L-L (with O-M)	Hp Range	Power Cell Types (Continuous Current Rating)
9	4160V	200-1100	40, 70, 100, 140
9	4160V	1000-2250	200, 260
15	6900V	300-3500	40, 70, 100, 140,200, 260

4.2.1   9 cell, 4160V Output, 200-1100 Hp

Figure 4-1 details the GenIV 4160V output 200-1100 Hp drive, and Figure 4-2 points out each core section. The default color of the enclosure is ASA 61 Gray.
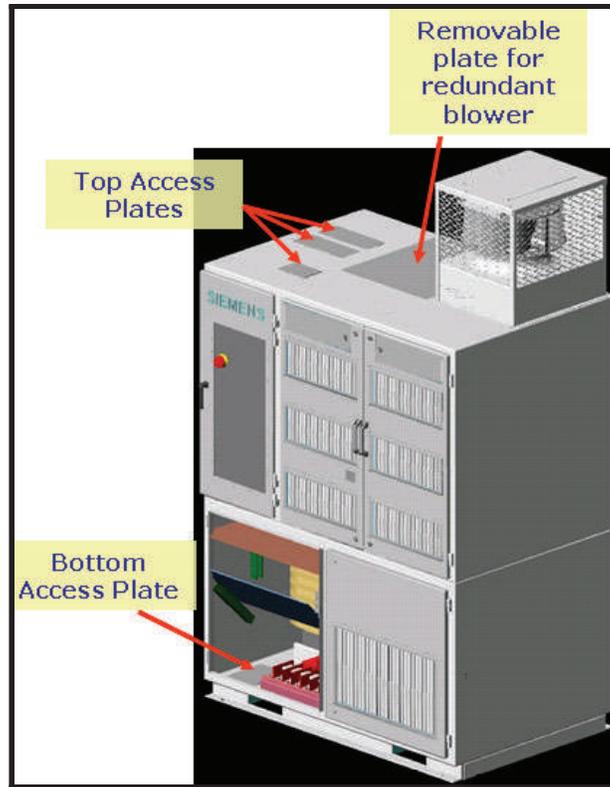
Figure 4-1: GenIV 4160V Output 200-1100 Hp General Arrangement

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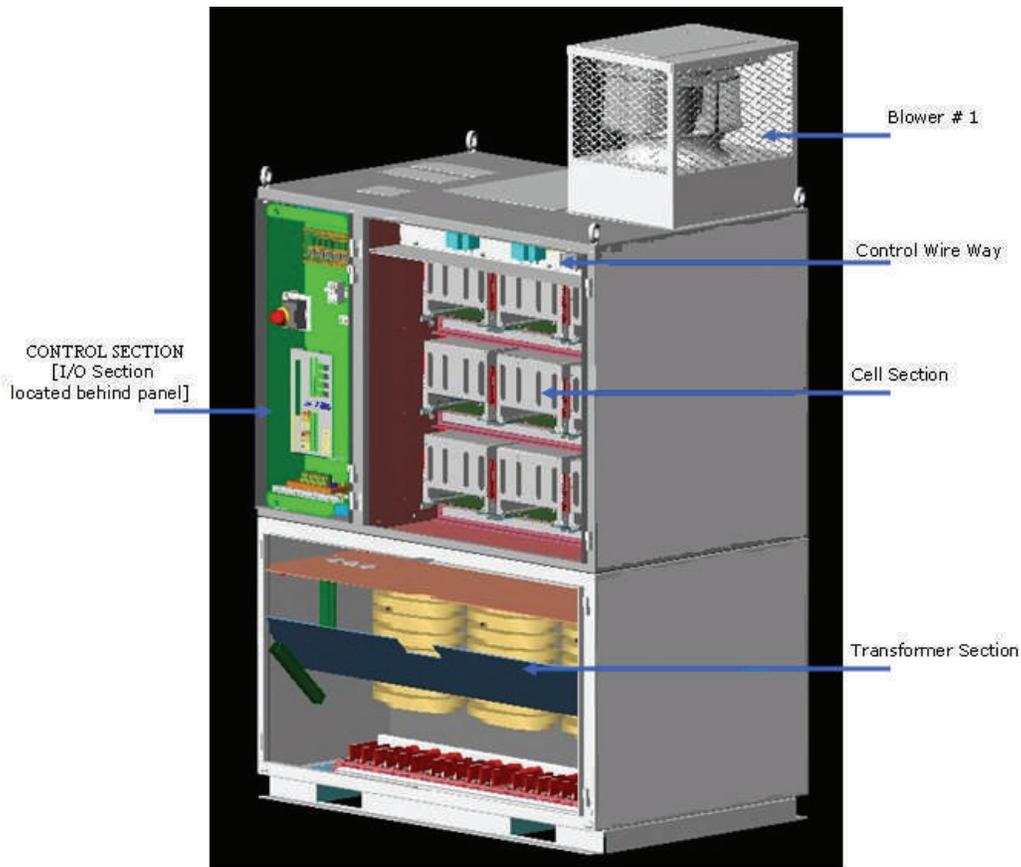
**Figure 4-2: GenIV 4160V Output 200-1100hp, Sectional View
(Redundant Blower #2 not shown)**

Table 4-2 gives detailed mechanical and electrical information for the core configuration. (Note the assumptions.)

Table 4-2: Nine Cell 4160V Output GenIV, 200-1100 Hp

Hp[1]	Losses (kW)[2]	Ventilation[3]	Footprint[4]	Weight (lbs)[5,6,7]	Voltage
200	5.25			4352	4160
300	8.00			4890	4160
400	10.50	4250 CFM @	66" Wide,	5438	4160
450	11.75	1.3" H_2O	42" Deep,	5674	4160
500	13.00		110" High	5900	4160
600	15.75	Note: For duct interface		6374	4160
700	18.25	projects, the added	Note: Shipping	6760	4160
800	20.75	pressure drop cannot	height is 86"	7108	4160
900	23.50	exceed 1.8" H_2O at	when blower	7467	4160
1000	26.00	4000 ACFM.	cage is removed.	7739	4160
1100	28.50			7973	4160

Hp[1]	Losses (kW)[2]	Ventilation[3]	Footprint[4]	Weight (lbs)[5,6,7]	Voltage
1000	26.00	6530 CFM @ 1.5" H_2O Note: Drive is not rated for duct interface projects.	82" Wide, 45" Deep, 119.5" High Note: Shipping height is 86" when blower assembly is removed.	8605	4160
1250	32.50			9380	4160
1500	39.25			10082	4160
1750	45.50			10798	4160
2000	52.25			11353	4160
2250	58.75			11834	4160
2500*	64.75			12242	4160
300	8.00	4600 CFM @ 0.96" H_2O (40-140 Amp Cell Section) 5900 CFM @ 1.8" H_2O (200-260 Amp Cell Section) 6250 CFM @ 1.62" H_2O (80" Transformer Section) Note: Duct interface capabilities vary depending upon drive configuration. Please consult factory for duct interface projects.	144" or 164" Wide 45" Deep, 115.2" High Note: Shipping height is 90.1" when blower assembly is removed	6980	6600
400	10.75			7330	6600
500	13.25			7580	6600
600	15.75			7790	6600
700	18.50			8320	6600
800	21.00			8530	6600
900	23.75			9080	6600
1000	26.25			9530	6600
1250	32.75			11225	6600
1500	39.50			11575	6600
1750	45.75			13275	6600
2000	52.50			13905	6600
2250	59.00			14925	6600
2500	65.50			15565	6600
3000	78.50			16685	6600
3500	91.50			18250	6600

1. Drive Rated Hp
2. Losses are shown as 2.59 kW per 100 Hp, rounded up to the nearest ¼ value
3. EC Blower operates at 80% speed typically (100% speed with Duct Interface)
4. Subject to change without notice
5. For 4160V 40-140 amp, add 160 lbs for redundant blower and 75 lbs. for cell bypass.
6. For 4160V 200-260 amp, add 200 lbs. for redundant blower and 75 lbs. for cell bypass.
7. For 6600V 40-260 amp, add 400 lbs. for redundant blower and 125 lbs. for cell bypass.
* This horse power can only be achieved with unity power factor at the motor terminals. This option is available for derating purposes.

4.3 Cabinet Details

The GenIV core enclosure is Nema 1 Ventilated (IP 31 degree of protection) and is provided with top and bottom cable access plates (see Figure). The doors are hinged and mechanical key interlock provisions are provided.

> **Note:** The following drive "Section" details include components by label and description as found on the core configuration. These labels are also found on customer outline "C" and wire diagram "W" drawing sets.

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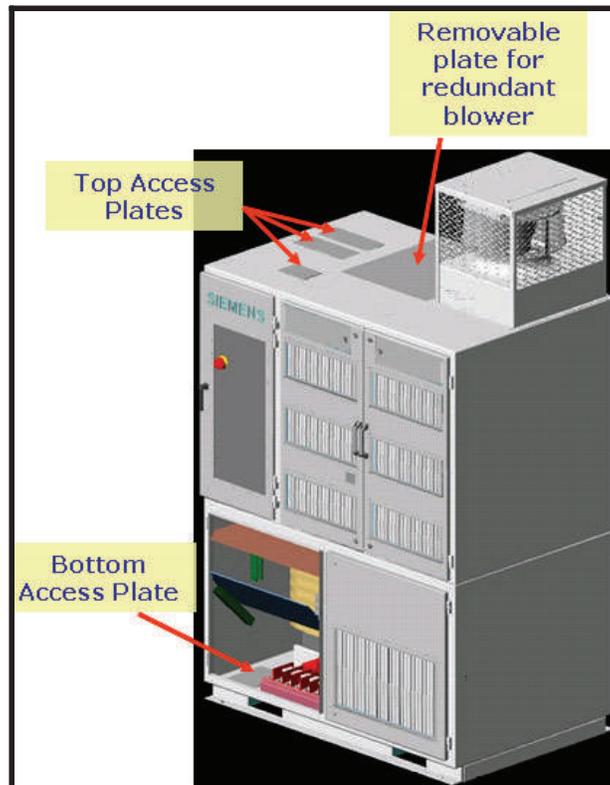
Figure 4-3: GenIV Enclosure (4160V Output, 200-1100Hp)

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REMOVABLE PLATE for REDNANT BLOWER

BOTTOM ACCESS LTE
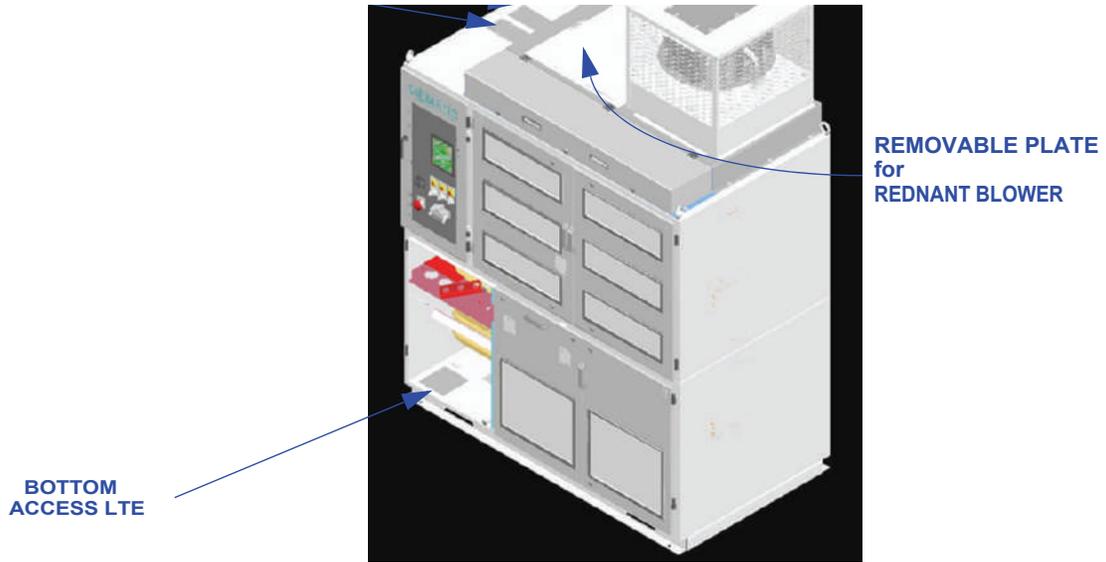
Figure 4-4: GenIV Enclosure (4160V Output, 1000-2500 Hp)

TOP ACCESS PLATES

REMOVABLE PLATE FOR REDUNDANT BLOWERS

REMOVABLE PLATE FOR REDUNDANT BLOWERS

BOTTOM ACCESS PLATES
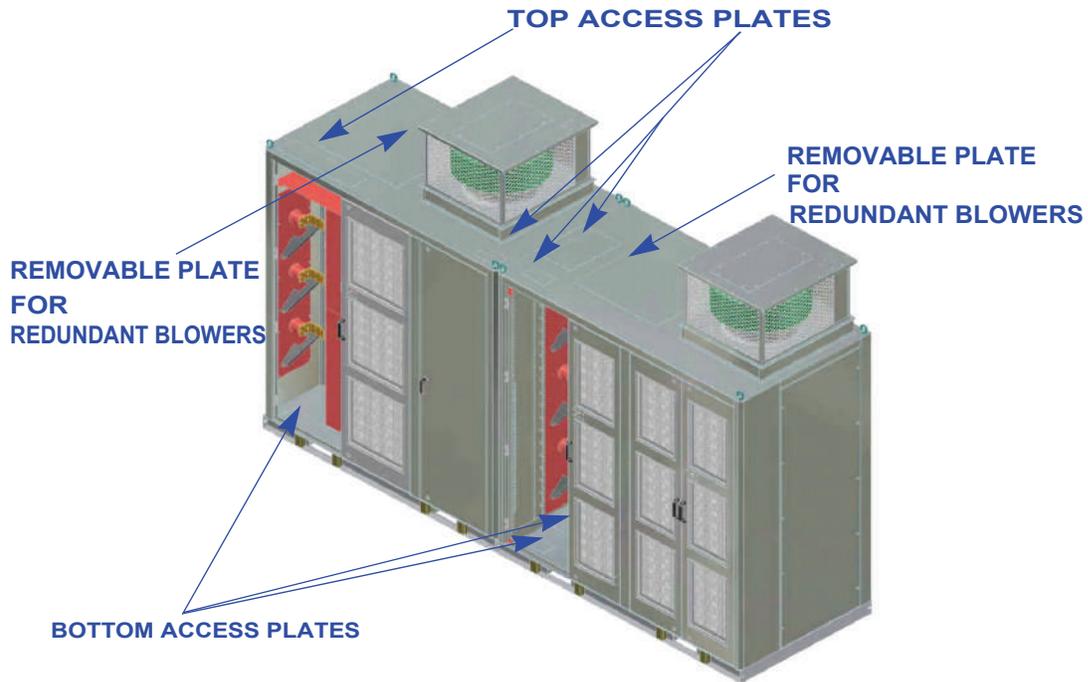
Figure 4-5: GenIV Enclosure (6600V Output, 300-3500 Hp)

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4.3.1   Input/Output Section

The Input/Output section is located behind the control section as shown in Figure 4-6.

Table 4-3: Input/Output Section Components

Component Label[1]	Part Description
L1, L2, L3	Medium Voltage Input Connections
T1, T2, T3	Medium Voltage Output Connections
CT1, CT2	Input B and C Phase Current Transformers
IATTA, IATTB, IATTC	Input Medium Voltage Attenuator Resistors
OATTA, OATTB, OATTC	Output Medium Voltage Attenuator Resistors
HEB1, HEC1	Output B and C Phase Hall Effect Current Transducers
X5	Auxiliary Voltage Control Transformer
BPPS	Bypass Power Supply (Optional)
BCC	Bypass Control Circuit (Optional)
TB1, TB2, TB2ELV, TB4	Terminal Blocks
GND2, GND3, GND7	Grounding Pads (GND7 is a Ground Lug - 4160V only)
GND2, GND3, GND7	Grounding Pads (6600V)
PE	Protective Earth

1. Refer to customer drawing "C" set and wiring diagram "W" set for references.
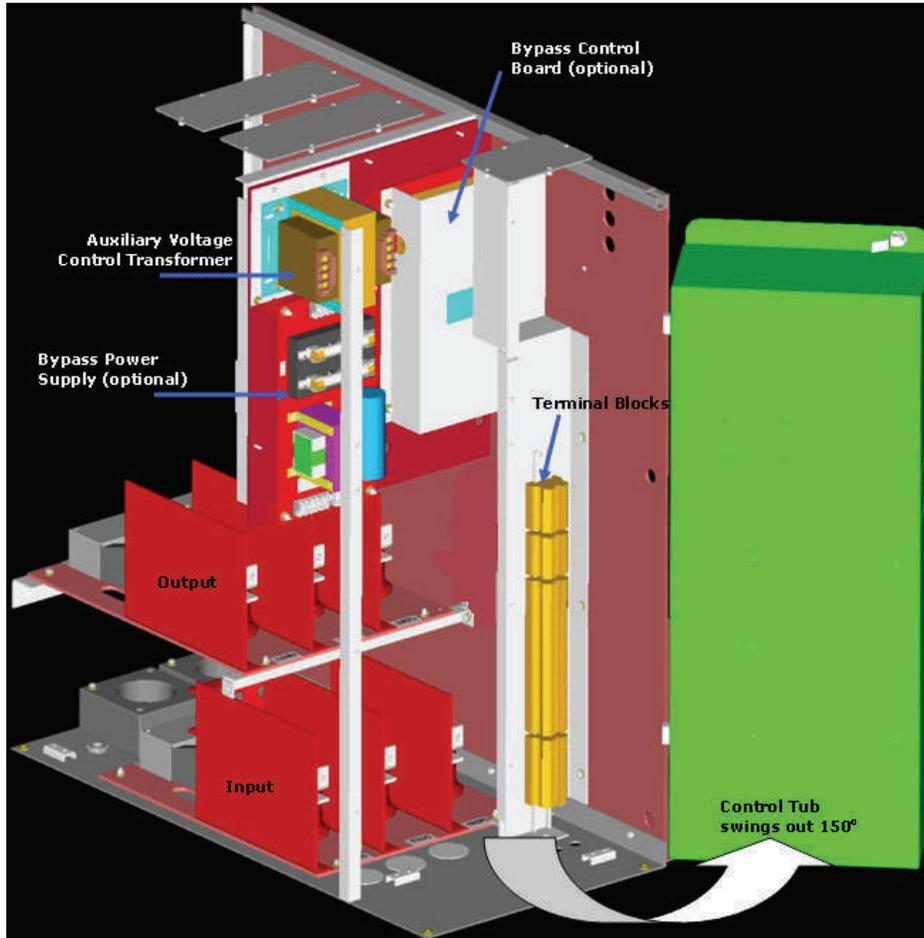
Figure 4-6: I/O Section

All medium voltage terminations and control terminal blocks are accessible from the front of the drive when the control section panel is in the open position. Side and rear access is not required for field installation; however, 4160V models have a left side removable panel that is provided for use with transition cabinets and can be used for greater access where applicable. Top and bottom access plates are provided for aiding installation. Swinging the control tub out is possible while the medium voltage input is energized; however, only the terminal blocks are accessible because two polyglass barriers (not shown) are installed on all units to the left of the terminal blocks. Qualified personnel can remove these polyglass barriers to access the bypass control circuit, bypass power supply, auxiliary voltage control transformer, and input/output medium voltage terminals.

The input and output medium voltage terminals (L1, L2, L3 and T1, T2, T3) are offset from one another and have two NEMA one-hole pattern configurations (vertical and horizontal) to facilitate top or bottom cable termination (see Figure 4-7).

> **Note:** The GenIV design is best accommodated for single conductor single core medium voltage cables. Three conductor single core cables **are not recommended** and may require special attention.
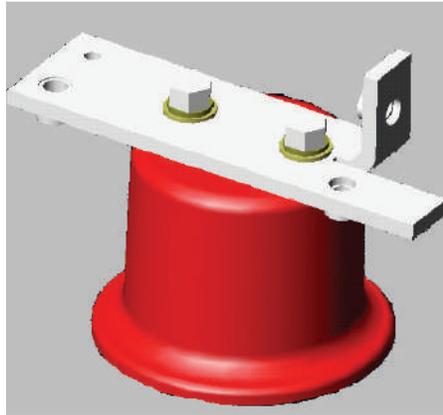
Figure 4-7: Medium Voltage Terminations (L1, L2, L3, or T1, T2, T3)

The input current transformers, output Hall Effect current transducers, and input/output voltage attenuators are pre-engineered according to each project's requirements. The metallic chassis, housing the hall effect current transducers and low voltage portion of the medium voltage attenuating resistors, are grounded at point GND3. The secondary of CT1 and CT2 are also grounded to point GND3. The bypass power supply and bypass control circuit are used when Mechanical Cell Bypass is selected as an option. The auxiliary voltage transformer steps customer-supplied three phase low voltage down to single phase 120V for use with the NXG II controller. This 500 VA transformer is protected by three control fuses (2 primary, 1 secondary) that are located in the Control Wire Way section.
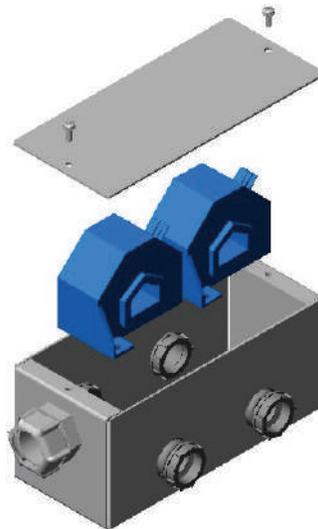
Figure 4-8: Output Hall Effect Current Transducers (HEB1, HEC1)

4.3.2   Transformer Section

The Transformer section is located in the bottom half of the GenIV enclosure and contains the following components:

Table 4-4: Transformer Section Components

Component Label	Part Description
X1	Integral Isolation Transformer
FA1A, FA1C, FB1A, FB1C, FC1A, FC1C, FA2A, FA2C, FB2A, FB2C, FC2A, FC2C, FA3A, FA3C, FB3A, FB3C, FC3A, FC3C	Power Cell A and C Phase Input Fuses
GND6	Grounding Pad

Table 4-5: Transformer Section Components (4160V, 200-260A)

Component Label	Part Description
X1	Integral Isolation Transformer
FC1A, FC1C, FC2A, FC2C, FC3A,FC3C	Power Cell A and C Phase Input Fuses
GND6	Grounding Pad

Table 4-6: Transformer Section Components (6600V, 40-260A)

Component Label	Part Description
X1	Integral Isolation Transformer
GND6	Grounding Pad

The transformer enclosure section primarily houses the transformer, polyglass air baffling, and the secondary fuse block containing each power cell's A and C phase input fuses. The left front side of this section also serves as the access point for input/output medium voltage cabling. The transformer core is grounded to the enclosure at GND6.

Transformer

The 4160V GenIV uses an isolating multi-winding nine secondary phase shifting transformer (see Figure 4-9). It is configured for an 18-pulse power quality reaction to the utility by using $+20^o$, 0°, and -20° extended delta 750V secondary windings with reference to the wye primary. The 6600V GenIV uses an isolated multi-winding fifteen secondary phase shifting transformer. It is configured for a 30-pulse power quality reaction to the utility by using 0, +32, +144,-12, -24 extended delta 750V secondary windings with reference to the wye primary. The transformer impedance is 6 - 7%. The transformer is a dry type forced air cooled unit, and polyglass air baffles are used to direct air movement across the coils. Some transformers are equipped with secondary winding coolers for improved thermal performance. The transformer is wound with 220^oC winding insulation and the BIL level depends on the input voltage rating. During Siemens' assembly, the transformer and polyglass baffling are installed through the top of the transformer section enclosure. Adequate ventilation is provided by the centralized blower to maintain less than a 15° C rise across the unit. A conservative winding design rise is used to ensure a 20-year life expectancy given the non-

linear secondary loading. All connections to and from the transformer are made with insulated wire. Two sets of normally closed thermal protectors are imbedded into the transformer primary windings and are continuously monitored by NXG Control (typically 170º C and 190 º C temperatures are used). The transformer is equipped with off-line taps to accommodate utility line variations, +5%, 0%, and -5% are supplied on typical units (at shipment, the units are placed on the 0% tap).

The default winding conductor is aluminum; however, some cases will require the use of a copper winding, which is dependent upon the apparent power (kVA) size, input voltage, frequency, and user preference. The transformer is optionally available with an electrostatic shield and/or primary distribution class surge arresters. Several line voltages, apparent powers (kVA), and frequencies are provided as customer options (see Chapter 3 for applicable ranges and frames). Values outside these boundaries will be considered CUSTOM and will be subject to engineering evaluation.

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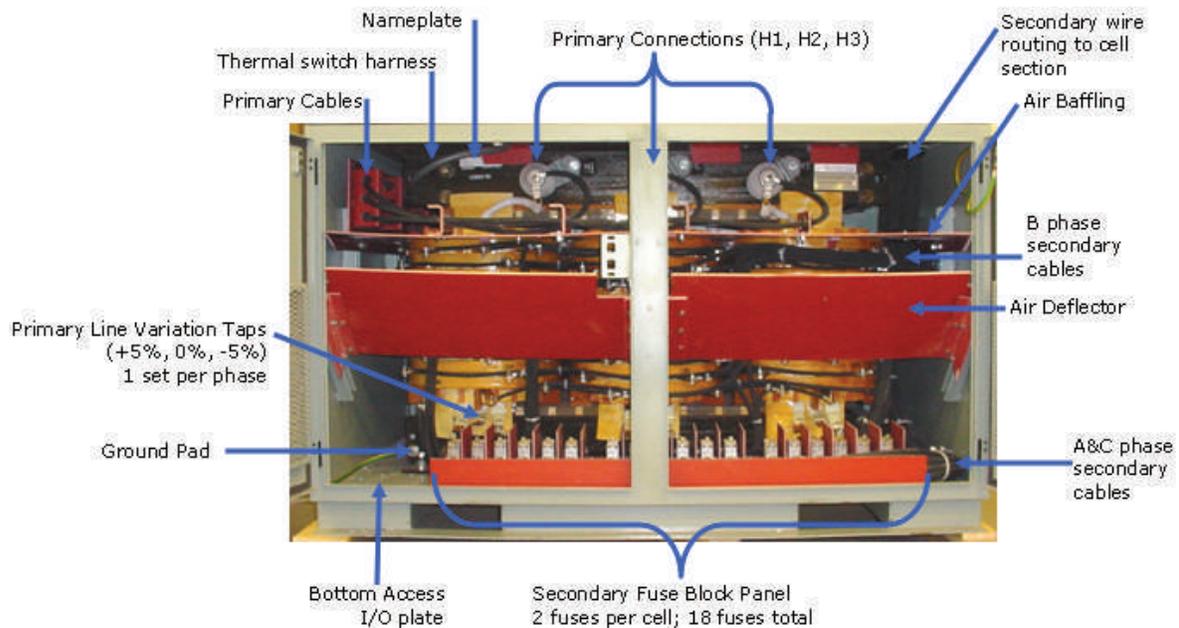
Figure 4-9: Typical GenIV 4160V, 40-140A GenIV Transformer

Note: In the unlikely event of a transformer failure requiring replacement, the drive must be disassembled, allowing for top removal from the transformer section.

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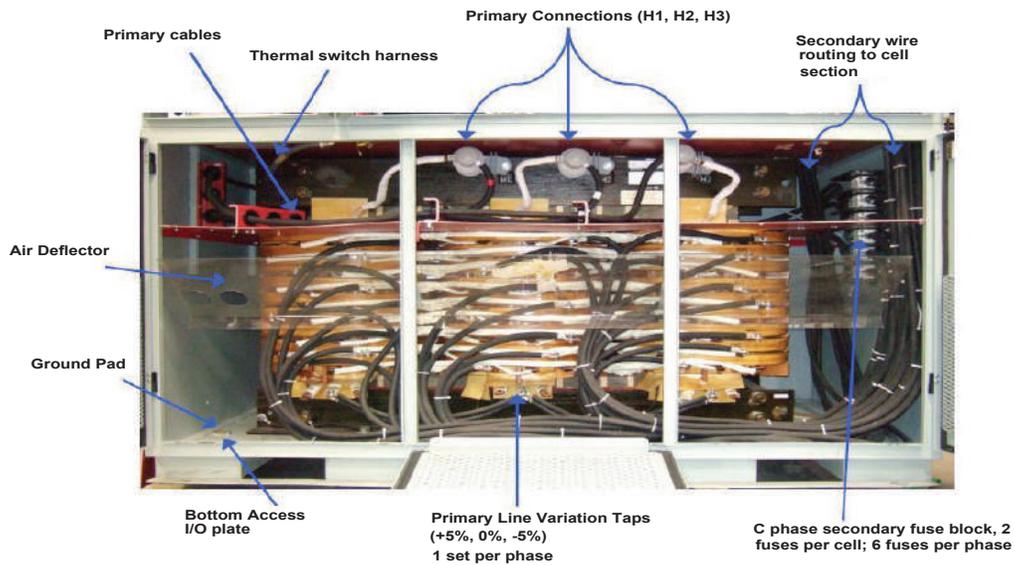
Figure 4-10: Typical GenIV 4160V, 200-260A Transformer

GenIV Transformer Sizing and Derating Factors[1],[2]

The transformers are sized on a 1000 VA per Hp basis (as shown in Chapter 1, and further shown below); however, other factors must be considered, such as motor lead length, motor service factor, environment ambient and altitude, and power cell redundancy (N+1 3300V project). These factors may increase the kVA size of the Perfect Harmony transformer as follows:

1. Transformer initial sizing is based upon 1000 VA per Hp (including motor service factor):

   $kVA_1 = Hp * Service\ Factor$

2. If ambient temperature exceeds 45 °C, then transformer size is increased by:

   $kVA_2 = kVA_1 * [175/(220\text{-}AMB)]^{0.5}$

3. If altitude exceeds 3300 feet above sea level, then transformer size is increased by:

   $kVA_3 = kVA_2 * [1+0.00003*(ALT\text{-}3300)]$

4. If Redundant N+1 operation is required then the transformer size is increased by:

   $kVA_4 = kVA_3 * 1.125$ (3300V Projects)

   or

   $kVA_4 = kVA_3 * 1.108$ (6000V Projects)

   or

   $kVA_4 = kVA_3 * 1.125$ (N+3, 4160V Projects using 6600V drive)

5. Choose the smallest rating greater than or equal to kVA_4 from the applicable frame size list shown in Chapter 3.

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1. Excludes long cable provisions
2. Maximum ambient of 60 ºC and maximum altitude of 6562 feet
   Note: At elevations above 6562 feet, a dielectric strength derate is required. Consult engineering.

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Fuses

For 4160V Systems, the secondary fuse block is located either in the front of the transformer section (refer to Figure 4-11) or on the right-hand side of the transformer and cell cabinets. 6600V Systems have the fuses located on the left-hand side of the cell cabinet behind the control. There are three approved fuse sources (Ferraz, Bussmann, and Siba). A label is located on the left side of the fuse block that shows all approved replacements. Only two phases of each transformer secondary (power cell input) are fused. Each fuse has visual blown indication, making it easy to diagnose a fuse's condition. Fuses are forced air cooled for longer life and less thermal stress.
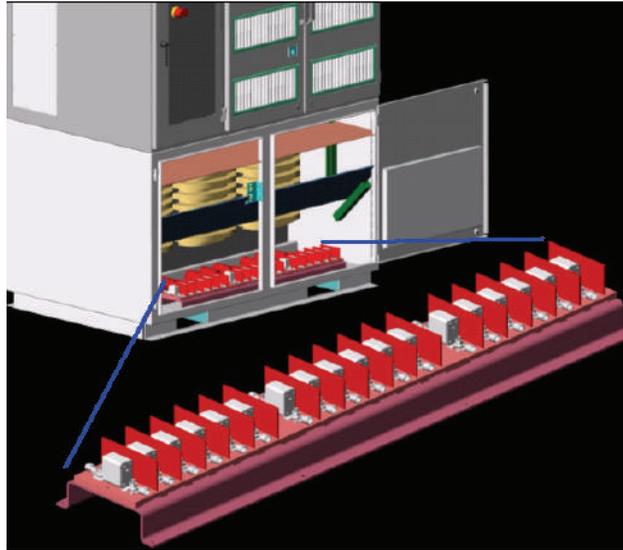
Figure 4-11: Cut-Out View of Fuse Assembly

The GenIV fuses are mounted external to the cell. This not only reduces the size of the cell, but also allows for the fuses to be located in an accessible location. They primarily provide secondary short circuit protection and are sized to accommodate power cell charging currents upon initial energizing.

> **Note:** A mixture of the three fuse vendors are permitted in terms of fuse replacement as long as any two fuses protecting the secondary windings are matched (i.e., FA1A and FA1C should be from the same vendor).

> **Note:** The GenIV core drive does not include primary fuses. When E-rated fuses are required, choose the smallest rating greater than or equal to the transformer's primary nameplate current value
> (e.g., 1000 KVA / (1.732 * 4160V) = 139A, use 150E fuses).

4.3.3   Cell Section

The Cell Section is located in the upper right hand portion of the GenIV drive enclosure. The basic electrical diagrams for all Perfect Harmony systems are similar. One of the most critical components of all Perfect Harmony drives is the power cell (see Table 4-7). Depending on the operating load voltage, in GenIV either 9, 15, or 24 cells are used to develop the multi-level PWM output waveform. The following table lists the components found in the Cell section.

Table 4-7: Cell Section Components 4160V, 40-140A

Component Label	Part Description
A1, A2, A3, B1, B2, B3, C1, C2, C3	GenIV Power Cells (40, 70, 100, or 140 Amp types)
BPKA1, BPKA2, BPKA3, BPKB1, BPKB2, BPKB3, BPKC1, BPKC2, BPKC3	Mechanical Cell Bypass Contactors (Optional)
K2	Mechanical Key Interlock (Optional)

Table 4-8: Cell Section Components 4160V, 200-260A

Component Label	Part Description
A1, A2, A3, B1, B2, B3, C1, C2, C3	GenIV Power Cells (200, or 260 Amp types)
BPKA1, BPKA2, BPKA3, BPKB1, BPKB2, BPKB3, BPKC1, BPKC2, BPKC3	Mechanical Bypass Contactors (Optional)
FA1A, FA1C, FA2A, FA2C, FA3A, FA3C, FB1A, FB1C, FB2A, FB2C, FB3A, FB3C	Power Cell A and C Phase Input Fuses
K2	Mechanical Key Interlock (Optional)

Table 4-9: Cell Section Components 6600V, 40-260 A

Component Label	Part Description
A1, A2, A3, A4, A5, B1, B2, B3, B4, B5, C1, C2, C3, C4, C5	GenIV Power Cells (40, 70, 100, 140, 200, or 260 Amp types)
BPKA1, BPKA2, BPKA3, BPK14, BPKA5, BPKB1, BPKB2, BPKB3, BPKB4, BPKB5, BPKC1, BPKC2, BPKC3, BPKC4, BPKC5	Mechanical Bypass Contactors (Optional)
FA1A, FA1C, FA2A, FA2C, FA3A, FA3C, FA4A, FA4C, FA5A, FA5C, FB1A, FB1C, FB2A, FB2C, FB3A, FB3C, FB4A, FB4C, FB5A, FB5C,	Power Cell A and C Phase Input Fuses
K2	Mechanical Key Interlock (Optional)

Note: The core GenIV drive does not include medium voltage input switchgear. The K2 mechanical interlock key must be coordinated with the input voltage switchgear.

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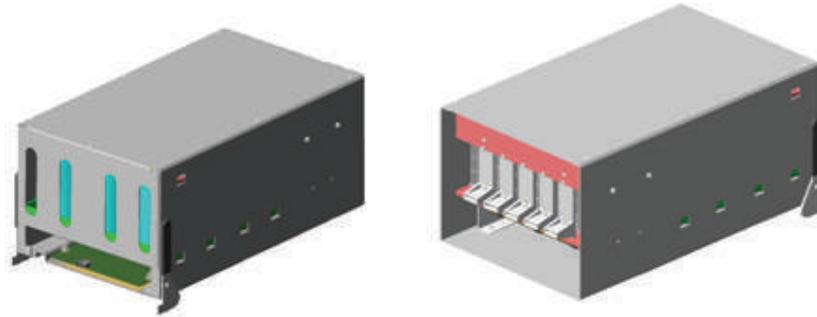
Figure 4-12: GenIV 40-140A Power Cell Frame

The Cell Section portion of the enclosure includes two hinged doors. The left door is master door of the GenIV system and has provisions for a K2 mechanical key interlock. A system requiring agency approval will require mechanical key interlocks. This K2 key should be interlocked with a keyed lock located in the incoming switchgear (coordinated with the Siemens project engineer). Only when the incoming switchgear is mechanically and electrically opened should the K2 key be released for use at the GenIV drive. The GenIV doors are coordinated mechanically to minimize the amount of keyed locks.

> **Note:** The Control Door, Control Section, and I/O Section are accessible without a K2 key. However, the medium voltage components located in the I/O section are separated by fixed polyglass barriers.

The cells are installed in the enclosure by sliding them on the polyethylene coated mounting rails. The cell's locking latches are then rotated into the mounting rail slots, aligning and locking the cell into place. High-temperature foam provides for an air-tight seal between the cell chassis and the backplane. Power Cell line and load connections are made via blind mate power plugs located at the rear of the cell. The plugs accept a special sized nickel plated copper chamfered power bus. No hardware is required to make the power connections or to physically mount the cell, making installation, replacement, and maintenance simple. See Figure 4-13 for a depiction of the cell racking system.

> **Note:** The blind mate power plugs have been factory tested at 250 insertions/extractions with no significant change in contact resistance.

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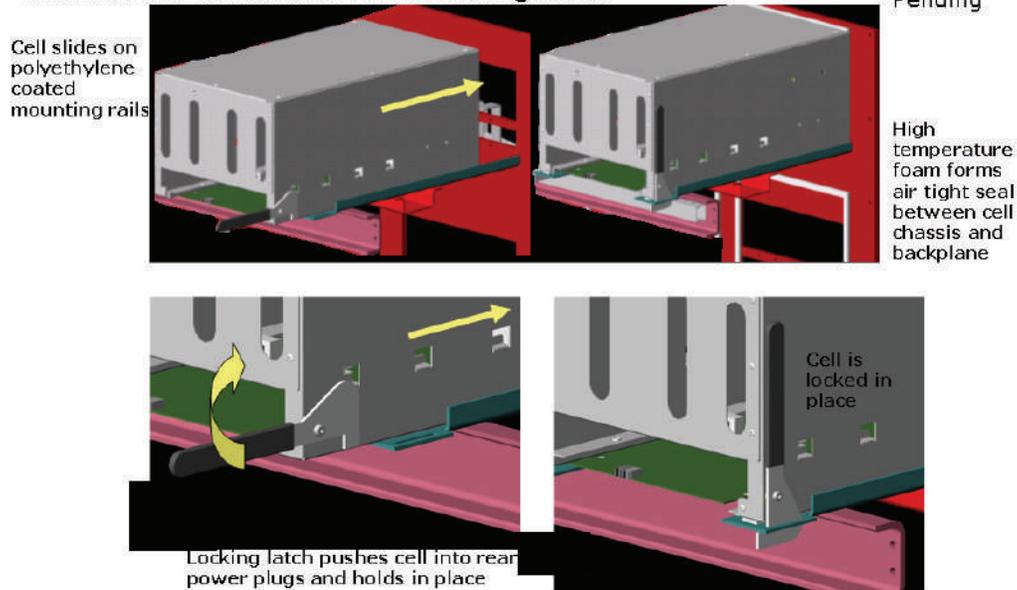
Figure 4-13: Cell Installation and Latching System

The cell mounting infrastructure consists of a polyglass backplane, cell mounting rails, and horizontal polyglass supports. Each of the nine Power Cell's three-phase AC input connections exit at the top right of the Transformer Section, and are routed to the cell via three large adalets (right enclosure wall) and two lexan wire trays. These trays are located underneath the cells. The Power Cell's single phase PWM AC output connections are made in the rear air plenum via bus connections. Projects requiring Cell Bypass will use an additional bus network scheme to connect and physically mount the bypass contactors. Contactors can be changed in the field through the front of the enclosure by removing a Power Cell, disconnecting the subject contactor, and pulling it through the polyglass back plane (only qualified personnel should access the contactors). The contactors and bus connections are forced air cooled (see Figures 4-14 and 4-15). Projects that do not require Cell Bypass use an alternative bus connection made between the power cells' T2 and T1 terminals.

☞   **Note:** A cell lifter, P/N A1A163496.08, may be required to install or remove power cells from the GenIV System.

4

One design accommodates all four cell frames (40, 70, 100, and 140 Amp)

Input connections are made at bus terminals under each cell; wired to transformer secondary B phase and fuses on A and C phase.

Output connections are made with bus behind each cell in the air plenum
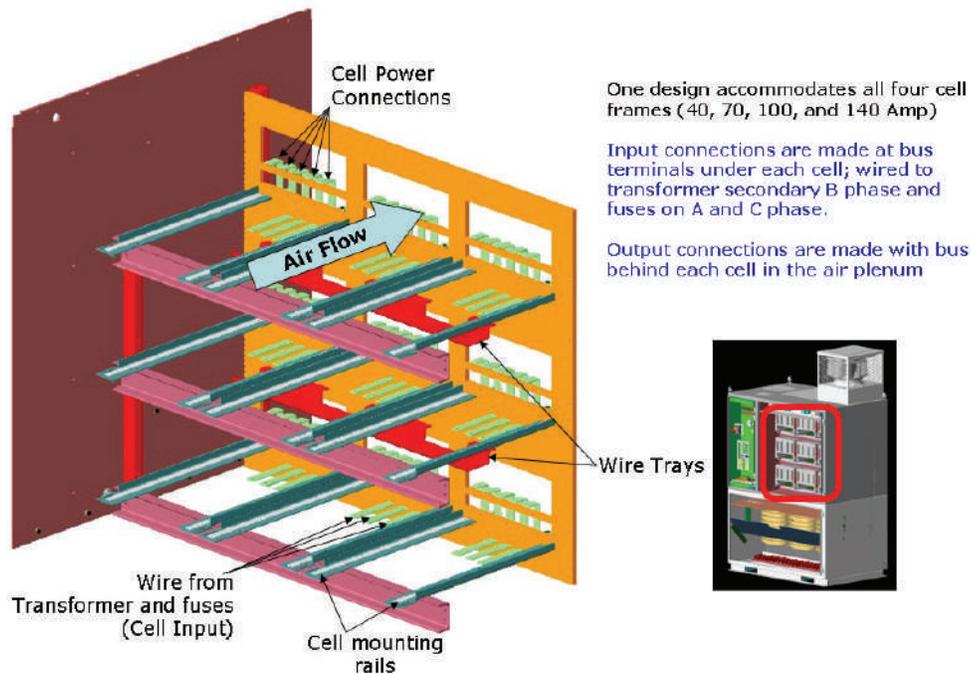
Figure 4-14: Nine Cell 40-140 Amp Mounting Structure

Cell Connections and Bypass Contactors

Contactors and bus assembled via rear access panel.

Contactors held in place by interconnecting 1″ x 0.125″ bus.

Failed contactors can be replaced from the front of the drive.

Contactors and bus are forced air cooled.
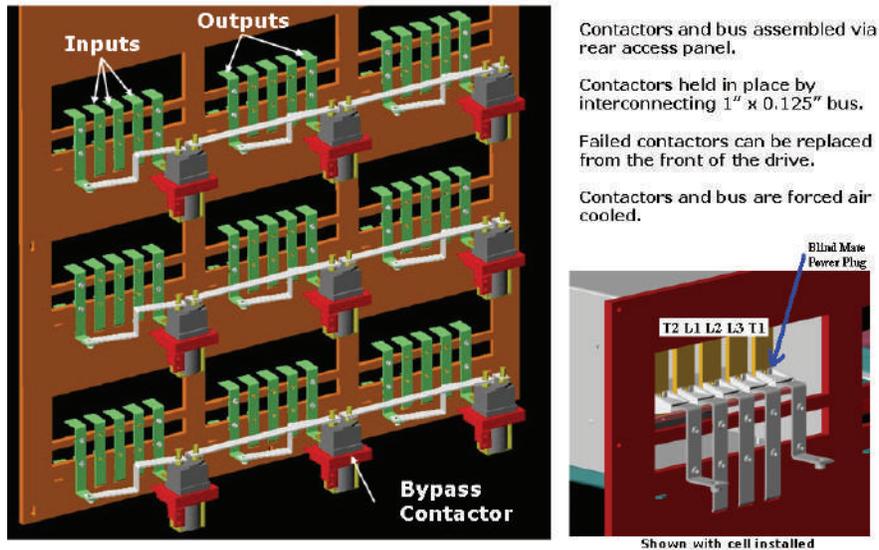
Figure 4-15: Bypass Contactors and Bus Connections

Cell Construction

GenIV MicroHarmony 750V Cells frames (40, 70, 100, and 140 Amp) have an identical footprint, see Figure 4-16 (dimensions and mass are detailed further in Chapter 3 of this manual). GenIV 750V (200 and 260 Amp) cells also have identical footprints. These cells are slightly larger but can use the same mountings as the 40 - 140 amp cells within certain drive systems. The cells in any given drive are mechanically and electrically identical, so that they may be interchanged. Each cell contains its own Cell Control Board (CCB), which communicates to the centralized controller (NXG II) via a fiber optic link. This link is the only connection between the Power Cells and the controller, thus each cell is galvanically isolated from the main control. A switch mode power supply located on the CCB allows the control power to be derived from the individual 3-phase secondary connections of the transformer feeding the power cell line inputs. This power supply is operational at a fraction of the rated voltage of the cell input voltage. The Perfect Harmony controller, known as NXG II, provides central control and interrogation of the nine cells, as detailed in previous chapters of this manual.

The following figures illustrate all power input/output terminals and fiber optic control terminals. Power connections are made via power plugs; no hardware is required. Fiber optic control connections are made at the front of the cell directly to the cell control board. The cell control board and power electronics can be accessed and tested at the same time by rotating the cell 90º as shown (only qualified technicians should examine the Power cells), removing the chassis top cover, and opening the CCB access plate (see Figure 4-16). The + and - DC bus can be accessed by removing the top lid (not shown). Threaded studs are located on the bus for test connections.
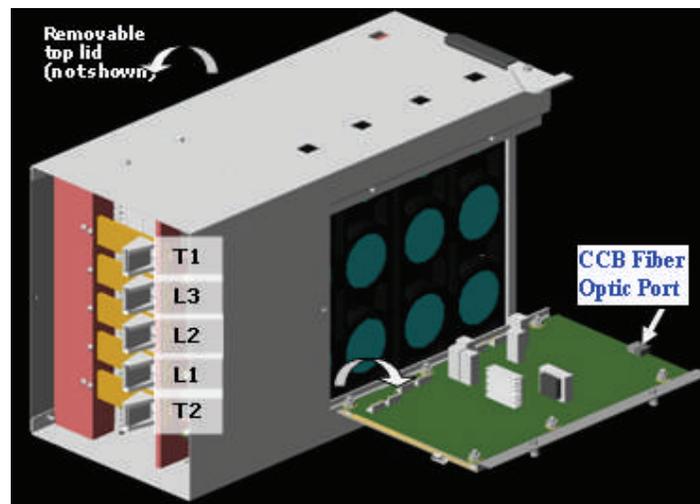
Figure 4-16: GenIV Power Cell with Board Shown

The 40, 70, 100, and 140 Amp power cells are only differentiated by the number of electrolytic capacitors that are installed and the semiconductor devices (diode rectifiers, IGBTs) on the heat sink. The 200 and 260 Amp power cells use a different frame size. However, the 200 and 260 Amp cells are differentiated only by the number and type of electrolytic capacitors and semiconductor devices.

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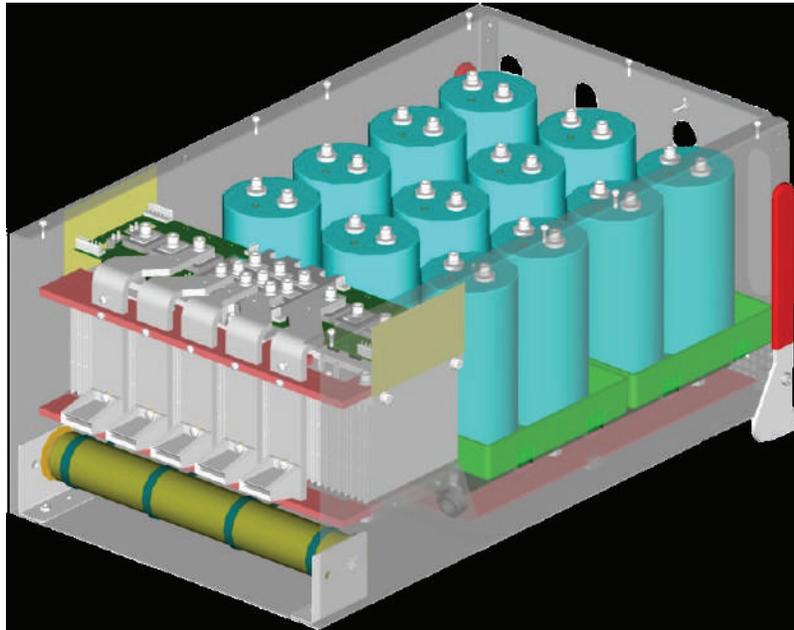
Figure 4-17: GenIV Cell, 40-140Amp, Anatomy

* Shown with full population of electrolytic capacitors

The GenIV cells use an uncontrolled diode rectifier to convert the three-phase secondary voltage to DC. Since power can only flow from the transformer to the cells, the converter is considered a two quadrant type (2Q).
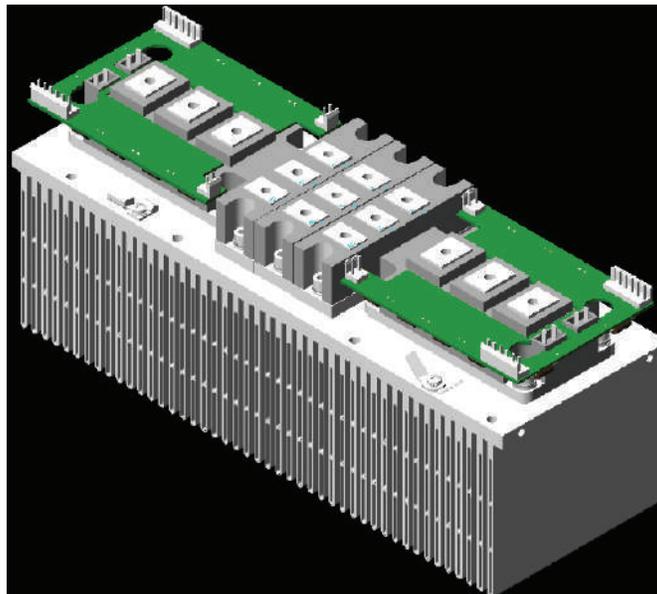
Figure 4-18: GenIV Cell, 40-140Amp, Heat Sink

Cell Data

Switching Frequency

Cells are typically switched at 600 Hz per pole, with an output switching frequency of 1200 Hz per cell. The total effective drive output switching frequency with 9 cells is 3600 Hz (15 cells for 6000 Hz). At this switching frequency, the output (motor) frequency can increase to 167 Hz. At motor frequencies beyond 167 Hz, its recommended to switch the cells faster. The cells can switch (with current de-rating) as high as 1200 Hz per pole, which allows a maximum output (motor) frequency of 330 Hz.

Communications

The Cell Control Board (CCB) communicates with the NXG Controller via a duplex fiber optic cable using a proprietary protocol.

Protection Features

The Cell Control Board (CCB) contains circuitry and firmware that protects the cell from the following abnormal operating conditions:

- DC Bus Over-Voltage
- DC Bus Under-Voltage
- Control Power Loss
- Capacitor Voltage Sharing
- IGBT Out of Saturation
- Cell Over-Temperature
- IGBT Device Failure
- AC Bus Under-Voltage
- Communication Fault

These conditions are interrogated by the main NXG Controller and may result in a Cell Fault, which inhibits the power cell output.

Indicators and Labels

Figure 4-19 illustrates the indicator functions and labels of the Power Cell. Particular attention should be paid to the DC bus voltage-indicator LED that shows that more than 50 VDC is present on the DC bus. This indicator light is located on the front of each cell's Cell Control Board (and may not be visible until the cell doors are opened). The cell should not be touched, removed, or serviced if the indicator is illuminated.

Danger! Remember that the cell chassis is not grounded and when energized can float to lethal voltages.

4

Figure 4-19: Indicators and Labels

Warning! The power cells include discharge resistors to dissipate stored energy after the input voltage is removed. The power cell DC bus voltage decays to less than 50 VDC in less than 5 minutes.

Cell De-rating

In some cases, a cell's continuous output current rating is de-rated due to site conditions and abnormal applications. (Refer to Figure 4-20.)

1. Power Cell initial sizing is based upon the motor parameters, (including motor service factor):

   $I_{MTR} = Hp * SF * 746 / (V_{MTR} * 1.732 * PF * EFF)$

2. If motor nameplate frequency exceeds 167Hz, the $F_{CAR} = 3.6 * F_{OUT}$ [Hz], and when F_{CAR} exceeds 600 Hz de-rate cell current as:

   $I_{BASE\ 1} = (1-[(F_{CAR}-600)/600]*0.2)$

3. If F_{OUT} is operated continuously below 10 Hz, de-rate cell current as:

   $I_{BASE\ 2} = (0.5 + F_{OUT} / 20)$

4. If altitude exceeds 3300 FASL, then de-rate cell current as:

   $I_{BASE\ 3} = (1-0.00003*[ALT-3300])$

5. If ambient temperature exceeds 45 °C, then de-rate cell current as:

   $I_{BASE\ 4} = ([60 - T_{AMB}]/15)^{0.67}$

6. Use only the smallest de-rate factor from $I_{BASE\ 1}$, $I_{BASE\ 2}$, $I_{BASE\ 3}$, and $I_{BASE\ 4}$ to size the cell (de-rates are not compounded). Select the smallest cell frame size equal or greater than $I_{MTR} / I_{BASE\ (1,2,3,\ or\ 4)}$

Figure 4-20: GenIV Cell Current De-Rate Factors [1], [2]

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1. Excludes long cable provisions
2. Maximum ambient of 60 °C and maximum altitude of 6562 feet

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Cell Bypass

As an option, the core GenIV drive can be equipped with Cell Bypass. Each cell output is fitted with a single pole double throw electromechanical contactor (as shown in Figure 4-21 below).
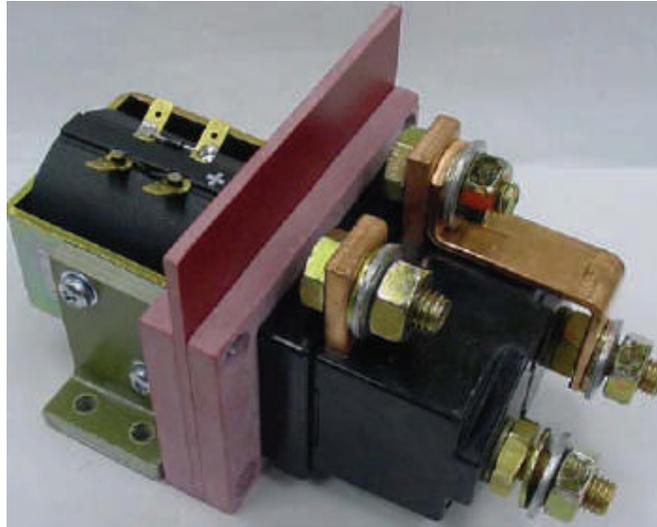
Figure 4-21: Electromechanical Contactor (Single Pole, Double Throw)

The bypass contactors are mounted behind the cell in the air plenum. All connections are made with insulated wire and bus connections. The Bypass Power Supply (BPPS) and Bypass Control Circuit (BCC) are located in the I/O Section. The BCC connects to the NXG controller via a fiber optic link and contactor controls are wired to the BCC. The BPPS is energized from one of the transformer secondary windings and is referenced to the VFD output neutral. Refer to Sections 1.3.5 and 5.13.1 for further details concerning power Cell Bypass.
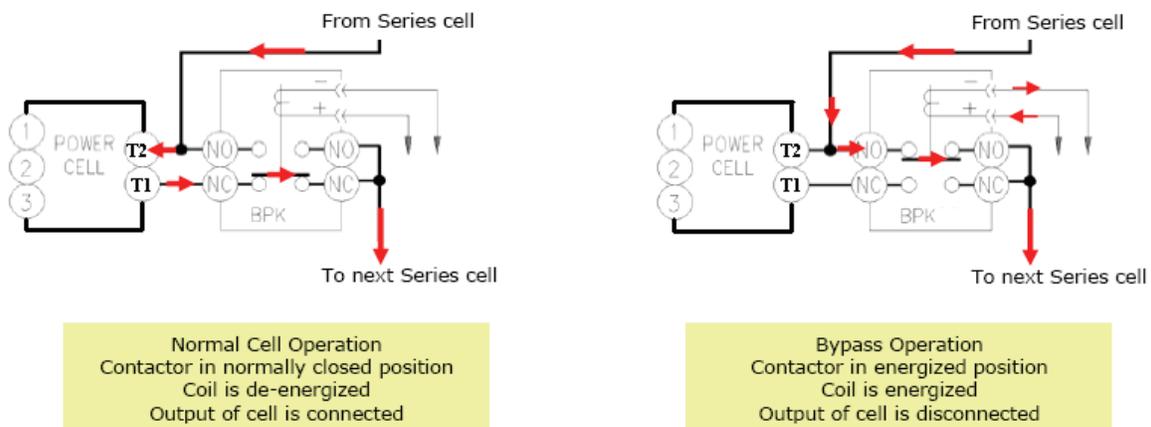
Figure 4-22: Cell Bypass Operation

4.3.4   Control Section

The Control Section is located in front of the I/O Section and contains the NXG II Controller, low voltage apparatus, and the auxiliary voltage disconnect switch; the Control Door is considered part of this section in reference to the "C" and "W" drawings. The door in the control section is hinged so that it can swing open 150 degrees to allow access to the input/output section for purposes such as terminating medium voltage cables. Upon opening the control door, two

polyglass barriers are encountered as describe previously. In addition, the terminal blocks are accessible with the door in the open position. See Table 4-10 for the components found in this section.

Table 4-10: Control Section Components

Component Label	Part Description
SCB	NXGII: Signal Conditioning Board
SW2	Latch Fault Relay Reset
DCR	NXGII, Digital Card Rack
	Slot 1: Keypad Interface Board
	Slot 2: Single Board Computer
	Slot 3: BGA Modulator with 12 Fiber Optic Ports
	Slot 4: Reserved
	Slot 5: Analog I/O Cable Assembly
	Slot 6: System I/O Board
	Slot 7: Digital I/O Cable Assembly
	Slot 8: Communications Board
CPS	Control Power Supply
DS1, AUX2	Auxiliary Voltage Disconnect and Position Switch
LFR	Latch Fault Relay
EPS	Encoder Power Supply (optional)
IOB	NXGII, Input/Output Breakout
GND1	Grounding Pad
PB4	Emergency Stop Pushbutton
KP1	Keypad
RS232NET	RS232 Port and Ethernet Port
SW1	Mode Selector Switch
ANYBUS1, ANYBUS2[1]	Network 1 and Network 2 communication cards (optional)

1.These expansion boards plug into the communications board in slot 8 of the DCR

Control Tub

The control tub contains all the components shown in Figure 4-23.

☞ **Note:** Encoder Power Supply option not shown; it mounts to the din rail beside DS1.

The auxiliary voltage for control is switched on with the disconnect, DS1. The encoder power supply, EPS, is a 120V powered +15 VDC output that is used in CLVC applications and is available as an option. GND1 is connected to GND2, located in the I/O section using a flexible ground conductor; several points within the Control Tub are grounded to GND1.

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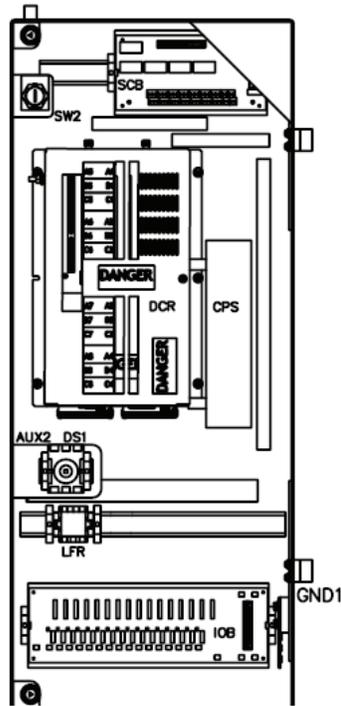
Figure 4-23: GenIV Control Tub (4160V Drives)

Figure 4-24: GENIV Control Tub (6600V)

NXG II

The four components comprising NXG II Control are SCB, DCR, CPS, and IOB. The components are fully detailed in the companion manual, *NXG Control Manual* A1A19001588.

Analog and Digital Input/Output

The input/output breakout (IOB) contains a finite amount of hard-wired I/O. Some of these signals are dedicated for use within the drive (refer to Table 4-12). The remaining SPARE I/O can be used in agreement with the Siemens project engineer for customer related signalization using the SOP.

Table 4-11: Analog and Digital Input/Output

Signal Type	Quantity	Core Configuration	Custom Options
Digital Inputs	20	120 VAC[1]	a) Customer powered[2] b) 24 VDC, drive powered[3] c) Other than Table 4-12 or 4-13
Digital Outputs	16	Dry N.O. Contacts, rated 250 VAC @ 6A	a) Dry N.C. Contacts b) Other than Table 4-12 or 4-13
Analog Inputs	3	4-20 mADC	a) (2) 0-10 VDC inputs b) Other than Table 4-12 or 4-13
Analog Outputs	2	4-20 mADC	a) Other than Table 4-12 or 4-13

1. Drive Powered Digital Inputs
2. Subject to Custom Engineering Requirements
3. Requires Custom Engineering

Note: Network communications have provisions for I/O signalization as described in the *NXG Control Manual* A1A19001588 and *NXG Communications Manual* A1A902399. For GenIV expansion, hardwired I/O must be treated as Custom Engineering and requires the use of a transition cabinet due to the limited space available within the core drive.

Table 4-12: Nine Cell, GenIV, Core Hardwired I/O Assignments
(Subject to Change. Always refer to the project "C" and "W" for I/O assignments)

Signal Type	Signal Name	Function
Digital Input	IDI-0A	Remote Inhibit
Digital Input	IDI-1A	Remote Start
Digital Input	IDI-2A	Remote Stop
Digital Input	IDI-3A	Remote Fault Reset
Digital Input	IDI-0B	SW1-Off
Digital Input	IDI-1B	SW1-Remote/Auto
Digital Input	IDI-2B	Output Reactor Winding Temperature, High (Else SPARE)
Digital Input	IDI-3B	Output Reactor Winding Temperature, High-High (Else SPARE)

4

Signal Type	Signal Name	Function
Digital Input	IDI-0C	SPARE
Digital Input	IDI-1C	SPARE
Digital Input	IDI-2C	SPARE
Digital Input	IDI-3C	Transformer Winding Temperature, High
Digital Input	IDI-0D	Transformer Winding Temperature, High-High
Digital Input	IDI-1D	Cooling Blower 1 O.K.
Digital Input	IDI-2D	Redundant Cooling Blower 2 O.K. (Optional)
Digital Input	IDI-3D	SPARE
Digital Input	IDI-0E	SPARE
Digital Input	IDI-1E	SPARE
Digital Input	IDI-2E	SPARE
Digital Input	IDI-3E	Latch Fault Relay (LFR) Feedback
Digital Output	IDO-0	Speed Demand in Local at VFD
Digital Output	IDO-1	Drive Ready to Run
Digital Output	IDO-2	Drive Running
Digital Output	IDO-3	Drive Alarm
Digital Output	IDO-4	Drive Fault
Digital Output	IDO-5	ProToPS, Process Alarm (Else SPARE)
Digital Output	IDO-6	ProToPS, Process Trip Alarm (Else SPARE)
Digital Output	IDO-7	SPARE
Digital Output	IDO-8	Cooling Blower 1 Starter
Digital Output	IDO-9	Redundant Cooling Blower 2 Starter (Optional)
Digital Output	IDO-10	SPARE
Digital Output	IDO-11	SPARE
Digital Output	IDO-12	SPARE
Digital Output	IDO-13	SPARE
Digital Output	IDO-14	Coordinated Input Protection Scheme
Digital Output	IDO-15	Latch Fault Relay (LFR), Set Pulse
Analog Input	IAI-1	Remote Speed Demand, 4-20 mADC

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Signal Type	Signal Name	Function
Analog Input	IAI-2	SPARE
Analog Input	IAI-3	SPARE
Analog Output	IAO-A	Motor Speed, 4-20 mADC
Analog Output	IAO-2	Motor Torque, 4-20 mADC

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Table 4-13: Fifteen Cell (6600V), GenIV, Core Hardwired I/O Assignments

(Subject to Change. Always refer to the project "C" and "W" for I/O assignments

Signal Type	Signal Name	Function
Digital Input	IDI-0A	Remote Inhibit
Digital Input	IDI-1A	Remote Start
Digital Input	IDI-2A	Remote Stop
Digital Input	IDI-3A	Remote Fault Reset
Digital Input	IDI-0B	SW1-Off
Digital Input	IDI-1B	SW1-Remote/Auto
Digital Input	IDI-2B	Output Reactor Winding Temperature, High (Else SPARE)
Digital Input	IDI-3B	Output Reactor Winding Temperature, High-High (Else SPARE)
Digital Input	IDI-0C	SPARE
Digital Input	IDI-1C	SPARE
Digital Input	IDI-2C	SPARE
Digital Input	IDI-3C	Transformer Winding Temperature, High
Digital Input	IDI-0D	Transformer Winding Temperature, High-High
Digital Input	IDI-1D	Cooling Blower 1 (TBLW1) O.K.
Digital Input	IDI-2D	Redundant Cooling Blower 2 (TBLW2) O.K. (Optional)
Digital Input	IDI-3D	Cooling Blower (CBLW1) O.K.
Digital Input	IDI-0E	Redundant Cooling Blower 2 (CBLW2) O.K. (Optional)
Digital Input	IDI-1E	SPARE
Digital Input	IDI-2E	SPARE
Digital Input	IDI-3E	Latch Fault Relay (LFR) Feedback
Digital Output	IDO-0	Speed Demand in Local at VFD

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Signal Type	Signal Name	Function
Digital Output	IDO-1	Drive Ready to Run
Digital Output	IDO-2	Drive Running
Digital Output	IDO-3	Drive Alarm
Digital Output	IDO-4	Drive Fault
Digital Output	IDO-5	ProToPS, Process Alarm (Else SPARE)
Digital Output	IDO-6	ProToPS, Process Trip Alarm (Else SPARE)
Digital Output	IDO-7	SPARE
Digital Output	IDO-8	Cooling Blower 1 (TBLW1) Starter
Digital Output	IDO-9	Redundant Cooling Blower 2 (TBLW2) Starter (Optional)
Digital Output	IDO-10	Cooling Blower (CBLW1) Starter.
Digital Output	IDO-11	Redundant Cooling Blower 2 (CBLW2) Starter. (Optional)
Digital Output	IDO-12	SPARE
Digital Output	IDO-13	SPARE
Digital Output	IDO-14	Coordinated Input Protection Scheme
Digital Output	IDO-15	Latch Fault Relay (LFR), Set Pulse
Analog Input	IAI-1	Remote Speed Demand, 4-20 mADC
Analog Input	IAI-2	SPARE
Analog Input	IAI-3	SPARE
Analog Output	IAO-A	Motor Speed, 4-20 mADC
Analog Output	IAO-2	Motor Torque, 4-20 mADC

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Coordinated Input Protection Scheme

Input currents and voltages to the drive input transformer are measured and processed continuously by the control system. Information such as efficiency, power factor, and harmonics are available to the user. The input monitoring also protects against transformer secondary side faults that cannot be seen by typical primary protection relaying. Thus it is very important that the drive input medium switchgear, if not supplied as standard, is interlocked to the control system so that input medium voltage can be interrupted upon the rare event of such a fault.

A dry contact output is supplied standard with each drive to trip the drive input medium voltage circuit breaker or contactor. This contact changes state whenever the drive input power and power factor are outside hardcoded normal operating conditions.

⚠️ | **Danger!** This contact must be integrated with input switchgear to deactivate the drive input medium voltage upon the rare event of a secondary circuit fault.

This scheme is active on all GenIV drives. Therefore, a medium voltage input circuit breaking device is required. As shown in Figure 4-25 below, the latch fault relay, LFR, and its reset switch, SW2, make a portion of the coordinated input protection scheme. The drive control continuously meters the input power, and if the drive exhibits excessive losses or reactive power, then a dedicated NXG II I/O digital output (IDO-15) is closed as a one-shot pulse latches the LFR coil. This causes the N.C. LFR contact to OPEN, and the NXG II I/O digital output IDO-14 also opens. As shown in the following figure, if the contacts looking into the drive are closed, the user is permitted to close the incoming breaker, hence the signal name "MV IP Breaker Enable". However, if the contacts are open, then the input breaker must also be immediately opened. In addition to the Input Protection scheme controlled by the NXG II Controller, GenIV also series connects one deck of the E-Stop (PB4) in series with the Coordinated Input Protection Scheme. Therefore, if the E-Stop located at the drive is operated, the contacts at TB2 will also open (this is only a portion of the protection scheme that is subject to change, based upon user preference). To reset the protection scheme, the LFR must be reset using SW2 (located in the Control Tub), which immediately recloses the LFR N.C. contacts, and then a Drive Fault Reset must be initiated (NXG Control will not re-close IDO-14 if the FAULT conditions still exist).
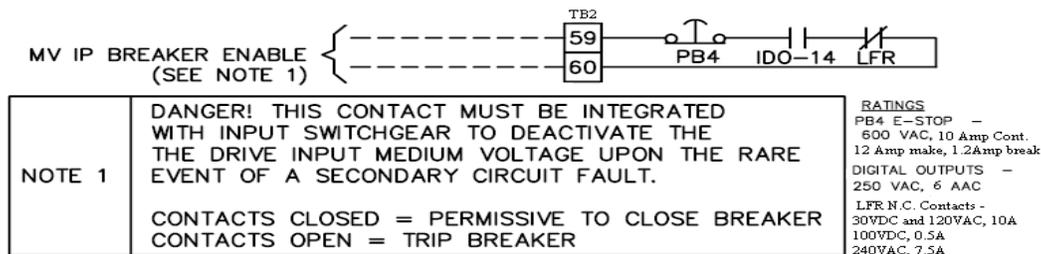
Figure 4-25: Input Protection Interface for Trip Contact

* This circuit is repeated in the "C" set of drawings. Contact ratings are shown for resistive switching.

☞ | **Note:** Given the amperage rating of the components used in the Coordinated Input Protection Scheme, an additional customer pilot relay may be required.

Terminal Blocks

The core drive uses 8mm 600V terminal blocks for the auxiliary input three-phase voltage (TB4). These terminals accept #8 - #22 AWG wire.

The control terminal blocks (TB1, TB2, TB2 ELV) accept #12 - #22 AWG wire.

☞ | **Note:** Only a small amount of spare terminals are available for custom engineering use.

4

Control Door

The Control Section includes the components mounted on the control door (see Figure 4-27). The operation of the keypad, KP1, is described in the *NXG Control Manual* A1A19001588 (see Figure 4-28 for a view of the keypad operator).

The RS232 communications port is located on the front of the Control Door and is used for Serial communications for debugging and uploading/downloading information to the NXG II controller. An Ethernet port is included on the front door. Ethernet Modbus is available on the SBC, depending on what communications networks are selected for Network 1 and 2 (see *NXG Communications Manual*, A1A902399).

SW1 is a Mode Select switch that is optionally selected as Off-Local-Remote or Off-Hand-Auto (SW1 can also be keyed). The functionality is the same. If SW1 is in the OFF position, the inverter output will be inhibited. If SW1 is in the Remote/Auto position, the control will use either a Remote 4-20 mADC speed demand or Network demand, depending on how the project SOP is written. If SW1 is not in OFF or Remote/Auto, the speed demand is set by the Keypad operator (this is considered the Local/Hand operation).

PB4, is a red mushroom-head maintained N.C. multi-deck operator that is used for emergency stops (E-Stop). One deck of the PB4 operator is drive power 120V powered, and is used in series with the CR3 function of the drive. In addition, this set of contacts is series connected to the terminal blocks, where the customer can wire in a N.C. set of E-Stop wires (reference the "C" set of drawings) (see Figure 4-26). The YELLOW jumper must be removed from the terminal blocks located in the I/O Section to allow proper operation of the remote E-Stop wiring. When activated, the inverter output will be inhibited immediately and the connected load will coast. A second deck of the N.C. PB4 operator is connected to the terminal block section for use by the customer and is a dry set of contacts. A third deck of the PB4 operator is connected in series with the Coordinated Input Protection Scheme. Therefore, in this scenario, when PB4 is activated at the drive, the "MV IP Breaker Enable" signal will open (some customers may prefer Custom engineering to alter the logic of this third deck).
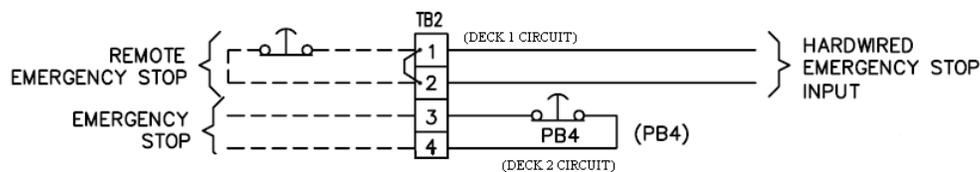
Figure 4-26: E-Stop Circuits (Deck 1 and Deck 2)
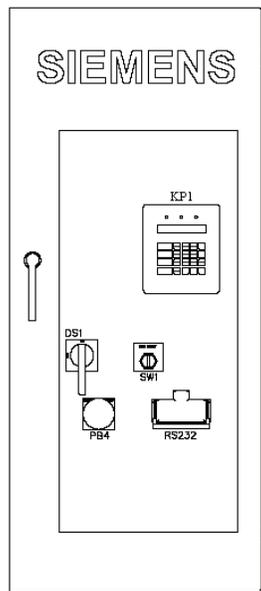
Figure 4-27: Control Door (Control Arrangement May Vary)
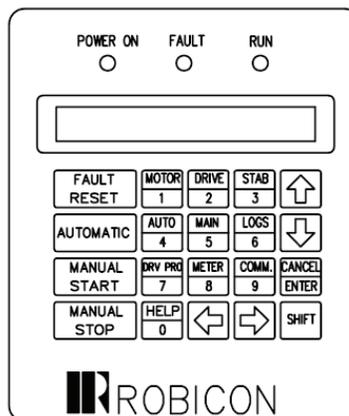
Figure 4-28: Keypad

4.3.5   Control Wire Way Section

The Control Wire Way Section is located within the enclosure and above the Cell Section. Two hinged door plates are provided so that this section can be accessed with ¼ turn cams even while the drive's medium voltage and auxiliary power are energized.

Note: Only qualified personnel should access the Control Wire Way Section at any time.

Following is a list of components found in this section (see Figure 4-29) for a view of the Control Wireway section with all options selected).

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Table 4-14: Control Wireway Parts (4160V)

Component Label	Part Description
F4, F21, F22	Control Power Fuses
F24, F25, F26	Blower 1 Line Fuses
F27, F28, F29	Blower 2 Line Fuses (Optional)
STR21, AUX21, SUPP21	Motor Starter for Blower 1, auxiliary contact, and AC coil suppressor
STR22, AUX22, SUPP22	Motor Starter for Blower 2, auxiliary contact, and AC coil suppressor (Optional)
X2	2.5% Line Reactor for EC Blower 1
X3	2.5% Line Reactor for EC Blower 2 (Optional)
FLTR1	EMC Filter for Auxiliary Control Voltage (Optional)
PL2, PL3	Blower Control Disconnect Harnesses
GND4	Blower and Line Reactor Grounding Pad
GND5	Redundant Blower Ground

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Table 4-15: Control Wireway (6600V)

Component Label	Part Description
F4, F21, F22	Control Power Fuses
F24, F25, F26	Blower TBLW1 Fuses 1
F27, F28, F29	Blower TBLW2 Fuses 1 (Optional)
F30, F31, F32	Blower CBLW1 Fuses 1
F33, F34, F35	Blower CBLW2 Fuses 1 (Optional)
CB10	Blower TBLW1 Circuit Breaker 2
CB11	Blower TBLW2 Circuit Breaker 2 (Optional)
CB12	Blower CBLW1 Circuit Breaker 2 (Optional)
CB13	Blower CBLW2 Circuit Breaker 2
STR21, AUX21, SUPP21	Motor Starter for TBLW1, auxiliary contact, and AC coil suppressor
STR22, AUX22, SUPP22	Motor Starter for TBLW2, auxiliary contact, and AC coil suppressor (Optional)
STR23, AUX23, SUPP23	Motor Starter for CBLW1, auxiliary contact, and AC coil suppressor
STR24, AUX24, SUPP24	Motor Starter for CBLW2, auxiliary contact, and AC coil suppressor (Optional)
X1	2.5% Line Reactor for EC Blower TBLW1
X2	2.5% Line Reactor for EC Blower TBLW2 (Optional)
X3	2.5% Line Reactor for EC Blower CBLW1
X4	2.5% Line Reactor for EC Blower CBLW2 (Optional)
FLTR1	EMC Filter for Auxiliary Control Voltage (Optional)
PL2, PL3, PL4, PL5	Blower Control Disconnect Harnesses
GND4	Transformer Blower Ground Pad
GND5	Cell Blower Ground
GND10	CPT and Line Reactor Ground

1. Fuses are omitted when the circuit breaker option is selected.
2. Blower circuit breakers are an option.

The auxiliary voltage control transformer, X5, is protected by three fuses that are located in this section. F21 and F22 are located on the primary of the auxiliary control voltage transformer, and F4 is located on the secondary of the transformer. These fuses are CC time delay 600V rated.

The EMC filter is typically used on agency projects requiring CE certification. FLTR1 is a two-stage zero sequence filter rated at 7A, and when used, is applied between the disconnect switch (DS1 in the Control Section) and the EC Blowers' motor starter.
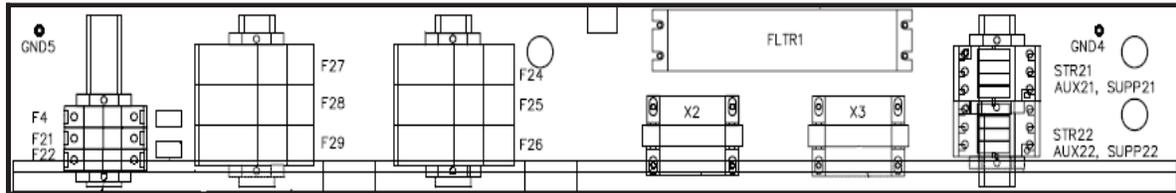
Figure 4-29: Control Wire Way Section (4160V with all options)

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Cooling System Control

The Cooling System consists of several parts other than the EC blower and Zener command circuit described in the next section. In addition to those components, each blower has three 600V Class J time delay fuses or a 600V three phase 10 Amp circuit breaker that feed a 2.5% line reactor. The line reactor is then connected to a motor starter that is controlled through the SOP of the NXG II Controller. The output of the motor starter connects to a quick disconnect plug associated with the blower. Fault logic is fed back through the plug back into the I/O system of the NXG II controller.

The default SOP logic is such that upon energizing the control power, Blower # 1 (TBLW1 & CBLW1 for 6600V drives) is operated immediately. The fault logic is ignored for a short duration to allow the blower to soft start-up. After this duration, if the SOP logic controller detects a FAULT feedback, the redundant blower(s) is started or else the drive trips on a ALL BLOWERS LOST fault, and the drive must be manually reset. The starter voltage is automatically removed for a brief duration to allow the EC blower(s) to reset. If redundant blowers are equipped on the drive, the blowers are cycled on a periodic basis (typically every 7 days). The 2.5% line reactors are used to decouple the EC blower from brief line disturbances; in addition, the reactors filter the current draw from the blower and make it more sinusoidal.

4.3.6   Cooling

An extremely important part of the installation process is making provisions for exhausting the heat that is generated by the operation of the drive. Although the GenIV drive is highly efficient, there may be as much as a 3.0% energy loss emitted in the form of heat from inside the system cabinetry. This heat must be transmitted to the outdoor air or into the structure of the building at a rate fast enough to prevent the ambient temperature from rising above the rated conditions stated in Chapter 3.

Blowers # 1 and #2

The GenIV blower cages are located on the roof of the enclosure. The 4160 drives require only one blower to operate. The 6600V drives require one blower in the cell cabinet and one blower in the transformer cabinet to operate. The cage assemblies are typically removed and packaged separately for shipment. All electrical connections between the drive and blower are made via a quick disconnect harness for ease of installation. The GenIV blower cage uses a rear tongue and groove lip and two front flange-mounted fasteners so that it is easily front-access-maintainable following installation. Components in these sections include:

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Table 4-16: Blower Components (4160 Drives)

Component Label	Part Description
BLW1	Solid state (inverter) Blower #1
RBLW1*, DBLW1*	Blower command; resistor and zener diode
BLW2	Solid state (inverter) Blower #2 (optional)
RBLW2*, DBLW2*	Blower command; resistor and zener diode (optional)

Table 4-17: Blower Components (6600V Drives)

Component Label	Part Description
TBLW1	Solid state (inverter) Transformer Blower #1
RTBLW1*, DTBLW1*	Blower command; resistor and zener diode
TBLW2	Solid state (inverter) Transformer Blower #2 (optional)
RTBLW2*, DTBLW2*	Blower command; resistor and zener diode (optional)
CBLW1	Solid state (inverter) Cell Cabinet Blower #1
RCBLW1*, DCBLW1*	Blower command; resistor and zener diode
CBLW2	Solid state (inverter) Cell Cabinet Blower #2
RCBLW2*, DCBLW2*	Blower command; resistor and zener diode (optional)

*Resistor and Zener diode form a clamp circuit to command the blower speed (see Table 4-18 for blower speed settings). However, if a duct interface is required, these components are removed and the command jumpers directly to the +10VDC for a 100% speed demand.

Table 4-18: Blower Speed Settings

Drive Descriptionl	Section	Speed Setting
4160 Drives ≤ 140A		80%
4160 Drives >140A		94%
6600VDrives ≤ 140A	Cell	82%
6600VDrives ≤ 140A	Transformer	82%
6600 Drives >140A	Cell	92%
6600 Drives >140A	Transformer	92%

The GenIV drive is a parallel path forced air cooling system using an electronically commutated blower(s); each of the cells are cooled in parallel. 4160V drives also cool the transformer in parallel with the cells allowing for a single blower to provide the cooling air for the entire drive. 6600V drives have a separate transformer section cooled by a second blower. Parallel air cooling allows each component to have the same inlet air temperature (close to the drive's ambient temperature) independent of the other components. The cell section has multiple air inlet paths, each with an

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inlet filter. The transformer section has multiple air inlet paths and the transformer is baffled to force air through the secondary coils and around the windings

The cell section and transformer section exhaust air into a common rear air duct. Each cell's input and output power connections are made via blind mate power plugs at the rear of the cell. The male connecting bus is located in line with the exhaust air of the cell. For systems with mechanical cell bypass, the contactors are mounted on an additional bus, located in the rear common exhaust air plenum. All of the bus and the contactors are therefore forced-air cooled, but at an elevated ambient due to cell and transformer losses. Two phases of each cell's inputs are fused. A common fuse block is located at the front of the transformer section. The fuse ambient is the same as the drive's ambient air temperature.

The blower cage is a modular design; if redundant blowers are required, a cover plate is removed from the top of the enclosure and an additional blower cage assembly is installed. A damper is installed at the base of each blower cage to prevent reverse air flow. The dampers are opened by air pressure differential and closed by springs. The blower cage assembly design consists of a steel frame with expanded metal mesh on three sides (duct interface jobs require alternative pre-engineered blower cage). Air is exhausted out of the front and sides of the cage. Air is not exhausted towards the back or top of the drive. A small portion of the blower's exhaust air crosses the EC blower's heat sink, allowing high exhaust air ambient temperatures. The GenIV drive uses an EC blower with inherent protection features (soft-start, under-voltage, phase failure, current limit, over temperature, locked rotor protection, and short circuit protection). A fault contact is wired into the NXG II control I/O. If a redundant blower is selected, the control cycles the blower periodically, and toggles them upon receiving a FAULT feedback from the blower.

☞ **Note:** The control removes power via a starter for a brief time following a FAULT signalization, according to the blower manufacturer's recommendation. See Figure 4-30 for a view of the blower cage and EC blower.
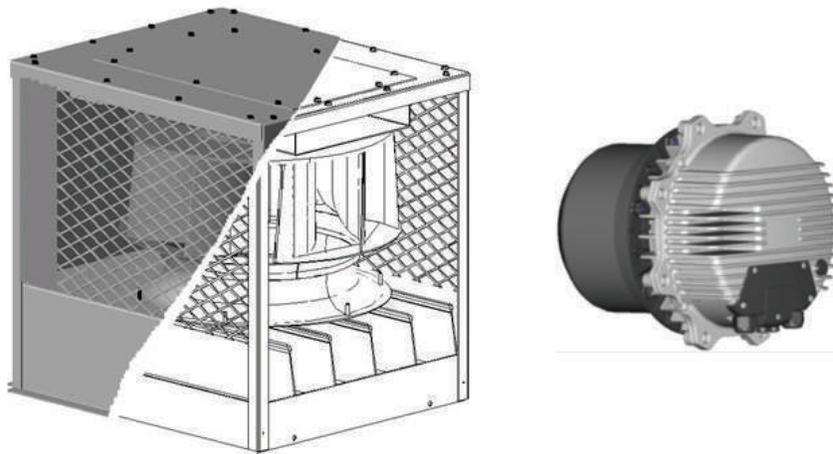
Figure 4-30: GenIV EC Blower and Cage Cutaway

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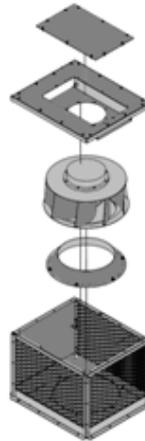
Figure 4-31: GenIV 500mm Blower Cage Assembly

> ☞ **Note:** Never energize the drive without operational blowers providing air flow. The drive contains components that have losses in the IDLE state. Without air flow, these losses may heat up components and eventually damage the drive over time.

4.4 Long Cable Filters

For GenIV, output filters are typically required when cable lengths on the output of the drive exceed 7500 feet. At this distance and beyond, the effective switching frequency harmonics and sidebands may excite a cable resonance, resulting in transmission line over-voltages at the motor terminals. The output L-C filter decouples the drive output from the cable/motor dynamics. NXG II control supports output filters for all control modes; however, torque responses and high starting torque capabilities are somewhat diminished due to the added components. The filter capacitor currents are monitored by NXG II control through the SCB, and active damping is provided in lieu of additional hardware resistors.

> ☞ **Note:** GenIV drives should not operate into the O-M region when output filters are required. Therefore, a nine cell system is limited to an output voltage of 4005V. Fifteen cell systems are limited to 6600V.

4.4.1 Reactors and Capacitors

When the GenIV requires an OUTPUT FILTER, the drive output is equipped with an output inductor and capacitor filter. These components cannot be packaged into the core configuration due to space limitations; therefore, they are housed in transition cabinets. Tables 4-19, 4-20, 4-21, and 4-22 list the required inductance and capacitance for GenIV output L-C filters.

The reactors are typically custom engineered, and may include an overload rating that matches the cell type and two sets of thermal protectors embedded into the windings.

The capacitors are heavy duty IEEE Standard 18 rated. Most commonly, available off-the-shelf capacitors are rated for 60 Hz.

The filter connects to the output of the motor drive's T1, T2, and T3 connections. The long cable load is then connected to the load side of the filter reactors. The filter may include a customer-supplied down hole monitoring system (DHMS). Special attention is required and small resistors may need to be placed in series with the DHMS to prevent fuse failures during motor starting. The filter components are sized, based upon the continuous current rating of the power cells and maximum voltage available (without O-M) of the drive.

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Table 4-19: Nine Cell Output Filter, Capacitance

Cell Size	Z_{FL} @ 4005V	Q, Reactive @ 60Hz, 4160V, 3Ph	C, Capacitance	C% @ 50 Hz	C% @ 60 Hz
40 A	57.81 Ohms	25 kVAr*	3.83 μF	6.96%	8.35%
70 A	33.03 Ohms	50 kVAr	7.66 μF	7.95%	9.54%
100 A	23.12 Ohms	75 kVAr*	11.5 μF	8.35%	10.02%
140 A	16.52 Ohms	100 kVAr	15.32 μF	7.95%	9.54%
200 A	11.56 Ohms	150 kVAr	22.99 μF	8.35%	10.02%
260 A	8.89 Ohms	200 kVar	30.65 μF	8.56%	10.28%

The filter reactor is sized to create a resonant frequency near 710 Hz for 4160V drives. This results in the inductance values found in Table 4-20.

Table 4-20: Nine Cell Output Filter, Inductance

Cell Size	L, Inductance	L% @ 50Hz	L% @ 60Hz	CT Ratio (# of turns)
40 A	14 mH	7.61%	9.13%	20:5A (2T)
70 A	7 mH	6.66%	7.99%	30:5A (2T)
100 A	4.8 mH	6.52%	7.83%	20:5A (1T)
140 A	3.5 mH	6.66%	7.99%	30:5A (1T)
200 A	2.38 mH	6.47%	7.76%	50:5A (1T)
260 A	1.83 mH	6.46%	7.76%	50:5A (1T)

Table 4-21: Fifteen Cell Output Filter, Capacitance

Cell Size	Z_{FL} @ 6600V	Q, Reactive @ 60Hz, 7200V, 3Ph	C, Capacitance	C% @ 50 Hz	C% @ 60 Hz
40 A	95.26 Ohms	50 kVAr	2.56 μF	7.66%	9.19%
70 A	54.44 Ohms	100 kVAr	5.12 μF	8.76%	10.51%
100 A	38.11 Ohms	150 kVAr	7.67 μF	9.18%	11.02%
140 A	27.22 Ohms	200 kVAr	10.23 μF	8.75%	10.50%
200 A	19.05 Ohms	2 x 150kVAr	15.33 μF	9.18%	11.01%
260 A	14.66 Ohms	2 x 150kVar	15.33 μF	7.06%	8.47%

The filter reactor is sized to create a resonant frequency near 840 Hz for 6600V drives. This results in the inductance values found in Table 4-22.

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Table 4-22: Fifteen Cell Output Filter, Inductance

Cell Size	L, Inductance	L% @ 50Hz	L% @ 60Hz	CT Ratio (# of turns)
40 A	15.9 mH	5.24%	6.29%	20:5A (2T)
70 A	9.1 mH	5.25%	6.30%	30:5A (2T)
100 A	7 mH	5.77%	6.93%	20:5A (1T)
140 A	4.8 mH	5.54%	6.65%	30:5A (1T)
200 A	3.5 mH	5.77%	6.93%	50:5A (1T)
260 A	2.38 mH	5.10%	6.12%	50:5A (1T)

Note: Actual project L and C values are subject to change.

Note: Three phase capacitor banks can be replaced with single phase-2 bushing units, where each single phase unit MUST have equal kVAr and voltage values as shown. This results in an equivalent per phase capacitance. Row entries shown with asterisks are most likely not available in single phase values.

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4.5   Synchronous Transfer Reactors

When the GenIV requires the SYNCH TRANSFER feature, the output of the drive is equipped with a reactor and switchgear (contactors). These reactors cannot be packaged into the core configuration due to space limitations; therefore, they are housed in transition cabinets. These reactors limit the rate of rise of current during transfers if the line voltage and drive output voltage amplitude, frequency, and phase angle do not exactly match. Table 4-12 lists the required inductance for GenIV synchronous transfer reactors. These reactors are typically custom engineered, and may include an overload rating that matches the cell type and two sets of thermal protectors embedded into the windings. They are sized, based upon the continuous current rating of the power cells and maximum voltage available of the drive.

Table 4-23: Nine Cell Output Transfer, Inductance

Cell Size	Z_{FL} @ 4160V	L Inductance	L% @ 50Hz	L% @ 60Hz)
40 A	60.04 Ohms	14 mH	7.30%	8.79%
70 A	34.31 Ohms	7 mH	6.41%	7.69%
100 A	24.02 Ohms	4.8 mH	6.28%	7.53%
140 A	17.16 Ohms	3.5 mH	6.41%	7.69%
200 A	12.01 Ohms	2.38 mH	6.23%	7.47%
260 A	9.24 Ohms	1.83 mH	6.22%	7.47%

Table 4-24: Fifteen Cell Output Transfer, Inductance

Cell Size	Z_{FL} @ 6600V	L Inductance	L% @ 50Hz	L% @ 60Hz)
40 A	95.26 Ohms	15.9 mH	5.24%	6.29%
70 A	54.43 Ohms	9.1 mH	5.25%	6.30%
100 A	38.11 Ohms	7 mH	5.77%	6.93%
140 A	27.22 Ohms	4.8 mH	5.54%	6.65%
200 A	19.05 Ohms	3.5 mH	5.77%	6.93%
260 A	14.66 Ohms	2.38 mH	5.10%	6.12%

Note: Actual project L values are subject to change.

4.6 Motor Compatibility

Although the Perfect Harmony topology output voltage contains a high THDv%, the drive was shown to have low harmonic content between the fundamental and 25th. The nine cell GenIV drive was factory tested at Siemens and was found to meet NEMA MG-1 for Harmonic Voltage Factor (HVF) < 0.03 and, therefore, motors do not need to be derated.

$hV =$	$\left|C_{hV}\right| =$	$hV \cdot Fout =$
1	88.987	60
2	0.109	120
3	0.617	180
4	0.93	240
5	0.349	300
6	0.287	360
7	0.437	420
8	0.177	480
9	0.31	540
10	0.295	600
11	0.42	660
12	0.201	720
13	0.41	780
14	0.333	840
15	0.425	900
16	0.265	960
17	0.894	$1.02 \cdot 10^3$
18	0.368	$1.08 \cdot 10^3$
19	0.384	$1.14 \cdot 10^3$
20	0.554	$1.2 \cdot 10^3$
21	0.157	$1.26 \cdot 10^3$
22	0.672	$1.32 \cdot 10^3$
23	0.383	$1.38 \cdot 10^3$
24	0.38	$1.44 \cdot 10^3$
25	0.245	$1.5 \cdot 10^3$

$THD200cV = 15.866$ % $HVF = 0.02195$
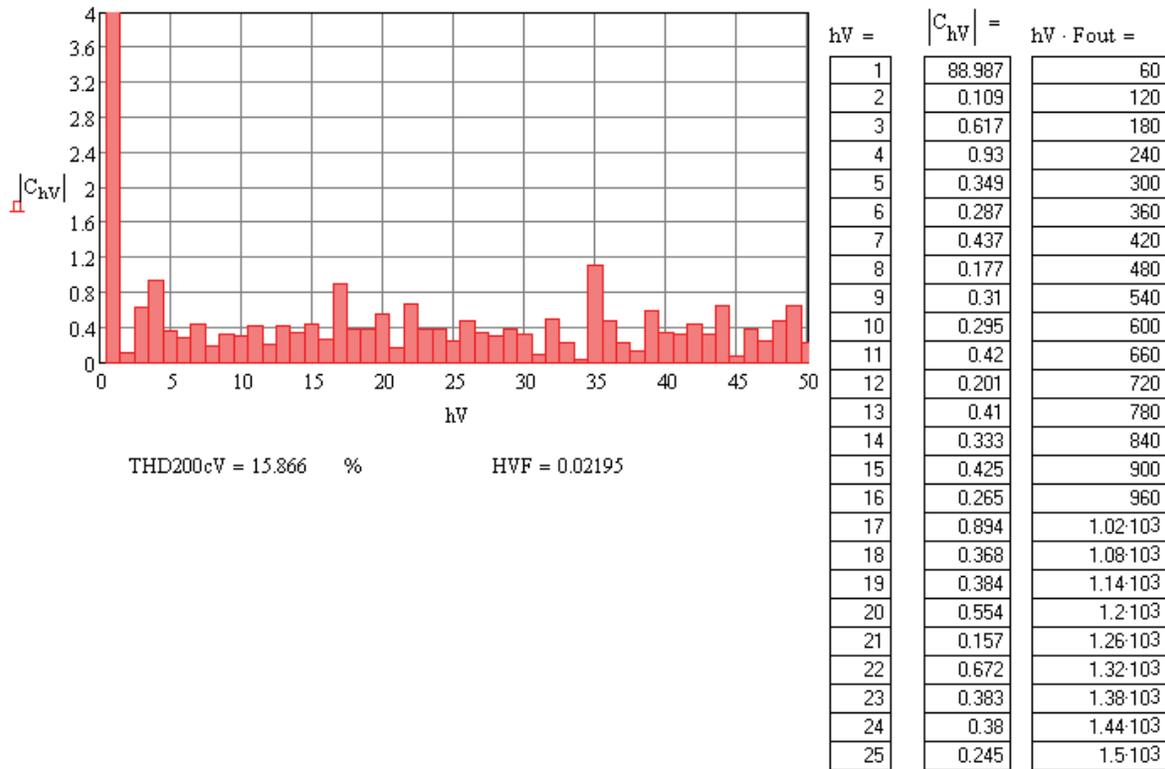
Figure 4-32: HVF for Nine Cell GenIV

* Results are shown for a 1100 Hp 4160V nine cell drive loaded at 505kW, 86A, and 4230 voltage output

Note: Fifteen cell drives further improve the drive output voltage by increasing the effective switching frequency and using the same voltage step size with a higher drive output voltage.

4.7 IEEE 519 Conformance

The eighteen-pulse nine cell GenIV drive was factory tested at SIEMENS and was found to meet IEEE 519 for the most stringent TDD limits. The pre-existing voltage distortion was less than 2% and the primary current contained a K-factor of less than 2.
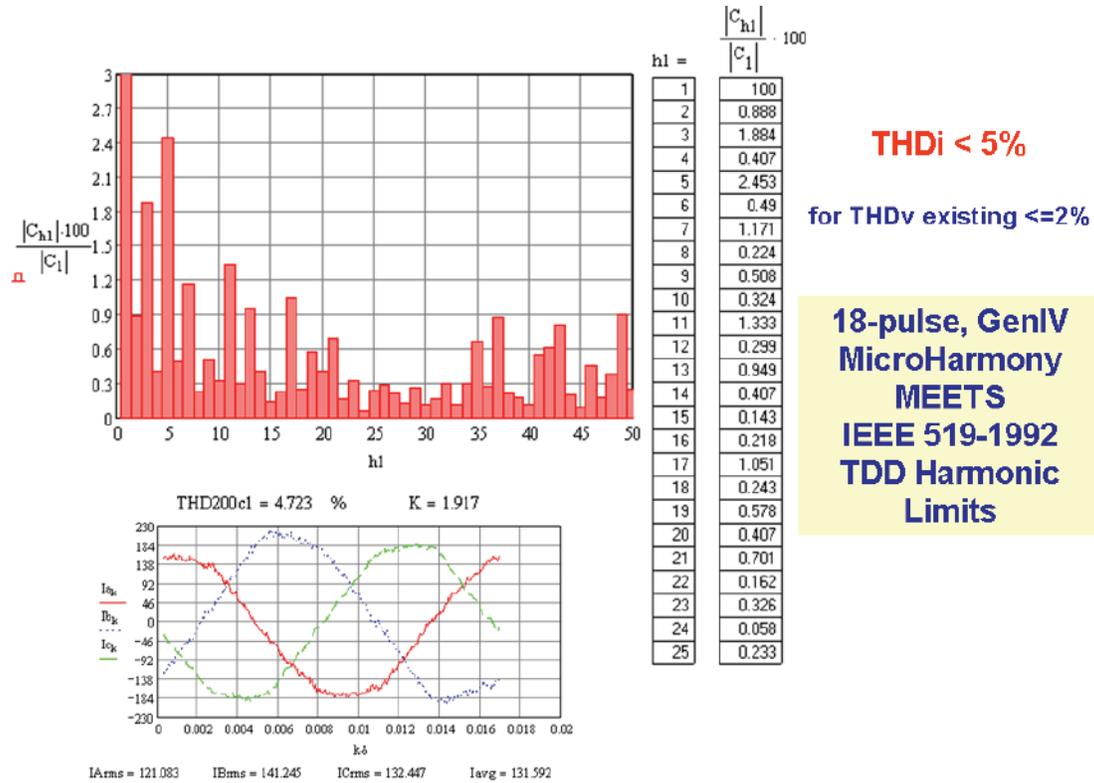
Figure 4-33: Nine Cell, Harmonic Current Distortion (TDD < 5%)

* Results shown for a 4160V input 1100 Hp drive.

Note: Fifteen cell drives further reduce the drive input current harmonics by increasing the input pulses to 30.

4.8 Ride Through

For NXG control, "Ride Through" occurs when the medium voltage input to the drive decreases below ~65% of nominal. During this condition, the control forces the drive to go into regeneration, thereby absorbing power from the rotating motor and maintaining the power cell stored energy. Such operation is maintained as long as medium voltage is absent (or below 65%) and all cells are functioning. Typically, with very large inertia loads such as fans, operation with no medium voltage is achievable for periods in excess of 5 cycles. If a cell reports a fault when the drive is operating in "Ride Through," the drive will trip on a "No Medium Voltage Fault."

The eighteen-pulse nine cell GenIV drive was factory-tested at SIEMENS for input line voltage immunity. The drive was shown to have a ride through capability of 5 cycles or more (line voltage was removed and then re-applied 7.5 cycles later).
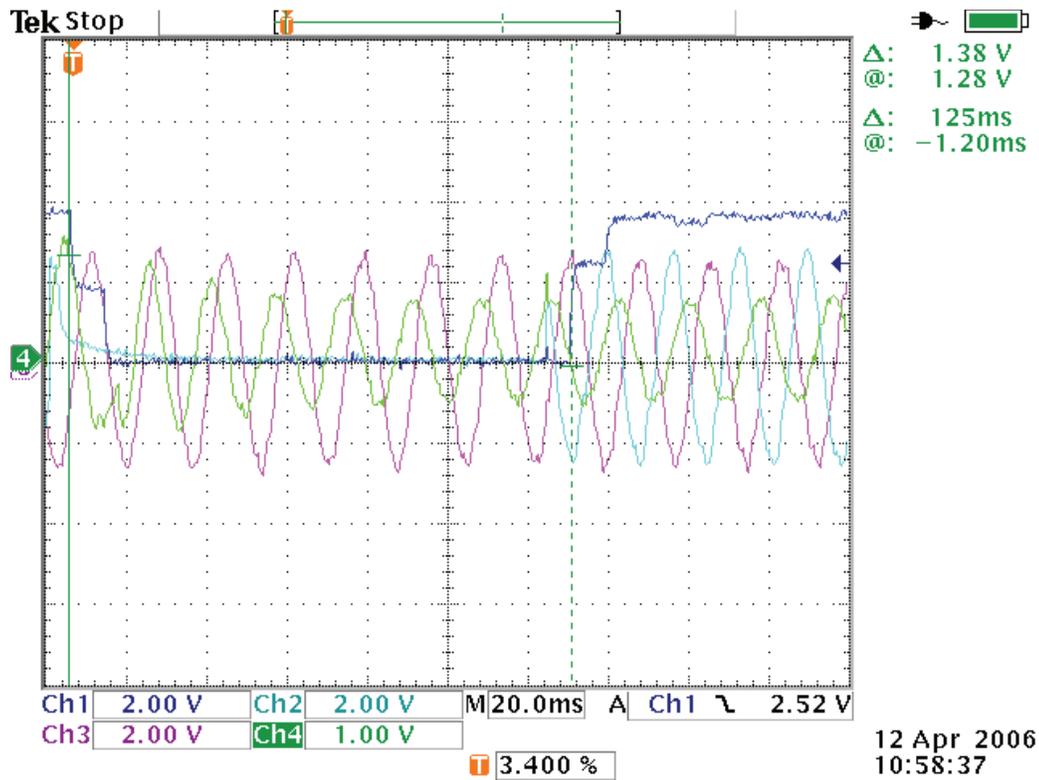
Figure 4-34: Five Cycle Ride Through Capability

* Results shown for a 4160V input 1100 Hp drive loaded at 515 kW output prior to the input medium voltage removal.

Note: Depending upon motor inertia, ride through in excess of 5 cycles is possible with the addition of a UPS for the auxiliary controls.

▽ ▽ ▽

4

CHAPTER

5   Application and Operation

This chapter provides an overview of some of the features, applications, and operating issues of the Siemens LD-A Perfect Harmony VFD. Detailed descriptions and setup of many of these features are provided in the *NXG Control Manual,* A1A19001588.

5.1 Signal Frame of Reference for Motor Control

The control signals used for controlling the motor must be assigned a polarity for use over four quadrants of control to maintain consistency of the algorithms. This section clarifies what they are and what their polarities mean in the various quadrants.

5.1.1   Frame of Reference

The four-quadrant frame of reference is defined as the four quadrants of operation of a motor. They are divided left to right by the direction of rotation and from top to bottom by the polarity of the torque in the machine. Energy flow from the drive into the machine is called motoring. Energy flow out of the machine and into the drive is called regeneration or braking.

Figure 5-1 shows the relationship between the polarities of the signals. For example, starting at rest (in the ordinances of the two axes), if a positive torque is applied to the motor, the acceleration is positive and the resultant speed increases in the forward direction. This is governed by the following equations:
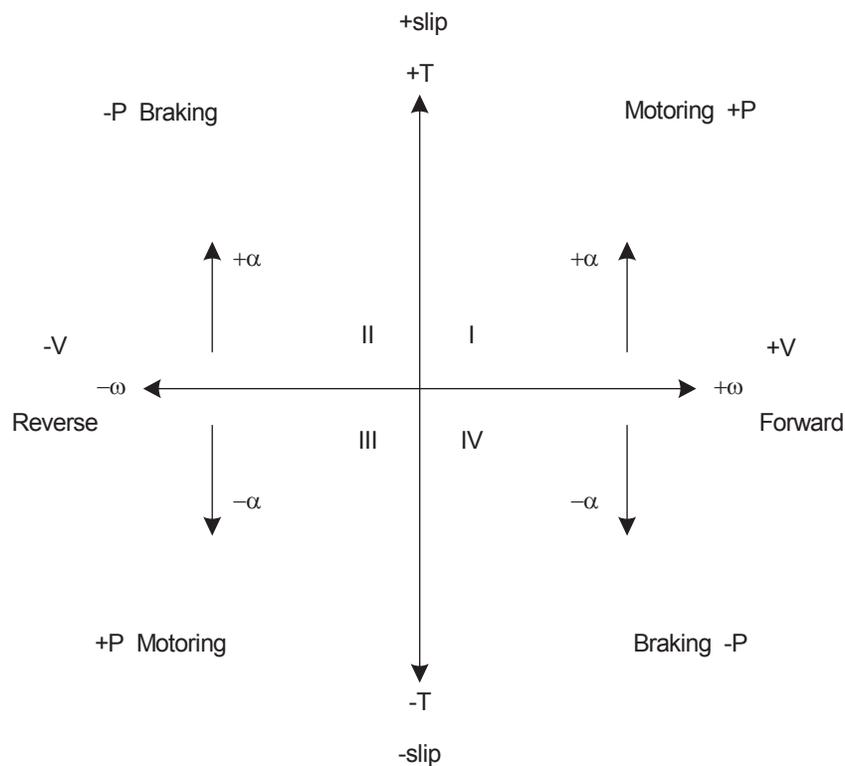
Figure 5-1: Four Quadrant Operation of a Motor

This then carries over into quadrant IV, showing that a negative torque produces negative acceleration (deceleration), stopping the motor. If, however, the same torque is applied continuously, the speed of the motor will decrease to zero and begin to accelerate in the opposite direction producing a negative rotational speed (ω) in what is now quadrant III. Now if a positive torque is applied, the motor enters quadrant II and begins to decelerate. Since the rotational speed is negative, and begins to diminish and approach a positive value, the acceleration must be positive to conform to the above equations. Again, if the torque is held constant, the motor will slow to zero and then accelerate in the forward direction, passing back into quadrant I.

The injection frequency must always be opposing the direction of rotation and is only used in the case of braking or negative energy flow. Therefore, it is zero in the motoring quadrants (I and III) and is the inverse polarity of the electrical frequency in the braking quadrants (II and IV).

5.1.2   Signal Polarities

Table 5-1: Signal Polarities

Signals	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
Rotation speed (ω_r)	+	-	-	+
Electrical frequency (ω_s)	+	-	-	+
Slip (ω_{slip})	+	+	-	-
Torque	+	+	-	-
Current (I_q)	+	+	-	-
Voltage (v_{qs})	+	+	-	-
Acceleration	+	+	-	-
Injection Frequency (ω_{inj})	0	+	0	-
Power (flow)	+	-	+	-
Mag Current (I_d)	+	+	+	+
Voltage (v_{ds})	+	+	+	+

☞ **Note:** For the electrical frequency **(ω_s)** in the braking quadrants (II and IV) where the slip opposes the rotational speed, when the speed magnitude approaches the slip magnitude, the electrical polarity is uncertain (when the slip magnitude is greater than the rotor speed, the sign will match that of the slip rather than the sign of the rotor speed).

5.2 The Control Modes

Harmony drives use vector control to control induction and synchronous motors. Vector control provides a framework that is simple to implement, but performs nearly as well as a DC motor. Figure 5-2 shows a simplified representation of the vector control algorithm implemented in Harmony drives. The basic components of vector control are:

1. **Motor model**: determines motor flux and speed.

2. **Current regulators**: these regulators are referred to as the inner loops.

3. **Flux and speed regulators**: these regulators are referred to as the outer loops.

4. **Feed-forward (FF) compensation**: improves the transient response of torque loop and flux loop.
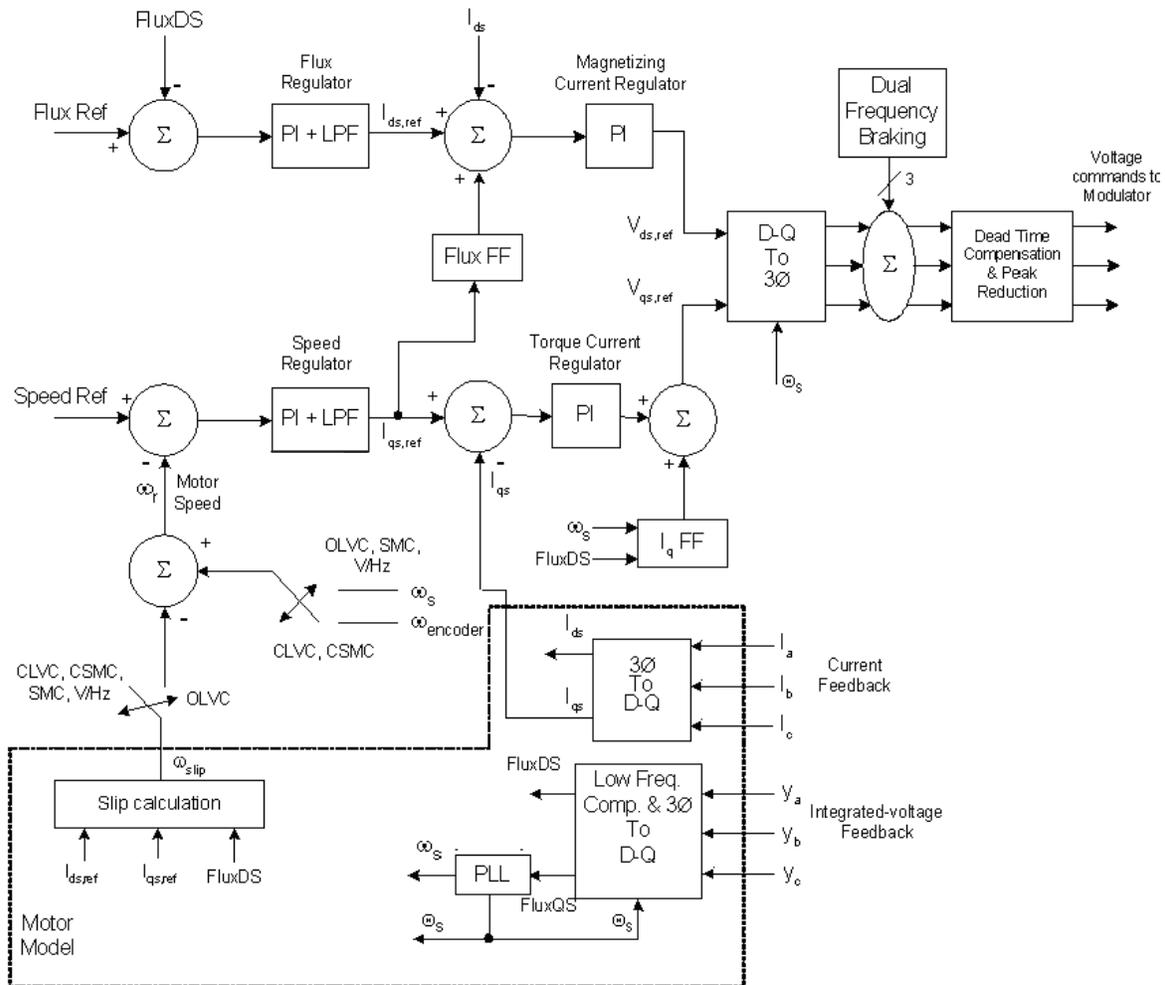
Figure 5-2: Block Diagram of Vector Control Algorithms for Induction and Synchronous Motor Control

The motor model uses measured motor voltage and estimated stator resistance voltage drop to determine stator flux amplitude, motor speed, and flux angle. This allows stator resistance compensation to be automatic. A simplification of motor equations is obtained by transforming the 3-phase AC quantities (which are referred to as being in a stationary reference frame) to DC quantities (that are in a synchronously rotating or DQ reference frame). A phase-locked loop (PLL) within the motor model tracks the (stator) frequency and angle of the flux vector.

Motor flux amplitude is controlled by the flux regulator; its output forms the command for the magnetizing (or flux producing) component. Motor speed is determined from stator frequency, and is controlled by the speed regulator. Its output is the command for the torque (producing) current regulator.

The flux angle is used to decompose the measured motor currents into magnetizing and torque producing components. It is this decomposition that allows independent control of flux and torque, similar to DC motor control. These current components are regulated to their commanded values by the current regulators. Outputs of the current regulators are combined to produce three-phase voltage commands that get modified with signals from various other control routines before being passed on to the modulator. These control routines include: (1) dead-time compensation (to compensate for dead-time in the switching of the upper and lower IGBTS of each pole in a power cell), (2) peak reduction for third-harmonic injection (to maximize drive output voltage, and for drive neutral-shift (during transparent cell-bypass), and (3) voltage commands to produce losses for dual-frequency braking. Transient response

of the flux and torque regulators is improved with the use of feed-forward compensation (FF) as shown in Figure 5-2. The following table describes the symbols used to represent various quantities in the control diagram.

Table 5-2: List of Symbols Used in Figure 5-2

Symbol	Description
FluxDS	D-component of motor flux; also equal to the motor flux, since Q-component is zero. Motor Flux is defined as: Motor_Voltage / Stator_Frequency (rad/s). Flux (which has units of Volt-seconds) is also proportional (but not equal) to Volts-per-Hertz ratio.
r	For an induction motor: Motor_Speed = Stator_Frequency / Pole_Pairs – Slip_Speed This is the rotor (mechanical) frequency, which is equivalent to the motor speed. For a synchronous motor: Motor _Speed = Stator_Frequency / Pole_Pairs
I_{ds}	Magnetizing component of motor current
I_{qs}	Torque component of motor current
$V_{ds,ref}$	Output of magnetizing current regulator used in the D-Q transformation to produce 3-phase voltages
$V_{qs,ref}$	Output of torque current regulator used in the inverse D-Q transformation to produce 3-phase voltages
s	Stator frequency or output frequency of the drive. This is motorspeed (r) + Slip.
s	Flux angle. This is the instantaneous position of the rotating Slip vector.
I_a I_b, I_c	Motor phase currents.

Motor torque (in Newton-meters) and shaft power can be calculated as:

Torque (Nm)= 3* Pole_Pairs * Flux (Vs)* Iqs (A)

$\approx$ 3* Pole_Pairs * Motor_Voltage (V) * Iqs (A) / (2π * Frequency (Hz)),

Shaft Power (W) = Torque (Nm) * Speed (rad/s) = Torque (Nm) * Speed (rpm) / 9.55

5.2.1 Open Loop Vector Control (OLVC)

This control mode should be used for most applications with single induction motors. In this method, the control estimates motor slip as a function of load torque, and provides a performance that matches a vector controlled drive (with speed sensor/transducer) above a certain minimum speed. With the correct motor parameters, the control can provide good performance even at 1% of rated speed.

Speed feedback is synthesized from the stator frequency and the estimated motor slip, as shown in Figure 5-2. With this control method, slip compensation is automatic.

In this control mode, if Spinning Load is selected, the drive begins by scanning the frequency range to detect the speed of the rotating motor (please refer to Section 5.8.2) for a description of Spinning Load Operation). Once the drive has completed the scan or if the feature is disabled, the drive goes into Magnetizing State. During this state, the drive ramps the motor flux to its commanded value at the specified Flux Ramp Rate. Only when the flux feedback is within 90% of the commanded flux, the drive changes to the Run State. Once in Run State, the drive increases the speed to the desired value. All motor and drive parameters as described in the *NXG Control Manual* (A1A19001588) are required for this mode of operation. Default values for the control loop gains are sufficient for most applications.

5.2.2 Open Loop Test Mode (OLTM)

In this control method, the motor current feedback signals are ignored. This control mode should be used during drive set-up, when the modulation on the cells is to be verified, or when testing the drive without a load. It can also be used when the motor is first connected to the drive to make sure that the Hall Effect Transducers are working correctly and are providing the correct feedback signals. This method should ***not*** be used to adjust scale factors for input and output, voltages and currents.

In this mode, the drive goes through the Magnetizing State to the Run State without looking at the motor flux. Only motor nameplate values and some drive related parameters are required for this mode. Special attention should be given to the following parameters:

1.   Spinning Load and Fast Bypass should be disabled.

2.   Acceleration and deceleration times (in the Speed Ramp Menu) should be increased.

3.   Flux Demand should be reduced.

5.2.3   Synchronous Motor Control (SMC)

For synchronous motor control (SMC), the drive is equipped with a field exciter that usually consists of a SCR based current regulator. The field exciter operates to maintain a field current level that is commanded by the flux regulator. An example application for a brushless synchronous motor is shown in Figure 5-3. For brushless motors, the diagram assumes that the exciter stator is wound for 3 phase AC in the range of 350 to 400 volts. If that is not the case, a transformer will be necessary between the auxiliary power and the field exciter. The circuit wheel needs only a rectifier. For the brushless case without bypass, the motor does not require any protection other than that included in the drive. Next Gen Control will trip the drive on a loss of field fault if the motor draws excessive reactive current, which will occur when the exciter fails full on or off.

The overall control strategy is similar to Open Loop Vector Control, except for the flux regulator implementation as shown in Figure 5-2. For synchronous motors, the flux regulator provides two current commands, one for the field exciter current, and another for the magnetizing component of stator current.

With synchronous motor control, scanning the motor frequency to determine motor speed is completely avoided. The control uses information from the rotor-induced speed voltages on the stator to determine rotor speed. The drive begins (in the Magnetizing State) by giving a field current command, which is equal to the no-load field current setting to the exciter. This lasts for a time equal to the programmable flux ramp time that is entered through the menu system.

After this period of time, the drive goes into the run state. In most cases, the regulator in the field exciter is slow, and the drive applies magnetizing current (through the stator windings) to assist the exciter in establishing rated flux on the motor. At the same time, the speed regulator commands a torque-producing current to accelerate the motor to the demanded speed. Once the field exciter establishes the required field current to maintain flux in the motor, the magnetizing component of stator current reduces to zero. From this point onward, the drive provides torque-producing current (for acceleration or deceleration) that is in-phase with the drive output voltage. In other words, under steady state conditions, unity power factor condition is automatically maintained at the drive output. The field current command is provided to the field exciter with the use of an analog output signal. Other differences between SMC and OLVC are summarized below.

*   The motor no-load current parameter represents the Field no-load current value in SMC.
*   With SMC, the flux loop gains are slightly lower than with OLVC.
*   Spinning Load should always be enabled with SMC.
*   The drive magnetizing current regulator uses only the proportional gain for the flux exciter.
*   Only Stage 1 Auto-Tuning can be used with synchronous motors.
*   When you are performing Stage 1 Auto-Tuning, you must short the field winding to get a proper setup of the stator resistance.

⚠️ **Attention!** Never use Stage 2 Auto-tuning with synchronous motors.

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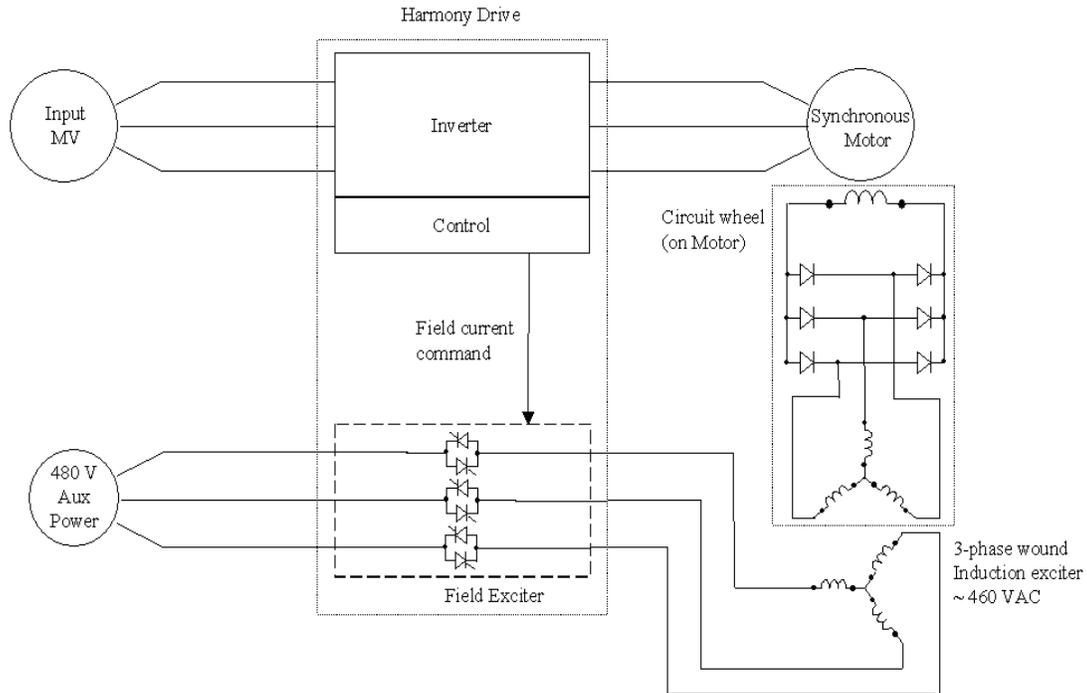
Figure 5-3: Harmony Drive Arrangement for Brushless Synchronous Motor (with no bypass)

5.2.4 Volts/Hertz Control (V/Hz)

This control mode should be used when the drive is connected to multiple motors in parallel. The control algorithm is similar to that of Open Loop Vector Control (OLVC), but it does not use some of the motor parameters in its control algorithm that OLVC does.

☞ **Note:** Many of the features available with OLVC, such as fast bypass, spinning load, and slip compensation, are not available with this method, as individual feedback and control of each motor is not possible.

5.2.5 Closed Loop Control (CLVC or CSMC)

In some applications, when stable, low speed (below 1 Hz) operation under high torque conditions is required, an encoder may be used to provide speed feedback.

The control diagram of Figure 5-2 remains the same, except for the slip calculation block, which is disabled so that encoder speed feedback is directly used as an input to the speed regulator.

When an encoder is used with the drive, the control loop type is required to be set to CLVC (for closed loop vector control with an induction motor) or to CSMC (for closed loop vector control with a synchronous motor). Spinning load should be enabled when this control mode is enabled.

5.2.6 Slip Compensation

NEMA B induction motors require slip of the rotor speed (RPM) relative to the stator speed (frequency) to develop torque. The amount of slip is directly affected by the loading of the machine. For induction motors, the control provides Slip Compensation to the speed reference to allow the motor to run at a constant speed, regardless of the torque output required.

Slip Compensation operates as an open loop speed regulator that increases the electrical output frequency of the drive as the load increases, or decreases the frequency as the load drops.

5

Effect of Slip Compensation on Motor Speed with NXG Control

With Slip Compensation, the electrical frequency is always greater than the desired shaft speed (mechanical frequency) for all non-zero loads. Therefore, at 100% speed demand, the NXG OLVC will maintain the shaft speed at the rated synchronous speed of the motor, not full load speed.

Example: A 6-pole motor rated for 60 Hz has a synchronous speed of 1200 rpm. The Full Load speed from the motor nameplate is 1192 rpm. Sending a speed demand of 100% will produce a mechanical (shaft) speed of 1200 rpm with slip compensation. This will result in a higher output (electrical) frequency to the motor, to provide the necessary torque to achieve the desired speed. The slip frequency is directly proportional to the required torque, up to the rated torque current.

Theory: Sending the drive a speed demand of 100% means that Synchronous or Rated Speed is desired. This is calculated by equation 1 below.

Synchronous Speed, Ns, is defined by the formula:

1. $N_S = 120 * f_{RATED} / \#$ of poles

Slip is defined as a percentage (at rated torque) of the difference between synchronous and full-load speed (NFL) divided by the synchronous speed:

2. $\text{Slip (\%)} = 100 * (N_S - N_{FL}) / N_S$

With slip compensation, the slip frequency is subtracted from the output frequency (f_{OUT}) to ensure that the mechanical speed matches the desired speed. In simple terms, this is done by taking the per unit (PU) Torque (T_{PU}) times the slip and subtracting it from the speed feedback (in frequency), effectively adding it to the speed reference:

3. $S_{MOT} = f_{OUT} - (\text{Slip} * T_{PU})$

4. $S_{ERR} = S_{DMD} - S_{MOT}$

In equation 4, S_{ERR} represents the error signal processed by the speed regulator. The implication for this is that for a speed command of 100%, based on the synchronous speed, the applied electrical frequency will be higher than rated frequency due to the increase created by the slip compensation (equation 3 and 4). This will result in the motor running at true requested mechanical speed with the electrical frequency adjusted to provide the torque necessary to produce that speed.

Limiting Frequency by Disabling Slip Compensation

If the motor is to be limited to a specific frequency, then the slip compensation can be disabled. In the same example, the Full Load speed must be set to 1200 rpm. This effectively disables the slip compensation by reducing equation 2 to produce a slip of zero. Then equation 3 and 4 reduce to:

1. $\text{Slip} = (1200 - 1200) / 1200 = 0$

2. $S_{MOT} = f_{OUT} - 0 = f_{OUT}$

The end result will be that the drive will regulate to the output frequency rather than the motor shaft speed (mechanical speed). No compensation for slip is done.

Conclusion

With Slip compensation:

- Output shaft speed will equal the percentage of synchronous speed requested
- The frequency will vary depending on load, but the speed will be fixed
- Motor Speed in rpm should be monitored

Without Slip Compensation:

- The Output Frequency will equal the speed demand percentage of rated frequency

- The mechanical (shaft) speed will vary with load, but the frequency will be fixed

- Motor Frequency in Hz should be monitored

5.2.7   Frequency Regulator

A Frequency Regulator generates the motor's torque-producing current reference. The Stator Frequency Reference (Ws_ref) is generated from the output of the Slip Compensator. The Stator Frequency (Wout) comes from Phase Lock Loop (an estimate of the actual stator frequency). The Frequency Regulator is evaluated at $1/5^{th}$ of the inner current loop update rate.

5.2.8   Torque Current Regulator

The Torque Current Regulator generates the motor's Q-axis motor voltage. The Torque Producing Motor Current Reference (Iqs_ref) is generated from the output of the Frequency Regulator. The Torque Producing Current Feedback (Iqs) comes from Motor Current D-Q converter. The Torque Current Regulator is evaluated at the inner current loop update rate. This regulator is the innermost (i.e., fastest) control loop in the NXG Control operating at the sampling rate of the system (typically 3 to 6 KHz).

5.2.9   Magnetizing Current Regulator

The Magnetizing Current Regulator generates the D-axis motor voltage reference. The Magnetizing Motor Current Reference (Ids_ref) is generated from the output of the Flux Regulator. The Magnetizing Producing Current Feedback (Ids) comes from Motor Current D-Q converter. The Torque Current Regulator is evaluated at the inner current loop update rate. This regulator is the innermost (i.e., fastest) control loop in the NXG Control operating at the sampling rate of the system (typically 3 to 6 KHz).

5.2.10   Flux Regulator

The Flux Regulator generates the magnetizing motor current reference. The Flux Reference (λds_ref) is generated from the control's flux ramp. The Flux Feedback (λds) comes from Motor Voltage D-Q converter. The Flux Regulator is evaluated at $1/5^{th}$ of the inner current loop update rate.

5.2.11   Phase Lock Loop

The Phase Lock Loop module generates the Flux Angle (θ) and Stator Frequency (ω_{out}). The Flux Q-axis term is generated by the motor voltage D-Q transformation (λ_{qs}). The Phase Lock Loop module is evaluated at $1/5^{th}$ of the inner current loop update rate.

5.3 High Performance Control

When applying the Harmony drives, applications requiring high starting torque or low speed operation are considered as "High performance" control.

5.3.1   High Starting Torque

When OLVC or CLVC control is used, the harmony VFD can deliver approximately 85-90% torque with 100% rated motor current. The V/Hz control mode can provide 95-100% torque at 100% motor rated current.

This control mode is useful for obtaining high starting torque in applications with high series resistance (> 10%). To enable this mode of operation, the following conditions should be satisfied:

- Drive control loop type should be set to V/HZ

- Rated slip should be non-zero

- Minimum speed limit should be greater than rated slip

For long cable applications, the minimum speed limit should be set to be the same as the percentage value of the total resistance in series with the motor. For example, if the total series resistance (motor + cable) is about 30% of the motor base impedance (this is a very long cable!), a minimum speed limit of 30% should be set.

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The magnetization time or the Flux Ramp Rate should be set to at least twice the rotor time constant of the motor.

Drive Operation in High Starting Torque Mode

Once the drive start is issued, the drive goes through the following stages to the minimum speed setting, irrespective of the speed demand. (Refer to Figure 5-4.) During the initial stages after the drive start is given, the drive operates in an open loop mode (i.e., both speed and flux loops are initially disabled).

During the magnetization stage, the drive applies a magnetizing component equal to the no-load current parameter. The drive then ramps up to rated slip speed while increasing the torque component (Iqs) of current to its rated value. The drive maintains rated current for a time duration equal to the magnetization time. During this time, the motor should produce rated torque under locked rotor (or high stiction) conditions.

The control then ramps the output from rated slip to the minimum speed limit while maintaining rated current. At minimum speed, the control holds the speed ramp for one second at this value, reduces the torque current (Iqs), and enables the speed loop. One second later, the flux loop is enabled and the drive resumes acceleration to the desired speed demand. After the flux loop has been enabled, if the drive senses that the motor flux is low (or Ids is too high), then the drive trips on Fail to Magnetize Fault within the time set by the Flux Ramp Time. Note that a "bump" in output voltage may be noticed when the flux loop is enabled, since the control transitions from an open loop control to closed loop using measured voltages and current.

When a stop command is issued, the drive ramps down normally from the operating speed to the minimum speed settings, and then transitions to a coast stop (i.e., drive output is disabled).

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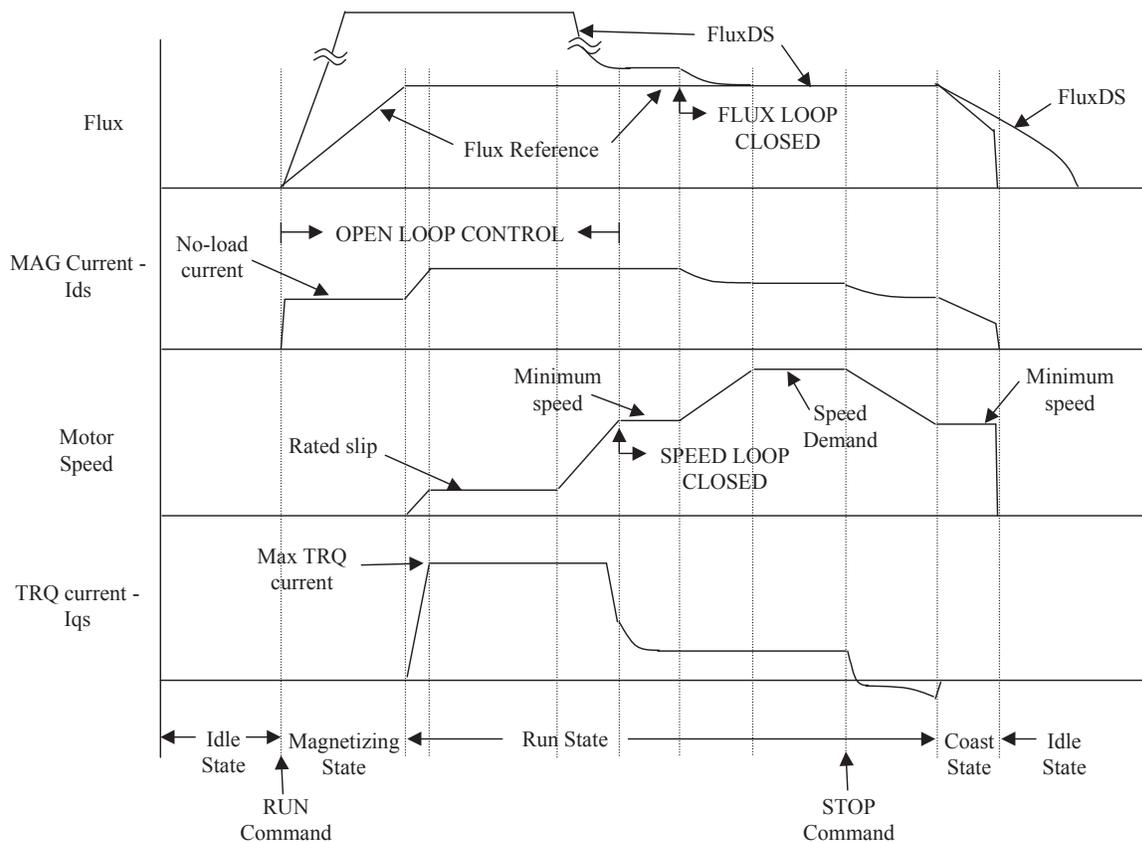
Figure 5-4: Drive Operation in High Starting Torque Mode

5.3.2   Low Speed Operation

In some applications, when stable, low speed (below 1 Hz) operation under high torque conditions is required, an encoder may be used to provide speed feedback. Use of a shaft encoder is recommended where the control's slip calculation block is disabled so that encoder speed feedback is directly used as an input to the speed regulator.

When an encoder is used with the drive, the control loop type is required to be set to CLVC (for closed loop vector control with an induction motor) or to CSMC (for closed loop vector control with a synchronous motor). The VFD's Spinning load function should be enabled when this control mode is enabled.

5.4 System Program (SOP)

The Harmony Series of digital drives contain customized programmable logic functions that define many features and capabilities of the drives. These logic functions are combined into a system program (SOP) that can be edited either at the factory or in the field. Examples of logic functions include start/stop control logic, reference signal handling, input/output control logic (e.g., annunciators, interlocks, etc.), drive-to-machinery coordination and more. The system program is stored on the drive's flash disk. Upon power-up, it is executed continuously by the drive's run-time software in a repetitive fashion, causing the intended logic statements to perform their functionality depending on system operating conditions.

The SOP is developed and compiled off-line and can be downloaded to the drive's flash disk via either serial or Ethernet ports. Note that while the drive flash disk can hold multiple system programs, only one SOP can be active at any time, and the VFD output must be idle to change the active SOP.

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5.5 Command Generator

This section defines the Command generator functional blocks shown in Figure 5-5.
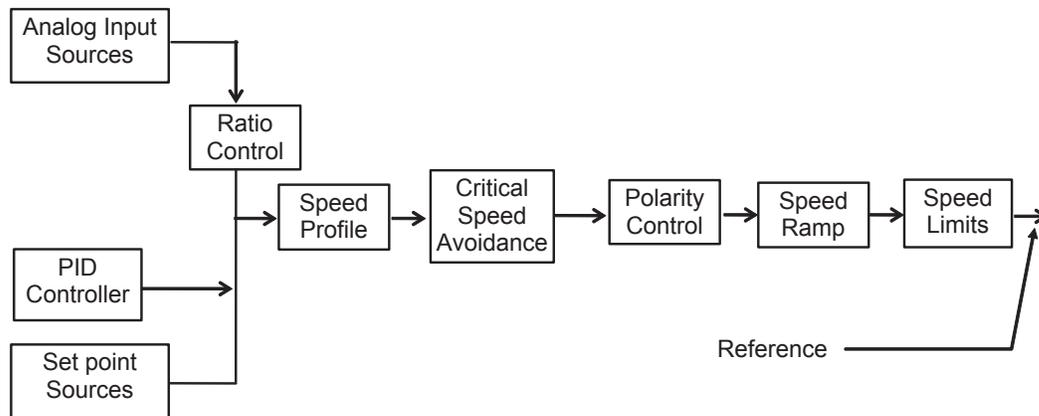
Figure 5-5: Command Generator

5.5.1 Raw Speed Reference

The NXG Control includes provisions for output speed demand entry as required for a specific application. The active reference source is configured per specific system requirements and can be dynamically changed. This is implemented via the drive's "System Program" as defined in Section 5.4. An overview of each of the major functional blocks is defined next, and a detailed description is provided in the *NXG Control Manual,* A1A19001588.

Analog Input Sources

The NXG control provides a means to provide multiple analog input sources that can be selected as demand inputs to the system. The control scales these analog values into internal units, and monitors the levels for possible loss of signal conditions. The control includes provisions for predetermination of VFD action upon loss of signal conditions, including maintain speed, transition to preset speed, or trip VFD.

Ratio Control

The Ratio control is simply a fractional scaling unit available for the analog reference signals. This feature allows multiple drives to share the same reference signal with rescaled output signal levels.

PID Controller

The PID loop is programmable from User Interface.   The PID Command set point can be either an external Analog Input or an internal set point. The PID Feedback is always from an Analog Input. The Proportional, Integral, and Derivative gains, as well PID output limits, are programmable.

Set Point Sources

Set Points are internal menu entries that are static values based on user entry, keypad settings, or remote demand from a network communication interface. There are a total of eight inputs that are menu entries from remote communications. There are two special additional entries that are reserved for safety override and jog level set points.

- Keypad

    o Front panel keypad (or ToolSuite computer) used to set speed demand

- Increment/Decrement (Sample and Hold)

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o Digital inputs (x2) that increase/decrease raw speed demand at the active acceleration/deceleration rate, while input is maintained

• Increment/Decrement Step

o Digital Inputs (x6) that provide programmable step change to output demand each time input transitions from Low to High state

• Preset levels

o Multiple user-defined preset values via menu system

• Jog

o Set to maximum active speed limit, intended for test purposes to "bump" motor

• Communication Network

o Digital Value as set per external communication interface to a PLC/DCS

5.5.2 Speed Profile

The Speed Profile uses the velocity demand signal as input, and generates a modified Best Fit Straight Line (BFSL) velocity demand output.

5.5.3 Critical Speed Avoidance

Critical speed avoidance is used to prohibit the drive from operating in frequency ranges that may cause resonant frequencies in mechanical systems. The NXG control provides three independent avoidance bands.

5.5.4 Polarity Control

Polarity control is simply an inverter. The output of the polarity block is the opposite polarity of the input. The selection of this feature is based solely on the system program logic.

5.5.5 Speed Ramp

The Speed ramp is a functional block that takes an input demand and generates an output with a controlled rate of change, based on the acceleration and deceleration limits established by the end user. Provisions are included for multiple sets of acceleration and deceleration settings. The control provides a means to use any one of three separate menu-defined acceleration/deceleration sets, or PLC network control as selected by the SOP.

5.5.6 Speed Limit

The Speed Limit simply limits the final output of the demand shaping chain to within preset operating limits defined by the user. Provisions are included for multiple sets of forward rotation maximum/minimum limits, and reverse rotation maximum/minimum limits. The control provides a means to use any one of three separate menu-defined speed limit sets, or PLC network control as selected by the SOP.

5.6 Energy Saver

The VFD automatically implements an energy-saver function that adjusts the motor voltage as a function of torque, and speed based on available voltage.

5.7 Drive Output Torque Limiting

The drive uses measured voltages and currents to implement torque-limit (rollback) conditions. Under one or more of these conditions, the drive will continue to operate, but at a lower output torque (or current) level. An output torque limit will force the motor (and the drive) to go into speed rollback, during which speed is reduced until the torque demanded by the load falls below the torque limit. Rollbacks, which are triggered by various conditions, are described in the following sections. The control will limit output current based on the lowest value determined.

5.7.1   Torque/Regeneration Limit

When the VFD output current exceeds the maximum torque-limit setting for the motor, the drive will limit output current.

An inverse speed function based on the Regeneration limit setting is used during drive deceleration. This forces the drive to absorb a constant amount of power from the load.

Provisions are included for multiple menu settings of torque/regeneration limits. The control provides a means to use any one of three separate menu-defined torque/regeneration limits, PLC network control, or analog signal as selected by the SOP.

5.7.2   Input Under-Voltage Rollback

When the input line voltage drops below 90% of its rated value, the drive limits the amount of power (and hence the torque) that can be delivered to the load. The maximum allowable drive power as a function of line voltage is shown in Figure 5-6. At 66% input voltage, the maximum drive power is limited to 50%, and is quickly reduced to a slightly negative value at 65%. This limit forces the drive to absorb power from the motor and maintain the (cell) DC-bus voltages, in case the input voltage recovers during MV ride-through. The limit is implemented as an inverse function of speed to maintain constant power flow to the (cell) DC-bus.

A regulator is implemented to match the maximum drive power (P_{MAX}) to the actual power flowing into the drive. The output of this regulator sets the output torque limit. The NXG control provides menu settings for the proportional and integral gains of this regulator.
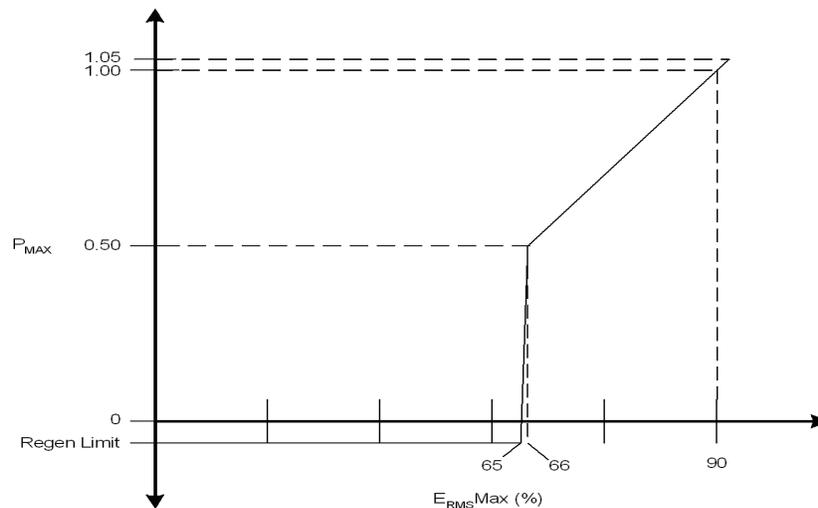
Figure 5-6: Drive Power (P$_{max}$) as Function of Input Voltage Magnitude (E$_d$)

5.7.3   Input Single-Phase Rollback

With Next Gen Control, input voltage unbalance ($E_{unbalance}$) is used for rolling back the drive output torque. Figure 5-7 shows the reduction in drive power as a function of the unbalance voltage. When the unbalance is less than 10%, the drive operates without any output limitation. There is a linear reduction as the unbalance voltage increases from 10% to 30%, at which point the input has a single-phase condition. When the input line voltage unbalance increases above 30%, the drive limits the amount of output power that can be delivered to the load to 40% of rated.
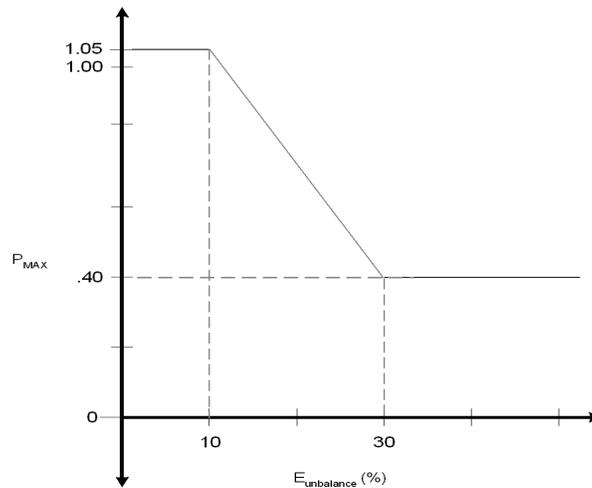
Figure 5-7: Drive Power (P$_{max}$) as Function of Input Unbalance Voltage (E$_{unbalance}$)

A regulator is implemented to match the maximum drive power (P$_{MAX}$) with the actual power flowing from the drive. The output of this regulator sets the output torque limit. The NXG control provides menu settings for the proportional and integral gains of this regulator, as well as an alarm setting for single-phase input detection.

5.7.4   Transformer Thermal Rollback

The input currents to the drive are monitored continuously. The largest among the three input phase currents is limited to be at or below 105% of the nominal rating of the transformer. Drive output torque is reduced when this current level is exceeded.

An integral regulator is implemented to limit the maximum input current to 105%. The output of this regulator sets the output torque limit. The NXG Control provides a thermal gain parameter to represent the integral gain of this regulator.

5.7.5   Field-Weakening Limit

The field-weakening limit is a torque limit that is based on the motor flux and motor leakage inductance. This limit prevents the motor slip from exceeding pullout torque slip. Thus, it prevents unstable operation of the motor. This limit normally occurs when motor flux is reduced significantly during energy-saver operation, or when operating beyond the base speed of the motor. Under such conditions, a large step (increase) in load will force the output to be limited, resulting in a loss of speed rather than motor pullout.

5.7.6   Cell Current Overload

The NXG Control provides a power cell (current) overload setting. A cell can operate at this overload value for 1 minute out of every 10 minutes. When the current is between the cell rating and the overload rating, the time spent at that level is inversely proportional to the overload current setting. Table 5-3 provides an example of the time versus current overload capability with a cell that has 120% overload capacity.

Table 5-3: Example of Overload Current Capability versus Time of Cell with 120% Overload

Drive current (%)	Allowed operating time (out of every 10 minutes)
120	1 minute
110	2 minutes
105	4 minutes
100	Continuous

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☞ **Note:** The power cells used in Harmony drives do not have a fixed overload capability. Please refer to the cell's overload rating as shown in Chapter 3 of this document to determine the overload capability for a specific power cell.

5.8 Drive Tuning

Section 5.8.1 describes the Auto Tuning feature provided by the NXG control and its use in determining motor and control parameters. Section 5.8.2 describes the setup of the Spinning Load function. This feature is used by the drive control to detect motor speed by scanning the output frequency over the operating range of the application.

5.8.1 Auto Tuning

The basic motor parameters can be divided into two categories: nameplate data and equivalent circuit data. Nameplate data, as the name suggests, is readily available (such as Motor Rated Voltage, Full Load Current, etc.). However, equivalent circuit data (such as Stator Resistance, No-load Current, etc.) is available only from the motor manufacturer. If this data is available, it can be entered into the NXG menu system. If this data is not available, either default settings or Auto-tuning functions can be used.

☞ **Note 1:** Auto Tuning is **optional**, but as stated above, it is recommended for applications in which high performance is required.

Note 2: The correct equivalent circuit data is required only when good control performance, such as high starting torque or very low speed operation, is desired.

When operating an induction motor, the drive control is capable of performing Auto-Tuning. This feature allows the drive to estimate parameters of the motor equivalent circuit. There are two stages of auto-tuning, each stage being selected individually. Apart from measuring the motor equivalent circuit parameters during auto-tuning, the control uses the measured motor parameters to adjust the control loops for the best possible control bandwidth (the bandwidth for each control loop is fixed internally in software), and hence provides good performance in demanding applications.

Such a feature provides drive tuning without the need for an extensive adjustment procedure. Although the auto-tuning feature can be used with all induction motors, there are some limitations. Both stages of auto-tuning can be performed with induction motors (OLVC or CLVC).

⚠ Warning! *Only Stage 1* should be performed with Synchronous Motors (SMC or CSMC) or when Output Filters are connected.

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☞ Note: In most general-purpose applications (such as pumps and fans), default data for the motor equivalent circuit is sufficient and auto-tuning is not necessary.

⚡ DANGER! LETHAL VOLTAGES!

Lethal voltages will appear on the drive outputs during **both** stages (1 and 2) of Auto Tuning.

Auto Tune Stage 1

Stage 1 determines the Stator Resistance and Leakage Inductance. This stage of auto tuning does not require the motor to be de-coupled from the load. The motor does not rotate during this Stage. The data obtained from Stage 1 is used to tune the inner regulators that control motor current. The current loop gains are automatically calculated and saved by the control.

Auto Tune Stage 2

Stage 2 determines the no-load motor current and the motor inertia. The motor rotates at 30% of rated speed during this stage. Generally, this stage of auto tuning requires the motor to be de-coupled from the load. Ensure that it is acceptable to spin the motor before this test is enabled. Data obtained in Stage 2 is used to optimize the operation of the outer loops that control motor speed and motor flux. The speed and flux loop gains are automatically calculated and saved by the control.

⚡ **DANGER!** The motor will spin during Stage 2 of Auto Tuning.

☞ Note: Quadratic loads, such as pumps and fans, do not require the motor to be de-coupled for Stage 2 auto tuning. The control is designed to minimize the errors introduced by such loads.

5.8.2   Spinning Load

The Spinning Load feature allows the drive to determine the speed of a motor that is already rotating. The drive is thus able to apply output voltages at the same frequency as the rotating motor, and minimize any chance of a speed transient. The Spinning Load feature in NXG Control is divided into two stages. During the first stage, Spinning Load operates automatically when enabled, and requires no user adjustments. The drive control monitors motor flux, and is able to provide an instantaneous restart. This stage is valid as long as there is detectable flux in the motor. Typically, the drive is capable of restarting instantaneously if the time duration between drive disable and re-start is within 3 to 4 motor time constants.

The second stage consists of a scan feature during which a preset level of current of varying frequency is applied to the motor. The control monitors the measured motor flux, and when the motor flux exceeds a programmable flux threshold, the control assumes that the applied frequency is equal to the rotating speed of the motor.

Spinning Load should be enabled if any of the following operating modes or features is selected:

- Fast Bypass
- VFD Startup while motor is spinning (forward or reverse)
  - o Note that the ability to catch and decelerate a motor spinning in the reverse direction is determined by the drive's regenerative current capabilities
- Synchronous Motor Control (SMC and CSMC)

- Close Loop Vector Control (CLVC)

☞ | **Note:** Spinning Load does not provide instantaneous restart with V/Hz control. With synchronous motors, spinning load is always instantaneous, i.e., the drive will never go into a scan mode.

5.9 User IO

The VFD provides terminal strips as required for end-user connection of isolated analog and digital input/output signals to the drive. Specific I/O implementation is customized for each drive where the end user must refer to drawings provided with the drive. The NXG control interfaces each of these IO points via either built-in or expansion IO modules. The built-in IO is dedicated to IO points critical to drive operation. The expansion IO connections, as required, are intended for system IO that is for typical drive operation or non-critical for protection.

The system includes provisions for the following types of IO where specific configuration is as shown with the drive's drawing set. Note that the SOP determines the routing of each of these IO points, while the NXG Control provides a means to define the type and scaling of the analog signals.

- Analog Inputs/Outputs

    o 0-20 mA

    o 4-20 mA

    o 0 ±10V

- Digital Inputs - low side switching

    o 24VDC

    o 120VAC

- Digital (Relay) outputs

    o Normally open or normally closed contacts available

    o Refer to system drawings for contact ratings

5.10 Data Logs

The NXG control includes 3 separate data loggers to record events detected by the software. Each of these logs are stored in non-volatile memory and can be captured by the user via the VFD's serial debug port or the Ethernet Port. The debug port is a standard RS232 interface. Data file access via the Ethernet port requires the user to connect a PC running the NXG Tool Suite software (as described in Section 5.15) to the drive, and uploading the files to the PC's hard drive or display.

5.10.1 Fault Log

The Fault Log consists of a circular buffer that records up to 256 faults or alarms. This log allows the user to access the 256 most recent faults and/or alarms that have been detected. The faults/alarms are time stamped to a resolution of 1 second, and also include a time stamp showing when the fault/alarm was reset/cleared.

5.10.2 Historic Log

The Historic Log records operating data of the drive and is frozen upon detection of a fault. The data recorded consists of both fixed and programmable data points, which are sampled at the slow loop rate (typically 300-600 Hz). Upon detection of a drive fault by the NXG software, the fault is recorded at time =0 and the drive continues to record data for a brief period after the fault. This allows recovery of data just prior to and after any fault so that operational data prior to and after the fault can be reviewed. Note that a new fault will overwrite the recorded Historic Log. The Event log includes provisions to copy/record the historic log so that all fault events are recorded.

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5.10.3 Event Log

The Event Log is a very large circular file that is used to record time stamped (1 second resolution) significant drive events that are encountered. Data in the log includes:

- All Faults/Alarms (essentially Fault Log data)

- Historic Log, if enabled

- Significant Events, including:

  o CPU Bootup

  o Medium Voltage status

  o Drive operating state changes (e.g., idle, magnetize, run, stop, etc.)

  o Fault reset requests from user

  o Menu entries

5.11 Faults and Alarms

If a fault or alarm condition exists, it will be annunciated on the keypad and recorded in both the Fault and Event Logs. External hardwire indicators are also set as defined in the System Program. PLC access is available for all faults/alarms.

All faults will immediately remove power from the motor and inhibit the drive from running, resulting in the motor coasting to rest. Some faults that are user-defined can control the drive response via the system program. Alarms are annunciated and logged, but usually do not inhibit the drive from operation. Faults are either detected via direct hardware sensing or by software algorithm.

The NXG control includes both internal faults and alarms and the ability to define "User Faults" via the SOP, which can be set as either faults or alarms.

Regardless of the source, all faults are user-friendly messages displayed in plain text where no fault "code" numbers are used. User Fault/Alarm messages allow the SOP writer to define the fault as desired, with a 24-character limit.

5.12 Motor Overload

NXG Perfect Harmony control provides Motor Thermal Overload (TOL) protection to prevent the motor from being subjected to excessive temperatures. TOL protection of the motor can be set up using the NXG control menu system. The "overload select" parameter allows one of three options to be selected for motor protection. The first model, which is called "constant," is based on the current flowing into the motor. A Motor Thermal Overload Alarm 1 is issued as a warning to the user (of an impending overload fault) when the motor current exceeds the "overload pending" parameter. When the drive current exceeds the "overload" setting, Motor Thermal Overload Alarm 2 is issued and a thermal trip timer is started. If this condition is present for a period greater than the time set in the "overload timeout" parameter, the drive will trip and annunciate the event as Motor Thermal Overload Fault. **It should be noted that both the Alarms 1 and 2 have to be enabled through the SOP for the drive to display these conditions.**

The second and third thermal models, which are called "straight inverse time" and "inverse time with thresholds," use a software motor thermal model to determine motor temperature (see Figure 5-8). For these options, the "overload pending" and "overload" settings represent the motor temperature limits (in percent of rated motor temperature) at which the overload warning and trip are generated. A brief description of the thermal model follows.
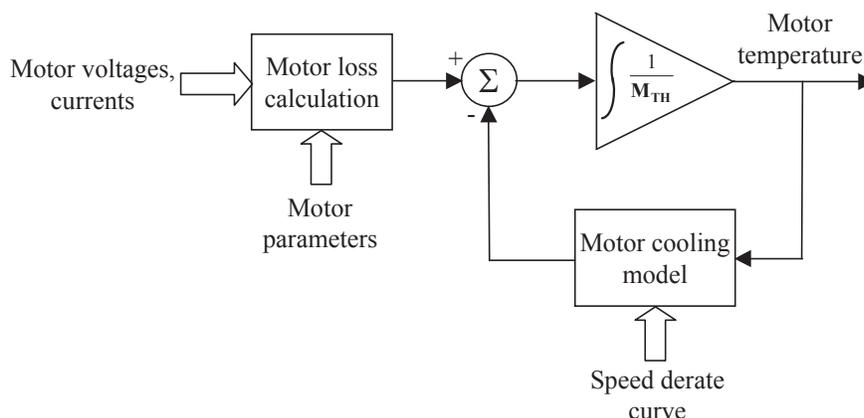
Figure 5-8: Block Diagram of Motor Thermal Model

The motor model estimates motor temperature based on the net heat generated in the motor and its thermal mass. A block diagram of the implementation is shown in Figure 5-8. The heat generated in the motor is estimated from the stator voltages, currents, and motor parameters, while an estimate of the heat transferred from the motor (due to motor cooling) is made from the allowable motor current (explained in the following paragraph). The motor loss calculation also includes the losses generated with Dual-Frequency Braking. The thermal mass (shown as MTH) of the motor (or its heat capacity) is determined from the maximum load inertia listed in Table 20-1 of *NEMA Standard MG-1 1993 Part 20.42*. The user has the option of entering a known value of max load inertia as well (which can be obtained from the manufacturer).

If "straight inverse time" protection is chosen, then it is assumed that the motor has an allowable current level of 100% (for example, when the motor is equipped with a constant-speed cooling fan). With "inverse time with speed-derating," the allowable current level is determined from the speed-derating curve entered through the keypad. This curve requires the user to enter allowable motor load for various speed breakpoints. The default-derating curve provides breakpoints for a quadratic cooling curve (and is shown in Figure 5-9). The motor manufacturer normally provides data for this curve. The control software uses the allowable current level to determine the cooling capability of the motor.

If the user's preference is to enter a fixed value of an allowable current level other than 100% (as with the "straight inverse time" option), the speed-derating curve can be modified to have the same desired level for all breakpoints.
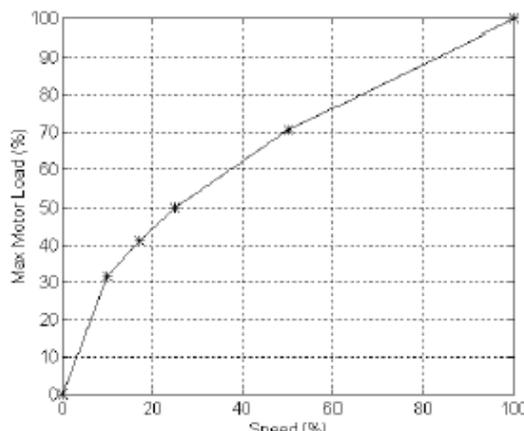
Figure 5-9: Default Speed-Derating Curve Showing Maximum Motor Load as Function of Speed

The plot in Figure 5-10 shows results from an experimental evaluation of the software thermal model with the "straight inverse time" option (100% "overload" setting) for various levels of drive current. A 4kV, 300 Hp motor was used for this test. The experimental data shows the time taken for the estimated motor temperature to go from rated temperature to 120% of rated. This curve is quite conservative as compared to a Class 10 TOL that trips at 280sec with 150% current and at 630sec with 125% current.
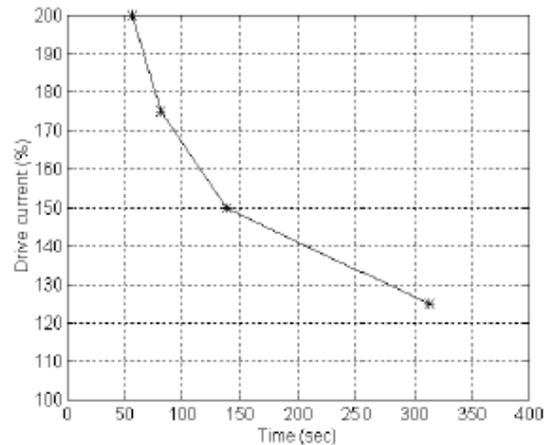
Figure 5-10: Drive Current (in percent of motor rated current) vs. Time taken for Motor Temperature to rise from Rated Temperature to 120% of rated *

* The data was measured with the "straight inverse time" option.

5.13 Input Side Monitoring and Protection

The NXG Control monitors input side voltages and currents, as well as those on the output side. This allows the control to monitor and respond to events on the input side of the drive. RMS values of the input currents and voltages are available, along with input power, kVA, energy, and power factor. Figure 5-11 shows a simplified view of the functions implemented for input side monitoring. Other quantities, such as drive efficiency, average input current THD, and individual harmonic component (in input voltages/currents), are also calculated. All variables have an accuracy of $\pm$ 1%, except for efficiency ($< \pm$ 2%) and input current THD ($\pm$ 1% above ~ 60% of rated power). A list of symbols used in Figure 5-11 and a description of the parameters they represent are given in Table 5-4. Note that the definitions of I_d and I_q components of the input current are different from the output side quantities.

Input side monitoring allows the drive to protect the secondary side of the transformer from abnormal conditions. Two faults, excessive drive losses, and one-cycle protection are generated under such conditions. Input side control also provides torque current limiting for line under-voltage, single-phasing, and transformer overload conditions.
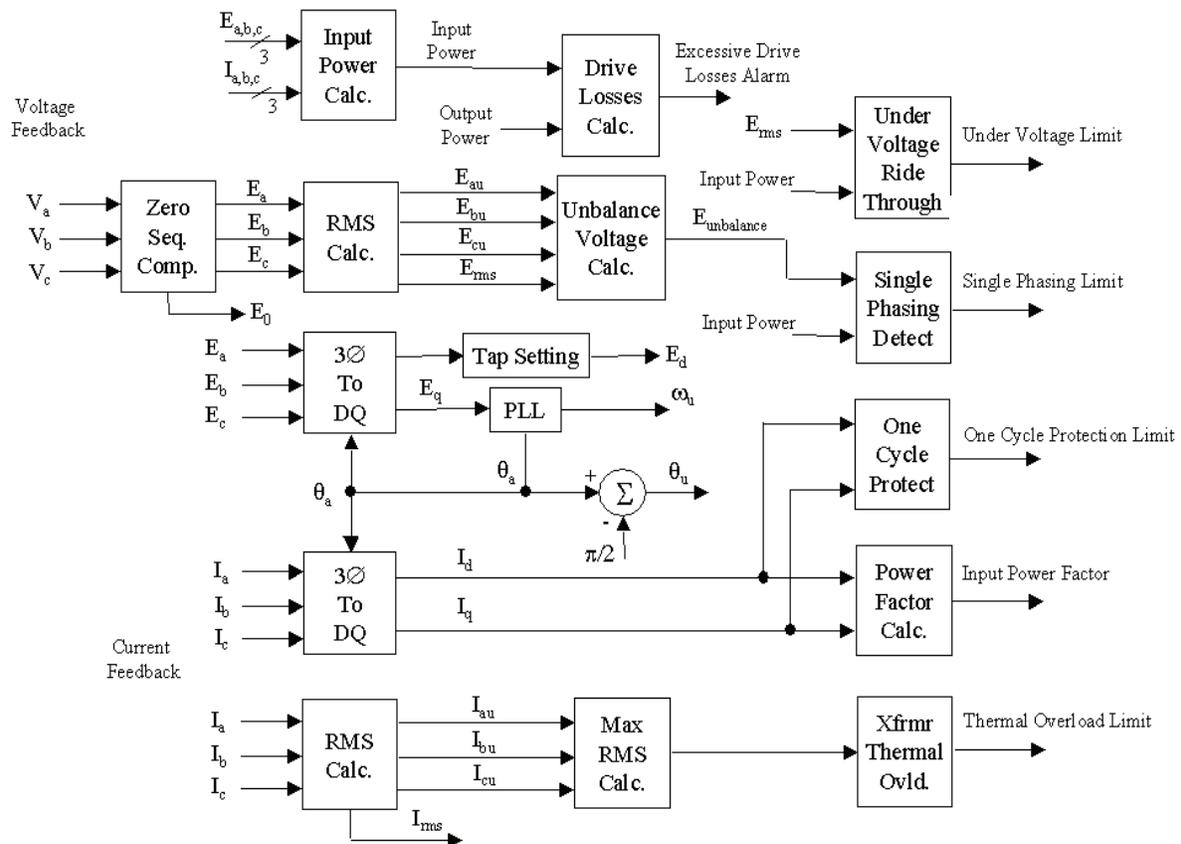
Figure 5-11: Block Diagram of Input-Side Monitoring

Table 5-4: List of Symbols Used in Figure 5-11

Name	Description
E_{rms}	Average rms voltage (of all 3 phases)
E_d	Amplitude of voltage taking the transformer tap setting into account. This represents the actual voltage being provided to the cells. If the tap setting is +5%, E_d will be 5% smaller than E_{rms}, and vice versa.
$E_{a,b,c}$	Zero sequence (DC offset) corrected input phase voltages
u	Input frequency
u	Angle of input-side flux
I_{rms}	Average rms current (in all 3 phases)
I_d	Real component of input current
I_q	Reactive component of input current
$I_{a,b,c}$	Single-phase components of input current

5.13.1 One Cycle Protection

NXG Control utilizes input reactive current to determine whether a "hard" fault on the secondary side of the transformer has occurred. For example, a short-circuit in one of the secondary windings will result in poor power factor on the high-voltage side of the transformer. A model of the transformer, based on the power factor at rated load, is implemented in the control processor. The drive input reactive current is continuously checked with the predicted value from the model. An alarm/trip is generated if the actual reactive current exceeds the prediction by

more than 10%. This check is avoided during medium voltage power-up to avoid the inrush current from causing nuisance trips.

Implementation

Figure 5-12 shows the implementation of One Cycle Protection.

I_{gain} = 1 Cyc Protect Integ gain

K_{tr} = Xformer protection constant
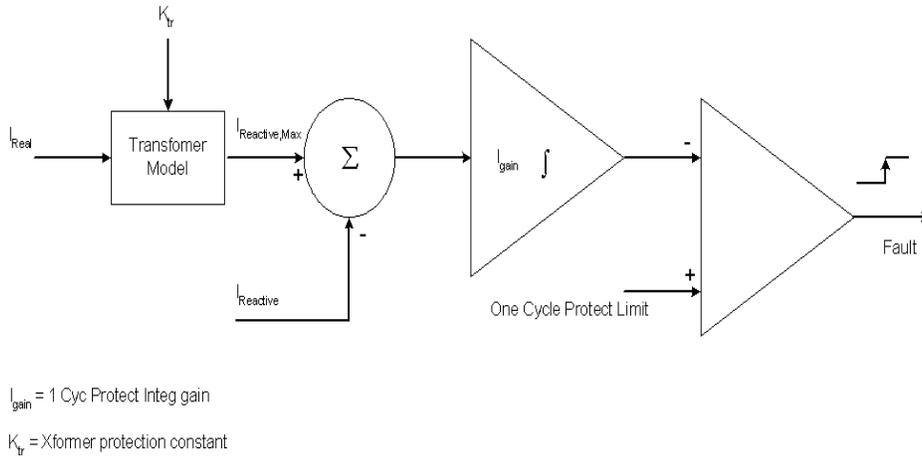
Figure 5-12: Implementation of One Cycle Protection

Transformer Model

The Transformer Model block in Figure 5-12 provides the maximum value of the input reactive current for a given value of transformer constant, Ktr, as given below:

$I_{Reactive,Max} = 1.10 * (0.05 + K_{tr} * I_{Real}^2)$

Figure 5-13 shows a plot of the Max Reactive Current versus Real Current with a transformer constant of 0.5.
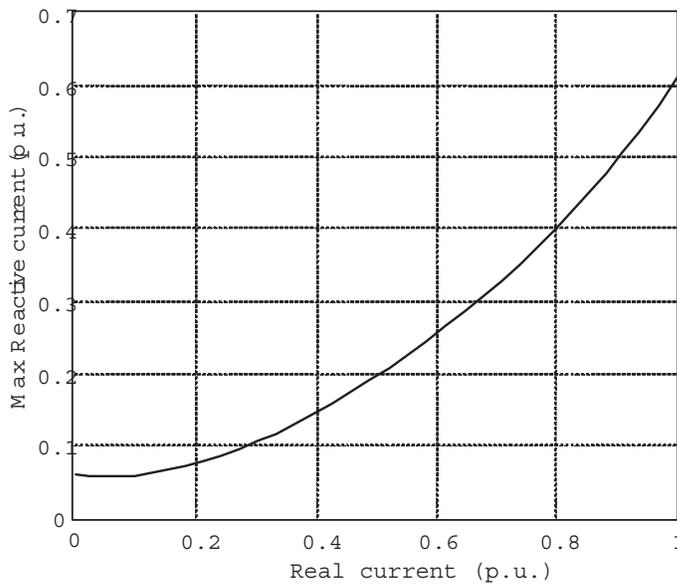
Figure 5-13: Plot of Max Reactive Current Versus Real Current with a Transformer Constant of 0.5

Integral Timer

The integral timer gain can be calculated based on the desired response time (T_{trip}) as shown below:

$I_{gain} = T_{trip}$ / (Error * Slow_loop_sample_rate)

Where:

- Error is the maximum error (in per unit) that can be tolerated between $I_{Reactive,Max}$ and actual reactive current $I_{reactive}$
- Slow_loop_sample_rate is the sample frequency of the slow loop (typically 450 – 600 Hz).

5.13.2 Excessive Drive Losses

NXG control utilizes input power and output power calculations to determine whether an internal fault has occurred. Drive Power Loss is estimated as the difference between input power and output power. This quantity is continuously checked with a pre-defined threshold that is inverse time-based, i.e., if the threshold is exceeded by a large margin, then the trip occurs a short time after the event, and vice-versa.

Implementation

Figure 5-14 shows the implementation of the Drive Loss fault circuit.
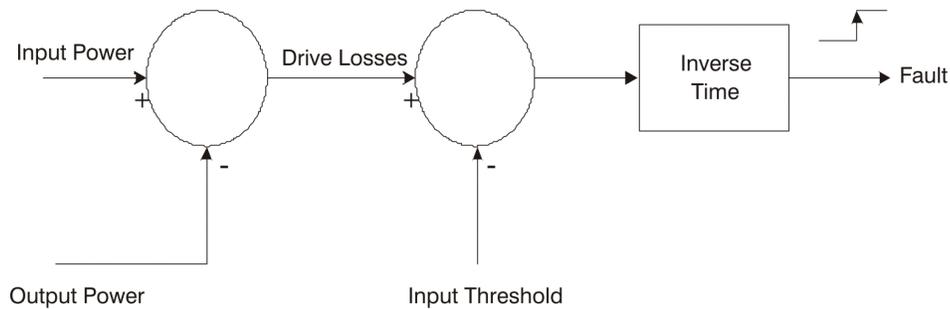
Figure 5-14: Implementation of the Drive Loss Fault Circuit

Inverse Time Curve

Figure 5-15 shows the inverse time-to-trip curves as a function of Drive Losses. Each plot shows two curves – one for Idle State and the other for Run State (slightly longer time to trip). For software versions 2.22 and lower, a fixed trip time of one second was used instead of the curves shown next.

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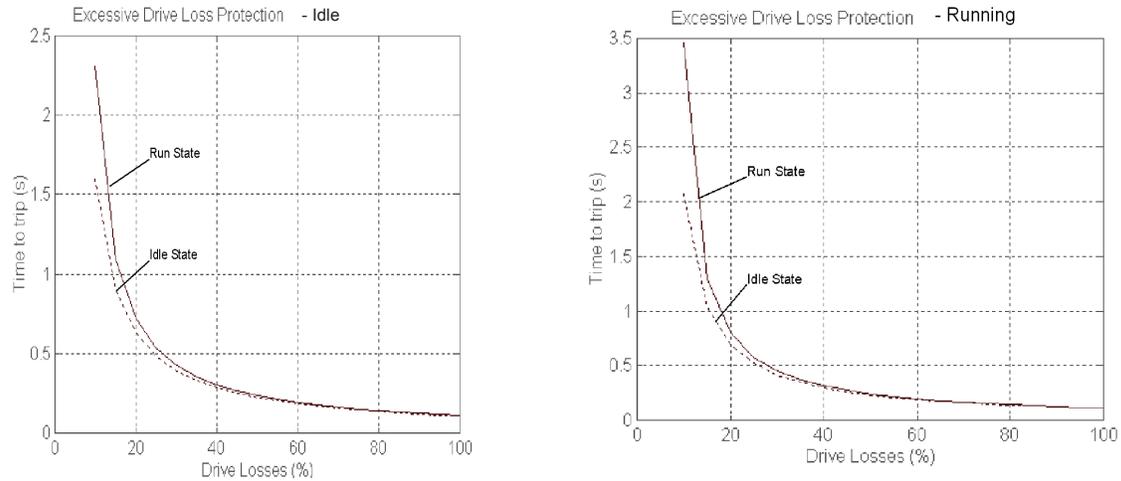
Figure 5-15: Inverse Time-To-Trip Curves Left – Idle State, Right – Run State

Internal Threshold

The internal threshold is a function of the rated drive input power. For example, in Run State, the internal threshold is given as:

Internal Threshold (Watts)= 0.07 * rated Drive Input Poser

$$= 0.07 * \sqrt{3} * \text{Rated Input Voltage} * \text{Rated Input Current}$$

☞ **Note:** The excessive losses threshold is programmable via the NXG menu system. This value is preset and should not be changed without consulting the factory.

5.14 Cell Bypass

When the Perfect Harmony was first introduced, its most salient attributes were improved power quality at both the utility interface and the motor interface. A third attribute is now recognized, which offers extremely high reliability by utilizing the inherent redundancy of these drives. Cell Bypass is the feature that allows this third attribute to be realized.

The Cell Bypass option is implemented by adding a contactor to the output of each cell as shown in Figure 5-16. When NXG control interrogates the cells and detects that a cell has faulted, a command is sent to close the appropriate contactor. This disconnects the cell output from the circuit. The drive can then be restarted and operation can continue at reduced capacity. The amount of reduction in capacity that can be tolerated will depend on the application, but in most cases a reduction in capacity is preferable to a complete shutdown. Neutral Point Shift is a feature that was developed to minimize the reduction in capacity after a bypass. Another related feature is Fast Bypass. This feature is designed to quickly bypass a cell and get the drive running again in less than ½ second. Neutral Point Shift and Fast Bypass are discussed in the following sections.
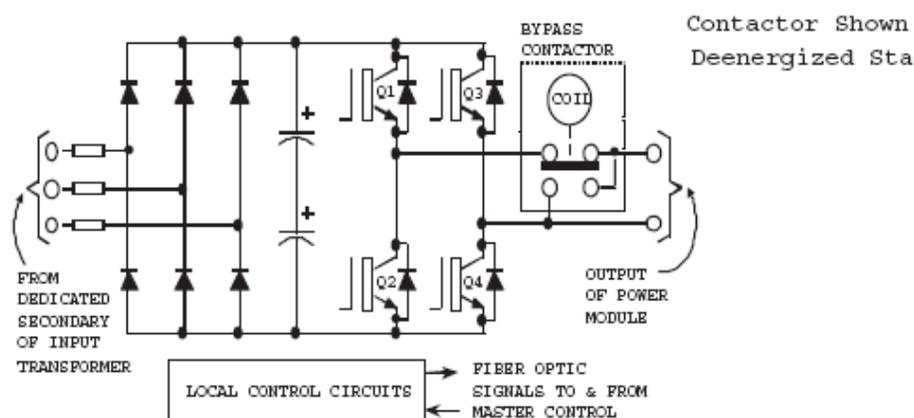
Figure 5-16: Typical Power Cell with Bypass Contactor

5.14.1 Fast Bypass

Up time is an important factor in many processes. A Medium Voltage drive is often a critical part of the process and even small interruptions in output torque of a Medium Voltage drive can cause the process to stop. This can result in lost material and production time. Fortunately, in general, a process can ride through an interruption of ½ second or less. The NXG control has a feature that is designed to limit the interruption of torque to the process by less than ½ second if a cell fault is detected. This feature is called Fast Bypass, which utilizes the capabilities of the NXG Control system and the cell bypass functionality. The conditions that must exist for the drive to meet this ½ second maximum interruption are described below.

Possible abnormal operating conditions are detected in cell control board hardware. This hardware is designed to quickly shut down the drive to minimize damage. Once this happens, NXG control is then signaled. The control can then quickly determine which cell faulted and the bypass process can be started. When the drive trips and stops delivering torque to the motor, the motor acts like a generator and produces a voltage on the drive output terminals. This voltage decays over time, but can be near the drive rated output voltage for a few seconds. If a cell is bypassed, the remaining cells may not be able to support this voltage and damage can occur. To prevent this damage, a check is done in the control to verify that the motor output voltage can be supported before a cell is bypassed. If sufficient output voltage is available, the cell can be bypassed and torque can be delivered to the motor in under ½ second from the time the cell fault occurred. If the motor voltage is too high, the control will delay the bypass process to allow the back EMF voltage to decay. To guarantee that the drive will bypass a cell fault in under ½ second, the drive needs to be operating at an output voltage that N-1 cells can supply. One way is for the drive to be sized so that it has more than the minimum number of cells required to provide the voltage needed, defined as N+X redundancy (where X is

typically 1 or 3), following cell bypass. Another solution is to limit the maximum speed following cell bypass. These issues must be studied and resolved before the drive is installed.

> ☞ **Note:** Fast bypass is dependent upon the available output voltage.

> ☞ **Note:** Acceleration following cell bypass is dependent upon parameter ramp rates and available torque current.

5.14.2 Fast Bypass Process

The Fast Bypass process is summarized as follows, where control mode must be OLVC, CLVC, SMC or CSMC, and Fast Bypass must be enabled.

1. VFD output enabled, output phase locked loop valid

2. Any cell fault occurs, output phase lock loop continues to track motor

3. VFD output disabled (all power cells disabled by NXG hardware)

4. NXG control detects cell fault(s)

5. NXG control monitors motor back EMF until it is within "safe" voltage

6. Control issues commands to bypass faulted cell(s)

7. Brief delay to allow mechanical contactors to fully close

8. Spinning load algorithm is performed (OLVC, CLVC) to detect motor voltage/frequency/phase

9. VFD output is enabled, synchronized to detected motor position/speed

10. VFD output ramps back to motor speed prior to cell fault

> ☞ **Note:** Maximum speed is a function of remaining VFD output voltage capability.

5.14.3 Neutral Point Shift During Bypass

Since the cells in each phase of a Perfect Harmony Drive are in series, bypassing a cell has no effect on the current capability of the drive, but the voltage capability will be reduced. Usually the required motor voltage is roughly proportional to speed, so that the maximum speed at which the drive can fulfill the application requirements will also be reduced. Therefore, it is important to maximize the motor voltage available after one or more cells have been bypassed. Figures 5-17 through 5-21 illustrate the voltage available from a Perfect Harmony drive, where the cells, represented by circles, are shown as simple voltage sources. Figure 5-21 shows a 15-cell drive in which no cells are bypassed. With 100% of the cells in use, 100% of the original voltage is available. The voltage commands to the three phase groups of cells will have phase A displaced from phase B by 120°, and from phase C by 120°.
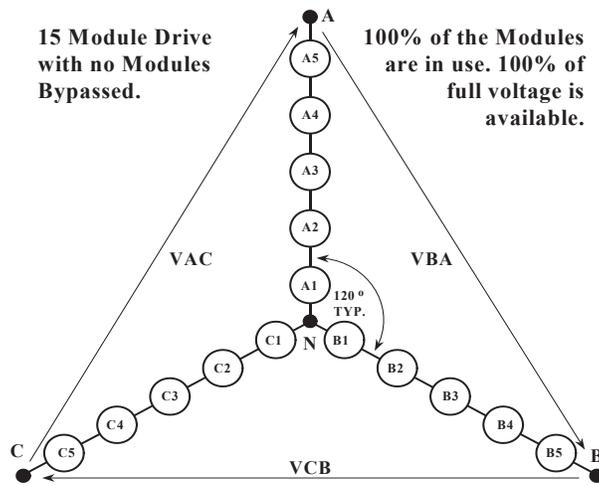
Figure 5-17: A Simplified Diagram of a 15 Cell Drive

When cells are bypassed in one of the drive phases, the output voltage will tend to become unbalanced, as illustrated in Figure 5-18. One possible remedy is to bypass an equal number of cells in all three phases, even though some may not have faulted. Figure 5-19 illustrates this approach. Obviously, this method prevents unbalance but sacrifices possible voltage capability. In Figure 5-19, 87% of the cells are functional, but only 60% are in use, and only 60% voltage is available.
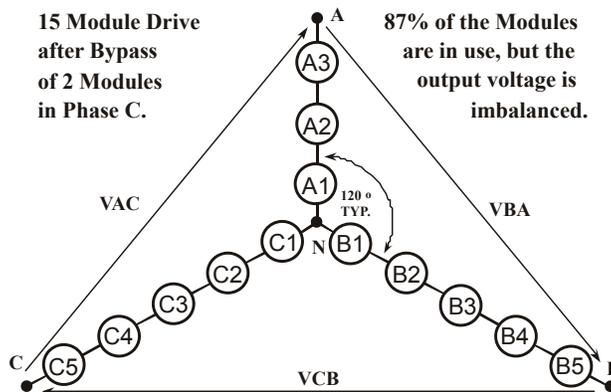
Figure 5-18: Drive Output with 2 Cells Bypassed

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15 Module Drive after
Bypass of 2 Modules in
all Phases. Balance
is restored.

87% of the Modules
are OK, but only
60% are in use.
60% of full volt-
age is available.
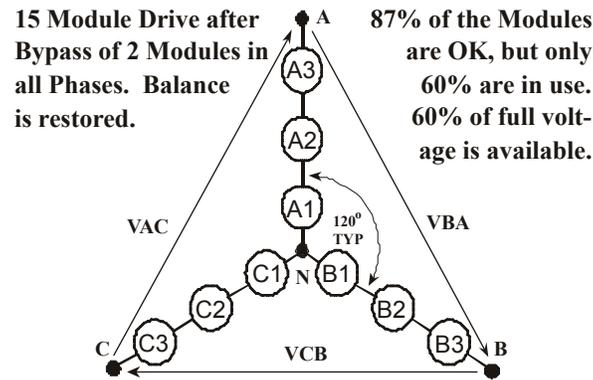
Figure 5-19: Drive Output Re-Balanced by Bypassing Functional Cells

A better approach is illustrated in Figure 5-20. This method takes advantage of the fact that the star-point of the cells is floating, and is not connected to the neutral of the motor. Therefore the star-point can be shifted away from the motor neutral, and the phase angles of the cell voltages can be adjusted, so that a balanced set of motor voltages is obtained even though the cell group voltages are not balanced.

Siemens calls this approach Neutral-Shift, and has a US Patent (5,986,909) that covers it. This approach is equivalent to introducing a zero-sequence component into the voltage command vectors for the cells. In Figure 5-20, the full remaining 87% of functional cells are in use, and 80% of the original voltage is available. The phase angles of the cell voltages have been adjusted so that phase A is displaced from phase B and from phase C by 132.5°, instead of the normal 120°.

15 Module Drive after
Bypass of 2 Modules
in Phase A only,
and Adjustment
of phase Angles.

87% of the Modules
are in use. 80% of
full voltage is
available.
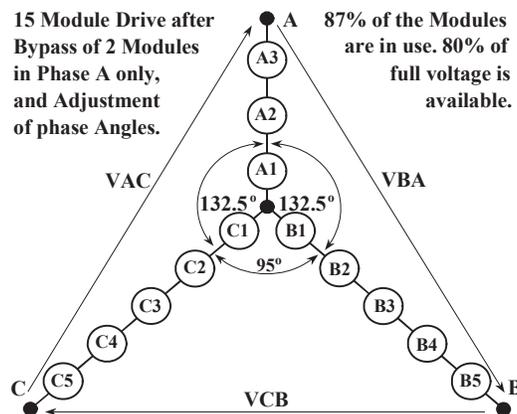
Figure 5-20: Drive Output Re-Balanced by Adjusting Phase Angles (Neutral-Shift)

The same neutral-shift approach can be applied to more extreme situations, as is illustrated by Figures 5-21 and 5-22. Figure 5-21 shows a drive which originally had five cells per phase, or a total of 15 cells. All five cells remain in phase A, but one cell has faulted in phase B and two cells have faulted in phase C. Without neutral-shift, all phases would need to be reduced to match the cell count of phase C to maintain balanced motor voltages. One functional cell would be bypassed in phase B, and two functional cells would be bypassed in phase A. Only 60% of the original cells would remain in use, and only 60% of the original voltage would be available.

However, with the neutral-shift approach shown in Figure 5-21, only the faulted cells are bypassed. The phase angles of the cell voltages have been adjusted so that phase A is displaced from phase B by 96.9° and from phase C by 113.1°, instead of the normal 120°. The star point of the cells no longer coincides with the neutral of the motor

voltages, but the motor voltage is still balanced. The neutral-shift keeps 80% of the original cells in use, and 70% of the original voltage is available.
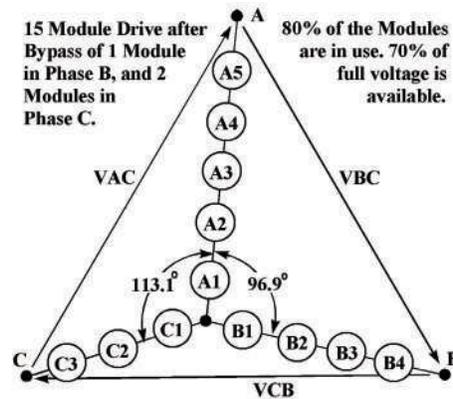
Figure 5-21: Drive Output after Loss of 3 Cells

As another example, Figure 5-22 shows the same 15-cell drive. All five cells remain in phase A, but two cells have faulted in phase B and three cells have faulted in phase C. Without neutral-shift, one functional cell would be bypassed in phase B, and three functional cells would be bypassed in phase A. Only 40% of the original cells would remain in use, and only 40% of the original voltage would be available. However, in Figure 5-22, only the faulted cells are bypassed. The phase angles of the cell voltages have been adjusted so that phase A is displaced from phase B by 61.1° and from phase C by 61.6°. The star point of the cells is far removed from the neutral of the motor voltages, but the motor voltage is still balanced. The neutral-shift keeps 67% of the original cells in use, and 50% of the original voltage is available.
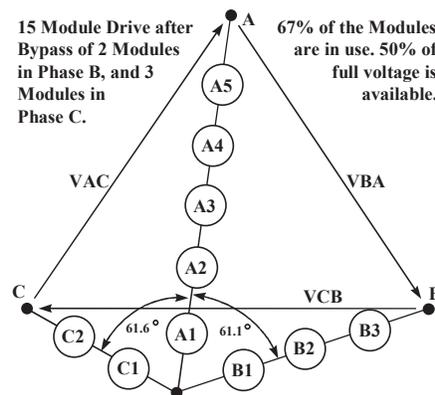
Figure 5-22: Drive Output after Loss of 5 Cells

Figure 5-23 compares the available voltage after one cell is bypassed with and without using neutral-shift. In many cases, the extra voltage available with neutral-shift will determine whether or not a cell fault can be tolerated. The voltage capability of a drive after cell bypass can be calculated by using the following procedure.

If X is the largest number of cells in bypass in **two of the phases**, then the maximum voltage at the drive output will be:

$$\text{Vout\_bypass} = \text{Vout} * (2*N - X) / (2*N)$$

where: Vout is maximum output voltage that the drive can deliver (Vout = 1.78*N*Vcell)

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N is the number of ranks (i.e., number of installed cells per phase)

Vcell is the cell voltage rating.

Example: Consider a drive with 18 cells, each rated for 750V. The maximum output voltage that this drive can deliver is (with N = 6 and Vcell = 750, and without O-M):

Vout = 1.78 * 6 * 750 = 8.01 kV

If after cell bypass, the drive has 6 cells operational in phase A, 5 cells in phase B, and 4 cells in phase C, then the maximum voltage that the drive can produce with neutral shift from the above formula is (with X = 1 + 2 = 3, because 2 cells in phase C and 1 cell in phase B are bypassed):

Vout_bypass = 8010 * (2 * 6 - 3) / (2 * 6) = 6 kV
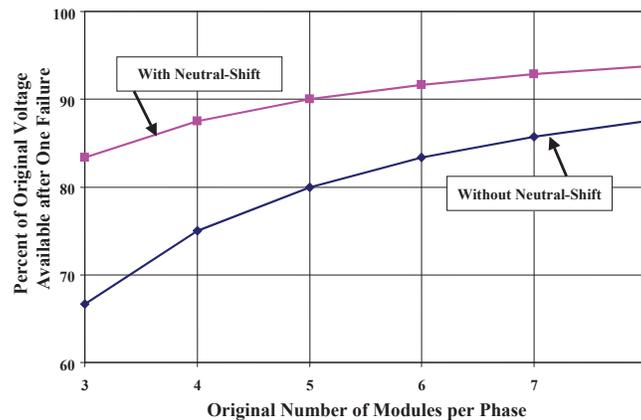
Figure 5-23: Available Voltage after One Cell Bypass

The drive control uses the information of faulted cells to automatically calculate the phase angles of cell voltages to maintain balanced motor voltages. During neutral-shift, each phase of the drive operates with a different power factor. Under lightly loaded conditions, it is possible that one or more phases are absorbing real power while the other phase(s) are delivering power to the motor. To prevent the cell dc-voltage (corresponding to cells that are absorbing real power) from increasing (and subsequently causing a drive trip condition), the control automatically enables the "Energy Saver" function. Under light loads, the energy saver function reduces motor flux sufficiently so that the motor operates with 70% power factor. At this operating point, the magnetizing and torque components of motor current are equal, and all cells deliver real power to the motor. As motor load is increased, the motor flux level is automatically increased to maintain 70% power factor until rated flux (or maximum possible flux) is achieved. This function ensures that the cells are delivering real power under all operating conditions.

☞ | **Note:** In Cell Bypass, the drive will invoke Energy Saver under light loads to prevent certain cells from charging-up.

5.15 Tool Suite

The NXG Tool Suite is a PC-based application software package that includes the Drive Host, Debug Utility, System Program Compiler, and Configuration tools for the NXG control. Note that the Drive Host and Debug utility communicate with an NXG drive via an Ethernet link. The System Program compiler and Configuration Update Tools are PC applications. Please refer to *NXG ToolSuite Software User Manual* 902291 for a complete description of the Tool Suite software package.

5.15.1 Drive Host

The NXG Drive Host is a PC-based application software package that provides a remote graphical user interface for Medium Voltage Perfect Harmony NXG series drives. With the Drive Host tool, the user can navigate through a drive's features using a PC and a mouse, allowing monitoring and control of the drive's functions quickly and easily. This makes the Drive Host Suite more convenient to use than the keypad on the front of the drive. The NXG Drive Host is a high-level GUI that runs on a PC equipped with the Microsoft Windows operating system. The NXG Drive software and the PC running the NXG Drive Host interface using Ethernet and TCP/IP protocols.

Configuration

- Multilevel password to limit access
    - o Passwords same as used in drive
- Folders for each drive configuration category (i.e., VFD Menu system)
    - o Icon colors to indicate default and modified parameter values
    - o On screen parameter identifier (matches keypad IDs for speed menus)
    - o Parameter editing assisted by minimum/maximum limits and defaults
- Ability to upload logs, parameters, system program
- Ability to download system program and/or configuration data files

Graphing

- Adjustable Time Scale
- Predefined variable list to select variable to be graphed
- Graph up to 10 variables
- Individual variable offsets
- Individual variable scaling
- Customizable Graphics - Fonts, Color, Styles
- Freeze Graphics
- Freeze graph on fault
- Freeze on selectable trigger
- Zoom graph
- Printable Graphics
- Exportable Graphics

Status

- Programmable display variables
    - o Pick list selectable variables, same as drive keypad display list
    - o First 4 synchronized to keypad display
- Fault and Alarm indicators (traffic lights: red = fault, yellow = alarm, green = none)

Control (only if enabled by SOP)**

- Manual Start Button
- Stop Button
- Fault Reset Button

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5.15.2 NXG Debug Utility

The NXG Control provides a built in debug function that provides real time status of various parameters, measured values, and calculations. This function is wholly contained in the NXG control, and user access is available from three separate ports:

- NXG CPU Video port using a standard VGA monitor with a standard PC keypad connected to the CPU card for navigating displays

- Ethernet port using the Debug Utility provided by the NXG Tool Suite

- RS232 Serial Port

The debug utility is intended for use during test, commissioning, and troubleshooting of the drive.

5.16 Serial Port

The NXG Control includes an RS232 serial port that can be used for downloading system program data from a PC, as well as for uploading parameter dumps, event logs, and historic data logs directly to a PC. Note that no automatic SOP downloads can be performed through this port; download activities must be initiated via the NXG Keypad. Upload functions in the default operating mode must also be initiated via the Drive keypad.

5.17 Dual Frequency Braking

5.17.1 Introduction to Dual Frequency Braking

There are many applications for VFDs that need occasional negative torque for braking. Unfortunately, at present the most popular static converters used for VFDs are not capable of returning energy to the utility. Such applications therefore require additional circuits to regenerate the braking energy into the AC mains, or to dissipate the braking energy in a resistor. Both of these solutions add cost to the VFD, and are especially undesirable for large modular medium-voltage VFDs.

Additional power devices can be avoided by using the existing circuits to inject DC current into the motor windings. This method dissipates the braking energy in the motor, and adds little cost to the VFD. However, DC injection braking is not very effective unless the available current is several times rated, especially for large motors. Another drawback is that estimation of motor speed is very difficult during DC injection braking.

Dual Frequency Braking (DFB) is another method in which braking energy can be dissipated in the motor. Dual Frequency Braking provides much higher torque per ampere than DC injection braking, and permits continuous estimation of motor speed. Like DC injection braking, this approach is implemented in software and requires no additional hardware that can reduce the reliability of the drive.

Siemens has a patent on Dual Frequency Braking (US 6,417,644).

5.17.2 Operation

Dual Frequency Braking causes extra losses to be induced in the motor by applying a second set of three-phase voltage vectors to the motor, in addition to the normal set of voltage vectors used for speed control. These extra losses are used to absorb the kinetic energy released during braking.

There are two side effects of Dual Frequency Braking (DFB) against which protection is applied as follows:

1. Torque pulsations: The motor can be subjected to as much as 1 per-unit torque pulsation at the pulsation frequency with DFB. However, the customer can select the torque pulsation frequency via the menu entry for Pulsation Frequency to avoid any mechanical resonance frequencies.

2. Motor heating: The losses generated during DFB cause motor heating and limit the number of deceleration ramps (from full speed to zero) that can be performed repetitively. Motor heating due to the additional losses is designed to be no worse than a line start. The software motor thermal model in NXG monitors motor heating due to these losses, and can provide an alarm and/or a trip to indicate excessive heating. The number of repetitive deceleration ramps (from full speed to zero) is limited to 2-per-hour (based on MG-1, Part 20,

which assumes that the motor has cooled down to its rated temperature before the second ramp down). This recommendation applies when the load inertia and load torque are those for which the motor is designed. With lower values of load inertia and/or smaller speed reductions, DFB can be used more frequently.

The second set of voltage vectors creates a counter-rotating flux vector that produces high slip in the machine and generates these additional losses in the motor. The injection frequency is always in opposite rotation to the applied motor electrical frequency (speed and direction of the machine).

Figure 5-24 is a block diagram showing how the two voltage vectors (normal VA1 and loss-inducing VA2) are added together to produce the braking function. Figure 5-25 is a scope picture of the two voltage vectors added together. The higher frequency voltage waveform VA2 is riding on the lower frequency waveform VA1.

☞ | **Note:** The pulsation frequency is programmable via the NXG Control, which is selectable by the end user. It provides the reference to produce the desired additional braking for the system and is adjustable to avoid resonance in the system.

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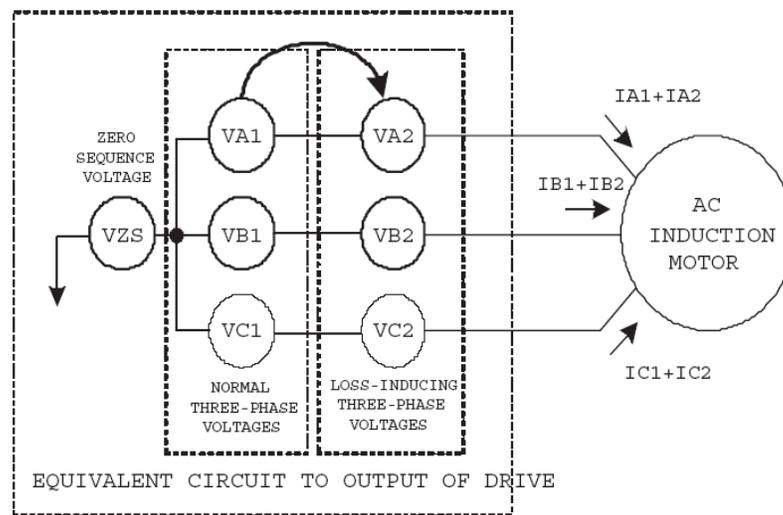
Figure 5-24: Dual Frequency Voltages Being Added Together with the Normal Three-Phase Voltages
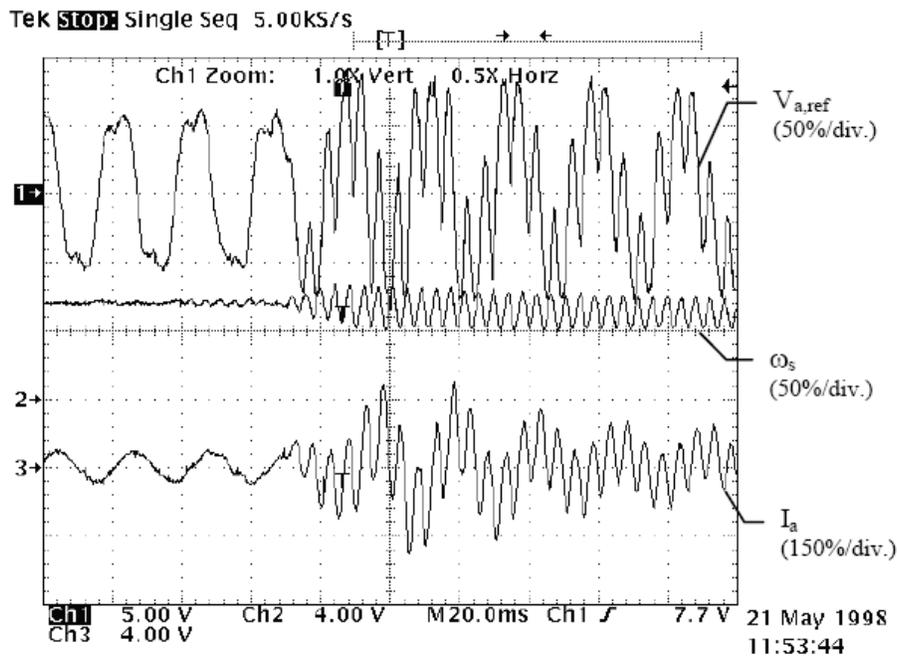
Figure 5-25: Scope Picture Showing Dual Frequency Braking Waveform

Using this method, the first vector set controls the torque and flux in the motor, and is nearly synchronous. The second vector set induces losses in the motor to absorb the braking power returned by the first vector set. The amplitudes of the two vector sets are coordinated to best utilize the current and voltage limitations of the converter. The frequency of the loss-inducing vector set is chosen with the goal of maximizing losses per ampere. This automatically minimizes the torque pulsations by minimizing the loss-inducing current.

The dominant losses in a motor are conduction losses, proportional to I^2R. Maximum losses per ampere require a large value of R. The nominal resistance of the motor windings is fixed by the design. Fortunately, the **effective** resistance depends on the frequency. The rotor windings are deliberately designed to exhibit a strong "deep-bar" effect, so that their resistance (above a low threshold) increases roughly proportional to frequency.

In principle, the frequency of the loss-inducing vector set should be as high as possible for maximum effective resistance. Since this high loss-inducing frequency produces negative slip, it will have negative sequence. The maximum applied frequency is limited by the control bandwidth of the converter, and also by the available voltage. However, because the loss-inducing vector set is negative sequence, the rotor frequency will be higher than the stator frequency due to the rotational speed.

5.17.3 Limitations

The drive output current plus the braking current must not exceed the current capability of the cells in the drive. Hence the braking torque is limited in the drive and is greatest at slow speed and smallest at high speed. Figure 5-26 shows the typical braking torque that can be expected with Dual Frequency Braking.
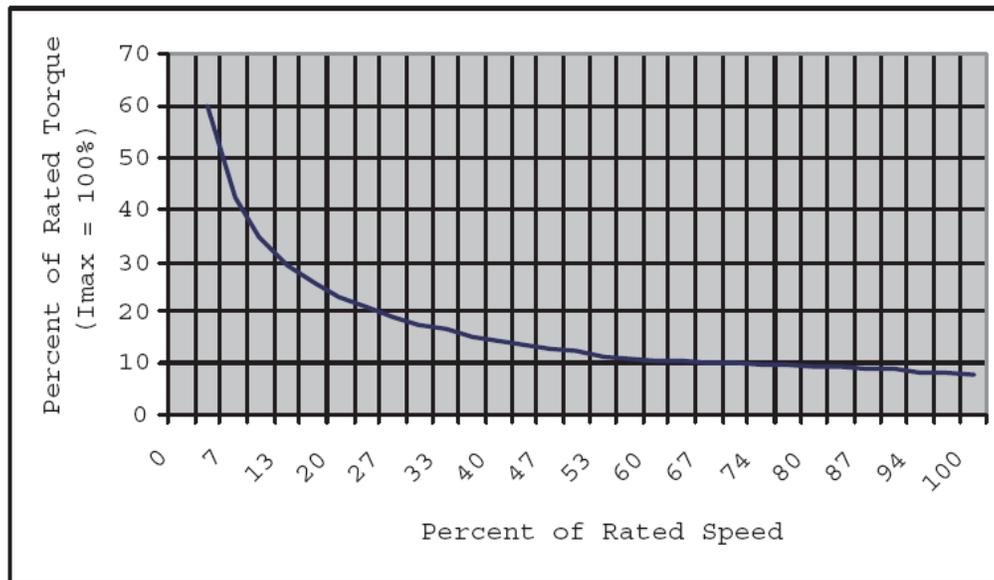
Figure 5-26: Typical Braking Torque with Dual Frequency Braking

With high efficiency motors and inverter duty motors, the braking torque that can be achieved with DFB is lower than the values shown in Figure 5-26. Contact Siemens Engineering with the following motor-related data to determine the braking torque capability with a higher efficiency motor:

- Rated HP

- Rated Voltage

- Rated Frequency

- Full/Half load speed

- Full/Half load efficiency

- Locked Rotor Torque and Current

- Pull out torque

- Critical frequencies of the mechanical system

5.18 Debug Functionality

The Serial Debug function of the NXG control serves as a means for the user to connect to an interactive menu that allows a user to capture VFD run-time data, including debug data described in Section 5.15.2. This port does not permit any data to be downloaded to the drive. It is provided as a means to extract human readable VFD status and logs from the NXG Control.

The port is configured as a standard RS-232 serial interface where no hardware handshake is required. The NXG control includes provisions to allow a serial modem to be connected so that drive status can be remotely accessed via telephone. When a modem is connected, it can be configured as an auto-answer device, or the NXG control is capable of configuring compatible modems to automatically answer.

> ☞ **Note:** Any RS232 compatible device can be connected to this port. The only requirement is that the user must initiate desired output data via single character inputs to the port.

Diagnostic data available via this port includes:

- Parameter Dump

- Fault/Event/Historic Log

- Drive Status/Id

- Debug Functions (as defined in Section 5.15.2)

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6 Application Specific Features

6.1 Control Mode Summary

The NXG Control provides six control modes for the Perfect Harmony drive family. These modes are described as follows:

- CLVC - Closed Loop Vector Control
  CLVC provides flux vector control for an induction machine utilizing an encoder for speed feedback.

- CSMC - Closed Loop Synchronous Machine Control
  CSMC is a flux vector control for a synchronous machine utilizing an encoder for speed feedback and providing a field excitation command for use by an external field exciter.

- OLTM - Open Loop Test Mode
  OLTM is intended for running the drive with no load attached to permit verifying the output voltage waveforms.

☞   **Note:** OLTM is intended for test purposes only and should not be used to control a motor.

- OLVC - Open Loop Vector Control, also known as Encoderless Vector Control
  OLVC is a flux vector control for induction machines that computes the rotational speed of the rotor based on measured output currents from the drive, and uses this computed speed as the speed feedback.

- SMC - Synchronous Motor Control
  SMC computes the rotational speed similarly to open-loop vector control, and controls the field reference or the synchronous motor as in closed-loop synchronous motor control. The field reference is controlled to achieve unity power factor.

- VHZ - Volts per Hertz control
  V/Hz is intended to be used when multiple induction motors are connected in parallel to the output of the drive. V/Hz operates similarly to open-loop vector control with de-tuned current regulators.

☞   **Note:** Spinning Load and Fast Bypass are not available in V/Hz control mode**.**

6.2 Control Loops

The NXG Control includes three main control loops that are defined in the following sections.

6.2.1   Current Loop

The current loops form the innermost loop of the NXG control system. It is essential that these loops are stable. When the current loop gains are very low, then the drive output currents do not have a sinusoidal waveshape, i.e., dead-bands can be seen around the zero-crossings, and the peaks are not smooth but appear flat. On the other hand, when current loop gains are too high, then a high frequency ringing appears on the sinusoidal current waveform. IOC trips can also occur if this is the case.

Default values of the current loop gains are sufficient for most applications. Tuning may be required for high performance applications and when output filters are used.

6.2.2 Speed Loop

Control of motor speed is accomplished with the speed regulator. The output of the speed loop forms the torque current command. The default speed loop gains work well when the inertia of the motor and the load are reasonable, i.e., motor and load have similar inertia. Examples of applications where this is not the case are given below. Speed loop gains require tuning when its output shows significant oscillations during small changes in speed command.

ESP applications have motors with very low inertia. In such applications, the speed loop gains can be safely reduced by a factor of 5 or more from their default settings.

Fan applications have motors with very high inertia. In such applications, the speed loop gains are typically reduced (by a factor of 2 to 5 from their defaults). These applications, in general, do not require fast/sudden response, and a reduction in speed loop gains prevents large/sudden changes in the torque current command.

6.2.3 Flux Loop

Regulation of motor flux is accomplished with the flux control loop. The output of the flux loop forms the magnetizing current command. The default flux loop gains work well for most induction motor applications. With synchronous motors, lower gains should be used. Flux loop gains will require tuning when the regulator output shows significant oscillations during steady state operation.

6.3 System Program

The System Program, as described in Section 5.4, is developed for each drive application to configure the VFD to function as desired by the end user. The System Program allows the end user to define the drive operation, where possible, so that system response and I/O configuration is configured for the application. The system program is used to define reference sources, select a subset of operating parameters, configure all I/O, and to define alarms/fault conditions as desired by the end user.

☞ **Note:** Internal drive-generated faults defined for drive protection cannot be modified by the SOP.

The System Program is downloaded onto the NXG drive in non-volatile memory, and can be field-modified for changing requirements. Note that the drive must be in an idle state (i.e., output disabled) for a new SOP to be utilized.

6.4 Speed Droop

Speed Droop is the decrease in the speed of a motor with a constant voltage and frequency when the motor is under load. The difference between the synchronous (unloaded) speed of the motor and the full load speed is known as slip. Normally, slip compensation increases the output frequency of the VFD as the motor speed attempts to decrease. This compensation maintains a constant motor speed by minimizing droop.

However, in some applications, droop is needed. For example, in a multiple motor application, such as two motors mechanically connected to a common load, there are inherent differences between the motors. In the case of a torque current increase, these differences may allow one motor to attempt to run faster, causing that motor to bear a greater portion of the load.

By adding droop to the more heavily loaded motor, its speed reference will proportionally decrease (based on load), shifting some of the load to the less loaded motor. The less loaded motor speed reference is not affected as much (because the current is lower) and will therefore start to pick up more of the load. As the loaded motor's speed reference is decreased, it begins to shed load until an equilibrium is reached, and each motor is bearing its share of the load.

6.5 Long Cable Applications

When a step of voltage from a drive is applied to one end of a transmission line, it causes a traveling wave to be propagated toward the opposite (or motor) end of the transmission line. When the traveling wave reaches the motor end of the cable, the motor leakage reactance is so high that the line behaves as if it were open-circuited. A reflection

wave begins to travel back toward the drive end. The total voltage at any point is the sum of all waves present, in this case the forward wave and the reflected wave. The reflection at an open circuit is such that the reflected voltage wave has the same polarity as the forward voltage wave. At the motor end, the reflected wave appears at the same instant as the forward wave arrives, so that the effective voltage step is doubled. At other points, there is a delay from the time that the forward wave passes until the reflected wave passes, so that two separate steps appear, each equal to the original.

When the reflected wave reaches the drive end of the cable, the drive impedance is so low that the line behaves as if it were short-circuited. A second reflection wave begins to travel back toward the motor end. The reflection at a short-circuit is such that the second reflected voltage wave has the opposite polarity as the first reflected voltage wave.

If the drive output remains static long enough after each step, then these reflected waves will bounce back and forth, losing energy at each reflection, until the voltage stabilizes. In this case, the worst step size imposed on the motor will be almost twice the step size from the drive, while the number of steps per second will be multiplied by the number of significant reflections per step.

However, a much worse scenario can occur if the drive produces another step before the waves from the previous step have decayed. The absolute worst case occurs when the next step from the drive coincides with the arrival of the first reflection back at the drive, and when the next step has the opposite polarity to the previous step. This happens most often when the propagation delay of the cable is equal to ¼ cycle at the effective switching frequency, which Siemens LD A defines as the critical length. In this case, the reflected waves from successive steps reinforce each other, and the worst step size on the motor can become many times higher than the step size from the drive.

The same effect will occur when the cable length is an odd multiple of the critical length, but it is less severe because the waves are reflected several times before they are reinforced.

For a Perfect Harmony Drive, the critical length is a function of the number of power cells per phase and the effective switching frequency of the drive. If the cable length exceeds a critical length (refer to Section 4.4), an output filter is included with the drive.

6.6 Output Filters

Output filters are required for down-hole pumping with long cables and also must be considered when shielded output cables are used. When required, the filter completely avoids any problem with cable reflections. NXG control supports output filters for all control modes. The output filter consists of an LC filter used to prevent the output cable dynamics from interfering with the drive output. An output filter might also be used to address EMI or DV/DT requirements. With the capacitors omitted, the filter can function as output reactors for Synchronous Transfer used to limit the current that can circulate while the VFD output is connected to the Medium Voltage input.

The output filter is designed to effectively remove all high frequency components in the drive output voltage. Because Perfect Harmony is already free of low-order output harmonics, the result is a nearly perfect sinusoidal output waveform.

Note that the filter adds losses proportional to the square of the RMS output current. The filter inductance is in series with the VFD output and motor load and can reduce the output voltage capability, depending on the load power factor. The filter also introduces an amplifying resonance, which could limit the closed-loop gain for high-performance applications. The filter consists of series inductors in each phase connected between the drive outputs and the load (motor) terminals. Shunt capacitors in each phase connect between the load terminals and are arranged in a floating wye configuration (capacitors are omitted for Closed Synchronous Transfer applications). Refer to Chapter 4 for output filter values.

6.7 Synchronous Transfer

6.7.1 Introduction

The synchronous transfer feature is used to avoid line start mechanical/electrical strain in constant-speed applications. The VFD soft starts the motor(s), and then NXG control matches line/load electrical characteristics, allowing "bumpless" synchronous transfer.

> **Note:** Beyond the core drive, synchronous transfer requires additional hardware: output reactor and switchgear. A PLC is recommended in multi-motor applications.

- "Up Transfer" - The process of transferring a VFD-controlled motor to the line, and then decoupling the motor from the drive.

- "Down transfer" - The process of transferring a line-energized motor to VFD control, and then decoupling the motor from the line.

To achieve successful up/down transfers, the output voltage of the VFD must match or exceed the amplitude of the line. If the line is unstable with frequency and/or voltage variations, the VFD may not be able to synchronize, and therefore transfer is inhibited.

> **Note:** In transfer applications, where a synchronous motor is used, the VFD must have control of the field supply.

> **Note:** Synchronous Up/Down transfer is not available in V/HZ or OLTM control modes.

> **WARNING!**
> - Improper phase sequence may result in a synchronous transfer related VFD fault.

6.7.2 VFD Synchronous Transfer Implementation

Synchronous transfer is inherent to NXG control. To optimize this feature, Siemens engineering should always be involved (regardless of scope of supply) in the switchgear configuration and logic sequencing for both equipment and personnel safety. Siemens engineering can supply switchgear and reactors as part of the drive, or provide recommendations as needed.

VFD Transfer Permissive

> **WARNING!**
> - The VFD output contactor and motor line contactors should never be simultaneously closed if the digital output signal "VFD Transfer Permissive" is low, or when the VFD input is not energized. Failure to ensure that this condition **does not** occur could result in severe damage to the VFD power cells.
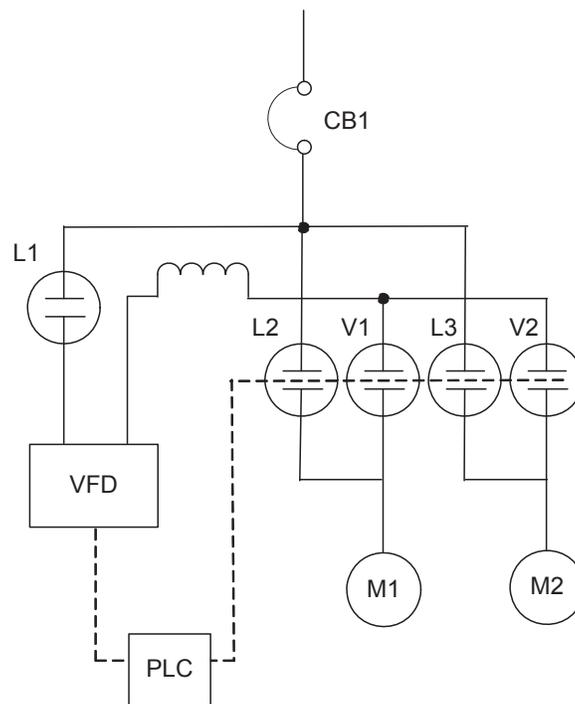
Figure 6-1: Multi-Motor, Synchronous Transfer

Figure 6-1 provides a block diagram showing the VFD configuration for synchronous transfer for a two motor implementation.

> **Note:** A PLC is recommended for multi-motor synchronous transfer applications. This PLC and its logic can be supplied by Siemens engineering to coordinate the transfer sequence and also control the switchgear. In addition, motor protection relays are recommended since the VFD cannot protect a motor operating from the line.

> **Note:** It is not required that all motors connected to a drive configured for synchronous transfer have matching ratings. If mis-matched motors are implemented, the drive must be sized for the worst case load. "Smaller" motor loads can be mechanized via parameter read/write functionality or the NXG Control Multiple Configuration file capability, as described in *NXG Communications Manual* (A1A902399) and *NXG Control Manual* (A1A19001588), respectively. As a rule, the smallest motor rating should be greater than 50% of the ratings of the largest motor to ensure feedback signal integrity. When mis-matched motors are used, the proper configuration file should be active for the subject motor.

Controller Implementation

Refer to the *NXG Control Manual*, A1A19001588, for a detailed description of NXG control configuration required for synchronous transfer.

6.7.3   Input/Output Signals for Sync Transfer

Excluding standard run, stop, and speed reference inputs, synchronous transfer requires four dedicated input signals and six dedicated output signals to be implemented. These signals can either be hardwired or implemented as digital control bits over one of the NXG-supported PLC communication links.

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Input Signals to the VFD:

- Up Transfer Request
- Down Transfer Request
- VFD Output Contactor Status
- Motor Line Contactor Status

Output Signals from the VFD:

- VFD Transfer Permissive
- Up Transfer Permit
- Up Transfer Complete
- Down Transfer Permissive
- Down Transfer Complete
- Open Motor Line Contactor

6.7.4   Up Transfer Implementation

Up transfers are accomplished by transferring the motor from the VFD directly to the line. Up Transfer requires that the VFD synchronize its output to match the voltage, phase angle, and frequency of the line. This is accomplished by using the drive input line frequency as a velocity reference and adjusting the VFD output voltage to match the line. Both functions are automatically implemented by the NXG control when an "Up Request" is received. The active acceleration ramps and torque limits set in the control are used during this period.

☞ | **Note:** Mismatched line/motor voltages are permitted when careful consideration is given to the configuration of the VFD (including step up/down transformers between the line and the motor).

Once the VFD output frequency is matched to the line, the output phase also needs to be matched with a pre-determined leading phase to ensure the power flow is out of the VFD when both the VFD output and motor line contactors are closed (both must be closed at one time to ensure bumpless transfer). When the synchronization is complete, the motor line contactor remains closed (i.e., motor connected to the line), the VFD output is disabled, and the drive output contactor is then opened to end the transfer.

A typical Up Transfer sequence is summarized as follows:

1. Start the VFD as a normal running drive with desired speed command. The drive must be in the "RUN" state to initiate transfer, and the "VFD Transfer Permissive" signal must be set true. In addition, the digital input flag "VFD Output Contactor Status" must be set true.

2. Initiate the transfer with the "Up Transfer" request digital input when an up transfer is desired. A timer should be used to establish a maximum time period for the transfer to complete. Transfer timeouts are rarely encountered and are usually due to an unstable source, a varying load, or improperly tuned drive.

☞ | **Note:** The VFD will attempt to perform the Up Transfer as long as the "Up Transfer Request" signal is set or until a VFD stop command is issued. If a VFD fault occurs at any time prior to closing the Motor Line Contactor, the external controller must reset its Up Transfer state machine and clear all Transfer related digital inputs sent to the VFD. As a rule, an Up Transfer typically will be completed within 10-20 seconds after the VFD output reaches the rated line frequency. Should a timeout occur, the transfer should be terminated and the NXG control will revert to its previous state, using the speed reference that was active prior to initiating the Up Transfer sequence.

3. The VFD will ramp the output to match the measured line frequency.

☞ | **Note:** The VFD will automatically ramp the output to rated frequency upon initiating the Up Transfer Sequence. There is no need to change the speed reference prior to issuing an "Up Transfer request."

4. The VFD ramps to line frequency and phase-locks for a minimum a 5 seconds. Note that the NXG control includes provisions for offsetting the phase should a configuration exist where the VFD Medium Voltage input is not the same phase as the line voltage to be used at the motor.

5. Once synchronized, the VFD issues a permit signal, "Up Transfer Permit", indicating that the Motor Line Contactor can be closed (VFD Output contactor also remains closed during this stage).

6. Once the Motor Line Contactor is closed and acknowledged at the VFD, the VFD will disable its output.

7. Once the VFD Output is disabled, the run request should be removed and the VFD output contactor must be opened. This completes the Up Transfer process, and the Up Transfer Request digital input can be removed.

6.7.5 Down Transfer Implementation

Down transfers are accomplished by transferring a motor from the line to VFD control. This is accomplished by using the voltage/frequency present at the motor terminals as a velocity reference, which is automatically implemented by the NXG control when a "Down Request" is received. Once the VFD output frequency is matched to the motor, the VFD output phase also needs to be matched with a predetermined leading phase to ensure the power flow is out of the VFD when both the VFD output and the motor line contactors are closed (both must be closed at one time to ensure bumpless transfer). When the de-synchronization is complete, the VFD output contactor remains closed (i.e., motor connected to the VFD), and the motor line contactor is then opened to end the transition. At this point, the VFD controls the motor.

A typical Down Transfer sequence is summarized as follows:

1. The motor is running directly from the line, VFD is idle, the VFD output contactor must be open, and the external speed reference must be set to the speed desired upon completion of the down transfer (remember to account for motor slip if bumpless down transfer is desired).

2. If the VFD indicates that it is capable of performing a down transfer (i.e., sufficient output voltage available, drive energized, and ready to run), the down transfer request is issued to the VFD.

3. Once the drive acknowledges the down request, the VFD output contactor is closed, and the VFD run request must be set.

☞ **Note:** The VFD output is not actually enabled at this time. The run request enables the VFD output phase locked loop (PLL) to monitor and lock to the line voltage/frequency. Since the VFD output contactor is closed while the motor is connected to the line, the line voltage and frequency are available via the drive's output sensors.

4. Once the VFD PLL maintains phase/frequency and voltage lock (typically 5-10 seconds), the VFD output is automatically enabled with a small frequency offset to ensure that current flows from the VFD to the line/motor.

5. Once the output current from the VFD reaches a predetermined level, the VFD signals that the line contactor can be opened. The output current will be limited to the maximum torque limit set in the NXG control.

☞ **Note:** The VFD will remain in the Down Transfer state as long as the "Down Transfer Request" signal is set or until a VFD stop command is issued. If a VFD fault occurs at any time prior to opening the Line Contactor, the motor should remain connected to the line and all input flags to the VFD should be cleared. As a rule of thumb, a Down Transfer typically will be complete within 30-60 seconds. There is no defined maximum or minimum time period required for opening the line contactor after the VFD issues the status flag to allow the Line Contactor to be opened.

6. Once the line contactor is opened, the Down Transfer Request must be removed and the VFD will control the motor as commanded. The run request must be maintained, and desired speed reference should be present to ensure a bumpless transition.

☞ **Note:** For induction machines: to maintain bumpless down transfer, the speed reference source to be used upon completion of down transfer should preset the speed reference to the mechanical shaft speed of the motor at rated line frequency (i.e., externally compensate for slip, where the speed reference should be set to 100% - RatedSlip).

6.8 Parallel Control

The Perfect Harmony drive family design includes the ability to combine multiple drives in parallel to provide a higher power output than is available from a single drive.

6.9 Communication Interfaces

The NXG control provides a means for the Harmony series of drives to be directly connected to several industry standard PLC communication networks, which provides the capability to control and/or monitor the VFD over these networks. A detailed description of the network capabilities is defined in the *NXG Control Manual*, A1A19001588, and the *NXG Communication Manual*, A1A1902399. A brief summary of the networks and their associated capabilities are provided in the following subsections.

6.9.1 Available Networks

At present, the NXG control supports the following industry standard PLC networks:

• Modbus RTU

• Modbus Ethernet

• Profibus DP

• ControlNet

• DeviceNet

• Modbus Plus

☞ **Note:** Modbus RTU or Modbus Ethernet is available as Network 1 without additional hardware. Other Network 1 communication protocols require an additional printed circuit board to be attached to the communications card within the NXG digital card rack.

6.9.2 Multiple Networks

The NXG controller allows the user to operate two independent network interfaces at one time, where both can monitor the drive, but only one can control the drive. The networks do not need to be identical, and each can map data separately. The second network, Network 2, is obtained by placing an additional printed circuit board to the communications card within the NXG digital card rack.

☞ **Note:** The ability to provide two networks is not implemented as a redundant or dual interface. The Harmony VFD simply provides a means to provide two separate ports where the user can define which of the ports may be used to control the VFD. Switchover from one network port to the other is implemented via the SOP.

6.10 Process Availability - The Perfect Harmony Advantage

Process availability is the primary prerequisite for applying a Medium Voltage VFD system in a process critical application. By combining the capabilities of Perfect Harmony's unique distributed power architecture with the power of the NXG control and the patented power cell bypass feature, it is possible to deliver unparalleled opportunities for improved process availability. It is also essential that the process operator receive complete and

accurate information on VFD status, to allow for process adjustments that can preclude process trips and disruptions in process capability.

6.10.1 What is ProToPS^{TM}?

ProToPS^{TM} is an acronym that stands for "Process Tolerant Protection Strategy." ProToPS^{TM} is a standard implementation of the VFD SOP (System Operating Program). The ProToPS goal is simply to put the process operator in control of the process. ProToPS^{TM} is a system program implemented from a customer process perspective.

ProToPS^{TM} provides the operator with indication of a change in state in the VFD. These annunciations identify changes that can impact the ability of the VFD to meet process demands, or to provide advance indication of a pending VFD trip. ProToPS^{TM} allows the process operator to make process corrections to maintain the VFD in service, or adjust the process to address a pending VFD trip.

With ProToPS^{TM}, the process operator not only knows the general status of the VFDs, but also understands the VFD condition that has caused the general alarm to exist.

6.10.2 How Does ProToPS^{TM} Work?

ProToPS^{TM} takes the standard fault indications available in the VFD and categorizes them into four basic major categories as follows:

1. Alarm - An alarm is an indication that a VFD parameter limit has been reached, or that a VFD system condition is present. An alarm provides the operator with awareness of the condition, but demands no immediate action. Examples of alarms include: over-voltage, under-voltage, and ground fault.

2. Process Alarm - A process alarm is an indication that a VFD parameter limit has been exceeded and that the process either should be limited, or that the VFD capacity to meet the process demand is limited. Examples of process alarms include thermal limits above the rated limit, and the condition of a cell having been bypassed.

3. Trip Alarm - A trip alarm provides a clear indication that a VFD high parameter limit has been reached. A trip alarm is an indication that a VFD trip is pending. The operator receives a message that, unless the alarm can be cleared by a process change, the VFD will trip.

4. Trip - Certain VFD faults cannot be provided with advance warning. This limited number of faults will result in a VFD trip. A trip message is also annunciated when a trip alarm time limit has been exceeded. The number of mandated trips is considerably reduced with the implementation of GENIV cell bypass.

With ProToPS the (VFD Run) signal is maintained as "true" and the (VFD Trip) signal is maintained as "false" for all alarm states.

6.10.3 ProToPS^{TM} Implementation

With ProToPS^{TM}, the four indication categories are provided as separate digital output signals (Alarm, Process Alarm, Trip Alarm, Trip). The concept is to provide the operator, or the process program, with a clear message to indicate a status change in the VFD.

The specific information on the VFD parameter change is indicated (along with the general category information) across a serial communications interface. Any serial communications protocol supported by the VFD product can be supported in the ProToPS^{TM} implementation.

If other specific digital output information is required for a specific customer project, that information must be mapped to a new digital output point on an additional digital output module. The four defined outputs must be present as digital outputs to validate the ProToPS^{TM} implementation.

6.10.4 The ProToPS^{TM} Advantage

With cell bypass, there are virtually no cell faults that are non-bypassable. With NXG control, the need for the designation "Transient Alarm" has disappeared as all bypassable faults become process transparent.

With ProToPS^{TM} and the NXG control, combined with the unique benefits of the Perfect Harmony cell based distributed power technology, process availability can be considerably enhanced and the process operator can truly control the process.

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<div style="background:#2aa8a0; color:white; display:inline-block; padding:4px 12px;">**CHAPTER**</div>

A   Glossary

This appendix contains definitions of terms and abbreviations used throughout the Perfect Harmony series manuals.

AND - AND is a logical Boolean function whose output is true if all of the inputs are true in SOP notation, AND is represented as "$*$" (e.g., C=A$*$B), although sometimes it may be omitted between operands with the AND operation being implied (e.g., C=AB).

ASCII - ASCII is an acronym for American Standard Code for Information Interchange, a set of 8-bit computer codes used for the representation of text.

Baud rate - Baud rate is a measure of the switching speed of a line, representing the number of changes of state of the line per second. The baud rate of the serial port of the Perfect Harmony is selected through the Baud Rate parameter in the Communications Menu [9].

Bit - Bit is an acronym for BInary digiT. Typically, bits are used to indicate either a true (1) or false (0) state within the drive's programming.

Boolean algebra - A form of mathematical rules developed by the mathematician George Boole used in the design of digital and logic systems.

Carrier frequency - Carrier frequency is the set switching frequency of the power devices (IGBTs) in the power section of each cell. The carrier frequency is measured in cycles per second (Hz).

"Catch a spinning load" feature - "Catch a spinning load" is a feature that can be used with high-inertia loads (e.g., fans), in which the drive may attempt to turn on while the motor is already turning. This feature can be enabled via the NXG menu system.

CLVC - An acronym for Closed Loop Vector Control - which is one of six control modes in the NXG drive. This is flux vector control for an induction machine (IM), utilizing an encoder for speed feedback.

CMP - Refer to the glossary term **SOP**.

Comparator - A comparator is a device that compares two quantities and determines their equality. The comparator submenus allow the programmer to specify two variables to be compared. The results of the custom comparison operations can be used in the system program.

Configuration Update - see Tool Suite definition.

Converter - The converter is the component of the drive that changes AC voltage to DC voltage.

Critical speed avoidance - Critical speed avoidance is a feature that allows the operator to program up to 3 mechanical system frequencies that the drive will "skip over" during its operation.

CSMC - An acronym for Closed Loop Synchronous Machine (SM) Control. One of six control modes of the NXG drive. This is a flux vector control for a synchronous machine, utilizing an encoder for speed feedback and providing a field excitation command for use by an external field exciter.

Debug Tool - see Tool Suite definition.

DC link - The DC link is a large capacitor bank between the converter and inverter section of the drive. The DC link, along with the converter, establishes the voltage source for the inverter.

De Morgan's Theorem - The duality principal of Boolean algebra used to convert system logic equations into sum-of-products notation.

Downloading - Downloading is a process by which information is transmitted from a remote device (such as a PC) to the drive. The term "downloading" implies the transmission of an entire file of information (e.g., the system program)

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rather than continued interactive communications between the two devices. The use of a PC for downloading requires special serial communications software to be available on the PC, which may link to the drive via RS232 or through the Host Simulator via an ethernet connection.

DRCTRY - Directory file for system tokens and flags used in the compilation of system programs. It provides a direct lookup table of ASCII names to internal ID numbers. It also identifies whether the flag is a word or bit-field, and also whether it can be used as an input or output only, or can be used for both.

Drive - The term "drive" refers to the power conversion equipment that converts utility power into power for a motor in a controlled manner.

ELV - ELV is an acronym for extra low voltage, and represents any voltage not exceeding a limit that is generally accepted to be 50 VAC and 120 VDC (ripple free).

EMC - EMC is an acronym for electromagnetic compatibility–the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

ESD - ESD is an acronym for electrostatic discharge. ESD is an undesirable electrical side effect that occurs when static charges build up on a surface and are discharged to another. When printed circuit boards are involved, impaired operation and component damage are possible side effects due to the static-sensitive nature of the PC board components. These side effects may manifest themselves as intermittent problems or total component failures. It is important to recognize that these effects are cumulative and may not be obvious.

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Fault log - Fault messages are saved to memory so that the operator may view them at a later time. This memory location is called the fault log. The fault log lists both fault and alarm messages, the date and time that they occurred, and the time and date that they are reset.

Faults - Faults are error conditions that have occurred in the Perfect Harmony system. The severity of faults vary. Likewise, the *treatment* or corrective action for a fault may vary from changing a parameter value to replacing a hardware component such as a fuse.

Flash Card - Non-volatile memory storage device for the NXG control. It stores the drive program, system program, logs, parameters, and other related drive files.

FPGA - Field Programmable Gate Array. An FPGA is an integrated circuit that contains thousands of logic gates.

Function - A function is one of four components found in the Perfect Harmony menu system. Functions are built-in programs that perform specific tasks. Examples of functions include System Program Upload/Download and Display System Program Name.

Harmonics - Harmonics are undesirable AC currents or voltages at integer multiples of the fundamental frequency. The fundamental frequency is the lowest frequency in the wave form (generally the repetition frequency). Harmonics are present in any non-sinusoidal wave form and cannot transfer power on average.

Harmonics arise from non-linear loads in which current is not strictly proportional to voltage. Linear loads like resistors, capacitors, and inductors do not produce harmonics. However, non-linear devices such as diodes and silicon controlled rectifiers (SCRs) do generate harmonic currents. Harmonics are also found in uninterruptable power supplies (UPSs), rectifiers, transformers, ballasts, welders, arc furnaces, and personal computers.

Hexadecimal digits - Hexadecimal (or "hex") digits are the "numerals" used to represent numbers in the base 16 (hex) number system. Unlike the more familiar decimal system, which uses the numerals 0 through 9 to make numbers in powers of 10, the base 16 number system uses the numerals 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F to make numbers in powers of 16.

Historic log - The historic log is a troubleshooting/diagnostic tool of the Perfect Harmony NXG control. The historic log continuously logs drive status, including the drive state, internal fault words, and multiple user-selectable variables. This information is sampled every slow loop cycle of the NXG control (typically 450 to 900 times per second). If a fault occurs, the log is frozen a predefined number of samples after the fault event, and data samples prior to and after the fault condition are recorded to allow post-fault analysis. The number of samples recorded are user-selectable via the NXG control, as well as the option to record the historic log within the VFD event log.

Host Simulator - see Tool Suite definition.

I/O - I/O is an acronym for input/output. I/O refers to any and all inputs and outputs connected to a computer system. Both inputs and outputs can be classified as analog (e.g., input power, drive output, meter outputs, etc.) or digital (e.g., contact closures or switch inputs, relay outputs, etc.).

IGBT - IGBT is an acronym for Insulated Gate Bipolar Transistors. IGBTs are semiconductors that are used in the Perfect Harmony drives to provide reliable, high-speed switching, high-power capabilities, improved control accuracy, and reduced motor noise.

Induction motor - An induction motor is an AC motor that produces torque by the reaction between a varying magnetic field (generated in the stator) and the current induced in the coils of the rotor.

Intel hex - Intel hex refers to a file format in which records consist of ASCII format hexadecimal (base 16) numbers with load address information and error checking embedded.

Inverter - The inverter is a portion of the drive that changes DC voltage into AC voltage. The term "inverter" is sometimes used mistakenly to refer to the entire drive (the converter, DC link, and inverter sections).

Jog mode - Jog mode is an operational mode that uses a pre-programmed jog speed when a digital input (programmed as the jog mode input) is closed.

Jumpers - Jumper blocks are groups of pins that can control functions of the system, based on the state of the jumpers. Jumpers (small, removable connectors) are either installed (on) or not installed (off) to provide a hardware switch.

Ladder logic - (Also Ladder Diagram) A graphical representation of logic in which two vertical lines, representing power, flow from the source on the left and the sink on the right, with logic branches running between, resembling rungs of a ladder. Each branch consists of various labeled contacts placed in series and connected to a single relay coil (or function block) on the right.

Loss of signal feature - The loss of signal feature is a control scheme that gives the operator the ability to select one of three possible actions in the event that the signal from an external sensor, configured to specify the speed demand, is lost. Under this condition, the operator may program the drive (through the system program) to (1) revert to a fixed, pre-programmed speed, (2) maintain the current speed, or (3) perform a controlled (ramped) stop of the drive. By default, current speed is maintained.

LVD - LVD is an acronym for Low Voltage Directive, a safety directive in the EU.

Lvl RH - This term refers the two security fields associated with each parameter of the system. These fields allow the operator to individually customize specific security features for each menu option (submenu, parameter, pick list, and function). These fields are shown in parameter dumps and have the following meanings. Lvl is the term for the security level. Setting R=1 blocks parameter change, and setting H=1 hides the menu option from view until the appropriate access level has been activated.

Memory - Memory is the working storage area for the Perfect Harmony drive that is a collection of RAM chips.

Microprocessor - A microprocessor is a central processing unit (CPU) that exists on a single silicon chip. The microprocessor board is the printed circuit board on which the microprocessor is mounted. The NXG drive employs a single-board computer with a Pentium® microprocessor.

NEMA 1 and **NEMA 12** - NEMA 1 is an enclosure rating in which no openings allow penetration of a 0.25-inch diameter rod. NEMA 1 enclosures are intended for indoor use only. NEMA 12 is a more stringent NEMA rating in which the cabinet is said to be "dust tight" (although it is still not advisable to use NEMA 12 in conductive dust atmospheres). The approximate equivalent IEC rating is IP52.

Normally closed (NC) - Normally closed refers to the contact of a relay that is closed when the coil is de-energized.

Normally open (NO) - Normally open refers to the contact of a relay that is open when the coil is de-energized.

OLTM - An acronym for Open Loop Test Mode - One of six control modes of the NXG drive.

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OLVC - An acronym for Open Loop Vector Control, also known as Encoderless Vector Control. OLVC is a flux vector control that is one of six control modes of the NXG drive. The drive computes the rotational speed of the rotor and uses it for speed feedback.

OOS - OOS is an abbreviation for out of saturation - a type of fault condition in which a voltage drop is detected across one of the IGBTs during conduction. This can indicate that the motor is drawing current too rapidly or in excess.

OR - OR is a logical Boolean function whose output is true if any of the inputs is true. In SOP notation, OR is represented as "+".

Parameter - A parameter is one of four items found in the Perfect Harmony menu system. Parameters are system attributes that have corresponding values that can be monitored or, in some cases, changed by the user.

PED - PED is an acronym for pressure equipment directive, a directive of the EU relating to pressure vessels.

Pick list - A pick list is one of four items found in the Perfect Harmony menu system. Pick lists are parameters that have a finite list of pre-defined "values" from which to choose, rather than a value range used by parameters.

PID - PID is an acronym for proportional + integral + derivative, a control scheme used to control modulating equipment in such a way that the control output is based on (1) a proportional amount of the error between the desired setpoint and the actual feedback value, (2) the summation of this error over time, and (3) the change in error over time. Output contributions from each of these three components are combined to create a single output response. The amount of contribution from each component is programmable through gain parameters. By optimizing these gain parameters, the operator can "tune" the PID control loop for maximum efficiency, minimal overshoot, quick response time, and minimal cycling.

Qualified user - A qualified user is a properly trained individual who is familiar with the construction and operation of the equipment and the hazards involved.

Quick menu - Quick menu is a feature of the menu system that allows the operator to directly access any of the menus or parameters, rather than scrolling through menus to the appropriate item. This feature uses the [Shift] button in conjunction with the right arrow. The user is prompted to enter the four digit ID number associated with the desired menu or parameter.

RAM - RAM is an acronym for Random Access Memory, a temporary storage area for drive information. The information in RAM is lost when power is no longer supplied to it. Therefore, it is referred to as volatile memory.

Regeneration - Regeneration is the characteristic of an AC motor to act as a generator when the rotor's mechanical frequency is greater than the applied electrical frequency.

Relay - A relay is an electrically controlled device that causes electrical contacts to change their status. Open contacts will close and closed contacts will open when rated voltage is applied to the coil of a relay.

RS232C - RS232C is a serial communications standard of the Electronics Industries Association (EIA).

Setpoint - Setpoint is the desired or optimal speed of the VFD to maintain process levels (speed command).

Slip - Slip is the difference between the stator electrical frequency of the motor and the rotor mechanical frequency of the motor, normalized to the stator frequency as shown in the following equation.:

$$\text{Slip} = \frac{\omega_S - \omega_R}{\omega_S}$$

Slip is the force that produces torque in an induction motor. Slip can also be defined as the shaft power of the motor divided by the stator input power.

Slip compensation - Slip compensation is a method of increasing the speed reference to the speed regulator circuit (based on the motor torque) to maintain motor speed as the load on the motor changes. The slip compensation circuit increases the frequency at which the inverter section is controlled to compensate for decreased speed due to load droop. For example, a motor with a full load speed of 1760 rpm has a slip of 40 rpm. The no load rpm would be 1800 rpm. If the motor nameplate current is 100 A, the drive is sending a 60 Hz wave form to the motor (fully loaded); then

the slip compensation circuit would cause the inverter to run 1.33 Hz faster to allow the motor to operate at 1800 rpm, which is the synchronous speed of the motor.

SMC - Is an acronym for Synchronous Motor Control - which is one of six control modes in the NXG drive.This mode computes the rotational speed similarly to open-loop vector control, and controls the field reference or the synchronous motor as in closed-loop synchronous motor control.

SOP - **(1)** SOP is an acronym for Sum Of Products. The term "sum-of-products" comes from the application of Boolean algebraic rules to produce a set of terms or conditions that are grouped in a fashion that represents parallel paths (ORing) of required conditions that all must be met (ANDing). This would be equivalent to branches of connected contacts on a relay logic ladder that connect to a common relay coil. In fact, the notation can be used as a shortcut to describe the ladder logic. **(2)** SOP, when used as a filename extension, refers to System Operating Program.

SOP Utilities - The program within the Siemens LD A Tool suite used for converting between text and machine loadable code. It can also be used for uploading and downloading files over the RS232 connection.

Stop mode - Stop mode is used to shut down the drive in a controlled manner, regardless of its current state.

Submenus - A submenu is one of four components found in the Perfect Harmony menu system. Submenus are nested menus (i.e., menus within other menus). Submenus are used to logically group menu items based on similar functionality or use.

Synchronous speed - Synchronous speed refers to the speed of an AC induction motor's rotating magnetic field. It is determined by the frequency applied to the stator and the number of magnetic poles present in each phase of the stator windings. Synchronous Speed equals 120 times the applied Frequency (in Hz) divided by the number of poles per phase.

System Operating Program - The functions of the programmable inputs and outputs are determined by the default *system program.* These functions can be changed by modifying the appropriate setup menus from the front keypad and display. I/O assignments can also be changed by editing the system program (an ASCII text file with the extension.SOP), compiling it using the compiler program, and then downloading it to the controller through its serial port, all by utilizing the SOP Utility Program with the Siemens LD A Tool Suite.

SOP Utilities - see Tool Suite definition.

Tool Suite - Is the suite of programs developed by Siemens that allows easier access to the NXG drive for programming and monitoring. It is comprised of the following components:

- **Tool Suite Launcher** - also referred to as Tool Suite; used for coordinating other tools.

- **SOP Utilities** - used to launch an editor that compiles or reverse compiles a System Program. It also allows for serial connection to the drive for uploading and downloading System Programs.

- **Configuration Update** - allows for backing-up, updating, and cloning drives via direct access to the Flash Disk.

- **Host Simulator** - used for monitoring, programming, and controlling a drive remotely from a PC over the built-in ethernet port of the drive. Parameter changes, status display, and graphing of internal variables are its main functions.

- **Debug Tool** - this tool is used to display the diagnostic screens of the drive for diagnosing drive problems or improving performance via the built-in ethernet port of the drive.

Tool Suite Launcher - see Tool Suite definition.

Torque - The force that produces (or attempts to produce) rotation, as in the case of a motor.

Uploading - Uploading is a process by which information is transmitted from the drive to a remote device such as a PC. The term uploading implies the transmission of an entire file of information (e.g., the system program) rather than continued interactive communications between the two devices. The use of a PC for uploading requires communications software to be available on the PC.

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Variable frequency drive (VFD) - A VFD is a device that takes a fixed voltage and fixed frequency AC input source and converts it to a variable voltage, variable frequency output that can control the speed of an AC motor.

VHZ - Is an acronym for Volts per Hertz control, one of six control modes in the NXG drive. This mode is intended for multiple motors connected in parallel. Therefore, it disables spinning load and fast bypass. This is essentially open-loop vector control with de-tuned (smaller bandwidth obtained by reducing the gain) current regulators.

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A

B Abbreviations

This appendix contains a list of symbols and abbreviations commonly used throughout this manual group.

Commonly Used Abbreviations

Abbreviation	Meaning
•	Boolean AND function
+	Addition or Boolean OR
Σ	Summation
μ	Microsecond
A	Amp, Ampere
AC	Alternating Current
accel	Acceleration
A/D	Analog to Digital Converter
ADC	Analog to Digital Converter
AI	Analog Input
alg	Analog
avail	Available
BIL	Basic Impulse Level
BTU	British thermal units
C	Centigrade or Capacitor
cap	Capacitor
CCB	Cell Control Board
ccw	Counter clockwise
CE	Formerly European Conformity, now true definition
CFM	Cubic feet per minute
CLVC	Closed Loop Vector Control
cmd	Command
com	Common
conn	Connector
CPS	Control Power Supply
CPU	Central Processing Unit
CSMC	Closed Loop Synchronous Motor Control
CT	Current Transformer
cu	Cubic
curr, I	Current
cw	Clockwise
D	Derivative (PID), depth

B

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D/A	Digital-to-analog (converter)
db	Decibel
DC	Direct Current
DCR	Digital Control Rack
DCS	Distributed Control System
decel	Deceleration
deg, °	Degrees
DHMS	Down hole monitoring system
div	Division
dmd	Demand
e	Error
EC	Electrically Commutated
ELV	Extra Low Voltage
EMC	Electromagnetic Compatibility
EMF	Electromotive Force
EMI	Electromagnetic Interference
EPS	Encoder Power Supply
ESD	Electrostatic Discharge
ESP	Electrical Submersible Pump
ESTOP, e-stop	Emergency Stop
fb, fdbk	Feedback
ffwd	Feed Forward
FLC	Full Load Current
freq	Frequency
ft, '	Feet
fwd	Forward
GenIIIe	Generation IIIe
GenIV	Generation IV
gnd	Ground
GUI	Graphical User Interface
H	Height
H_2O	Water
hex	Hexadecimal
hist	Historic
hp	Horsepower
hr	Hour
HV	High Voltage
HVAC	Heating, Ventilation, Air Conditioning
HVF	Harmonic Voltage Factor
Hz	Hertz

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I	Integral (PID)
ID	Identification
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IGBT	Insulated Gate Bipolar Transistor
in	Input
in, "	Inches
INH	Inhibit
I/O	Input(s)/Output(s)
IOB	I/O Breakout Board
IOC	Instantaneous Overcurrent
IP	Input Protection
k	1,000 (e.g., Kohm)
kHz	KiloHertz
kV	Kilo Volts
kVA	One Thousand Volt Amps
kW	Kilowatt
L	Inductor
LAN	Local Area Network
lbs	Pounds (weight)
LCD	Liquid Crystal Display
ld	Load
LED	Light-emitting Diode
LFR	Latch Fault Relay
lim	Limit
LOS	Loss Of Signal
lps	Liters Per Second
mA	Milliamperes
mag	Magnetizing
max	Maximum
MCC	Motor Control Center
mg	Milligram
min	Minimum, Minute
msec	Millisecond(S)
msl	Mean Sea Level
MV	Medium Voltage
mvlt	Motor Voltage
MW	Megawatt
NC	Normally Closed
NEMA	National Electrical Manufacturer's Association

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NMI	Non-Maskable Interrupt
No	Normally Open
NVRAM	Non-Volatile Random Access Memory
NXG	Next Generation Control
NXG II	Next Generation Control II
oamp	Output Current
OLVC	Open Loop Vector Control
O-M	Overmodulation
OOS	Out of Saturation (IGBT)
overld	Overload
P	Proportional (PID)
Pa	Pascals
pb	Push Button
PC	Personal Computer or Printed Circuit
PCB	Printed Circuit Board
PID	Proportional Integral Derivative
PLC	Programmable Logic Controller
PLL	Phase Locked Loop
pot	Potentiometer
pp	Peak-to-peak
ppm	Parts per Million
PPR	Pulses per Revolution
PQM	Power Quality Meter
ProToPS™	Process Tolerant Protection Strategy
PSDBP	Power Spectral Density Break Point
psi	Pounds Per Square Inch
pt	Point
PT	Potential Transformer
PWM	Pulse Width Modulation
Q1,Q2,Q3,Q4	Output Transistor Designations
rad	Radians
RAM	Random Access Memory
ref	Reference
rev	Reverse, Revolution(S)
RFI	Radio Frequency Interference
RLBK	Rollback
rms	Root-mean-squared
RPM	Revolutions Per Minute
RTD	Resistance Temperature Detector
RTU	Remote Terminal Unit

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RX	Receive (RS232 Communications)
s	Second(s)
SCB	Signal Conditioning Board
SCR	Silicon Controlled Rectifier
sec	Second(s)
ser	Serial
SMC	Synchronous Motor Control
SOP	Sum of Products; System Operating Program
spd	Speed
stab	Stability
std	Standard
sw	Switch
T1, T2	Output Terminals TI and T2
TB	Terminal Block
TBD	To Be Determined
TCP/IP	Transmission Control Protocol/Internet Protocol
THD	Total Harmonic Distortion
TOL	Thermal Overload
TP	Test Point
trq, τ	Torque
TX	Transmit (RS232 Communications)
UPS	Uninterruptable Power Supply
V	Voltage, Volts
VA	Volt-Amperes
VAC	Volts AC
var	Variable
VDC	Volts DC
vel	Velocity
VFD	Variable Frequency Drive
V/Hz	Volts per Hertz
vlts	Voltage(s), Volts
VSI	Voltage Source Inverter
W	Width, Watts
WAGO	Expansion I/O System
WCIII	Water Cooled III
xfmr, xformer	Transformer

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NOTES

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Additional Comments

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Sales Order Number (SO #) (see system door or system panel)	
Start-up Date	
Start-up Completed by	

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- Spare Parts Kits　　　　　　　❐

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Attention: Customer Service Operations

Siemens LD A

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SECTION 3

GENIV INSTALLATION, COMMISSIONING, AND MAINTENANCE MANUAL
MANUAL NO. A5E01454341D

Customer Name: PXP INC., Customers P.O.: **IR 68898 KK ALT1**
Project Name: PXP – IRENE 600HP, Siemens S.O. No.: 3001789510
Air Cooled Perfect Harmony Series, Adjustable Speed, AC Motor Drive
System Part Nos.: A5E02318880, A5E02320163 and A5E02320164

Siemens Energy & Automation, Inc. regrets that because of product liability issues, **edited, incomplete manuals may not be furnished**. Once the equipment is shipped from Siemens Energy & Automation, Inc., its ultimate application is outside of Siemens Energy & Automation, Inc. control, and allowance must be made for the possibility that the VFDs may be applied in ways that are not currently part of this contract. (For example, the Owner at some later date would decide to remove a VFD from service then sell it with its documentation.) To guard against the possibility of misapplication or misuse (and any possible attendant risk of injury) in the future, Siemens Energy & Automation, Inc. requires that *"complete"* User/Operation and Maintenance Manuals "must" be provided.

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GenIV

Installation, Commissioning, and Maintenance Manual

Manual Number: A5E01454341D
Version AC
July 2008

Siemens Energy & Automation, Inc.

Large Drives A

For the support representative nearest you, please call Siemens main office at 724.339.9500.

Version History

Version AC (13032)	July 2008	
Version AB (12988)	July 2008	
Version AA (original)	June 2008	
	This manual was previously released as 19001851	
	• Version 1.0 (original) March 2007	

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Safety Precautions and Warnings

The GenIV is designed with considerable thought to personal safety. However, as with any piece of high power equipment, there are numerous internal connections that present potentially lethal voltages. In addition, some internal components are thermally hot to the touch. Follow the warnings below when working in or near the GenIV System.

Danger - Electrical Hazards!

- **Always** follow the proper lock-out/tag-out procedures before beginning any maintenance or trouble-shooting work on the drive.
- **Always** follow standard safety precautions and local codes during installation of external wiring. Protective separation must be kept between extra low voltage (ELV) wiring and any other wiring as specified in IEC61800-5-1.
- **Always** work with one hand, wear insulated or rubber safety shoes, and wear safety glasses. Also, always work with another person present.
- **Always** use extreme caution when handling or measuring components that are inside the enclosure. Be careful to prevent meter leads from shorting together or from touching other terminals.
- **Use** only instrumentation (e.g., meters, oscilloscopes, etc.) intended for high voltage measurements (that is, isolation is provided inside the instrument, not provided by isolating the chassis ground of the instrument).
- **Never** assume that switching off the input disconnect will remove all voltage from internal components. Voltage is still present on the terminals of the input disconnect. Also, there may be voltages present that are applied from other external sources.
- **Never** touch anything within the GenIV cabinets until verifying that it is neither thermally hot nor electrically alive.
- **Never** remove safety shields (marked with a HIGH VOLTAGE sign) or attempt to measure points beneath the shields.
- **Never** run the drive with cabinet doors open. The only exception is the control cabinet which contains extra low voltages (ELV).
- **Never** connect any grounded (i.e., non-isolated) meters or oscilloscopes to the GenIV system.
- **Never** connect or disconnect any meters, wiring, or printed circuit boards while the drive is energized.
- **Never** defeat the instrument's grounding.
- **Only** qualified individuals should install, operate, troubleshoot, and maintain this drive. A qualified individual is "one familiar with the construction and operation of the equipment and the hazards involved."
- **Hazardous voltages** may still exist within the GenIV cabinets even when the disconnect switch is open (off) and the supply power is shut off.
- When a system is configured with drive bypass switchgear (e.g., contactors between line and motor, and drive and motor), these switches should be interlocked so that the line voltage is **never applied** to the drive output if the medium input voltage is removed from the drive.

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Warning!
- **Always** comply with local codes and requirements if disposal of failed components is necessary (for example, CPU battery, capacitors, etc.).
- **Always** ensure the use of an even and flat truck bed to transport the GenIV drive system. Before unloading, be sure that the concrete pad is level for storage and permanent positioning.
- **Always** confirm proper tonnage ratings of cranes, cables, and hooks when lifting the drive system. Dropping the cabinet or lowering it too quickly could damage the unit.
- **Never** disconnect control power while medium voltage is energized. This could cause severe system overheating and/or damage.
- **Never** store flammable material in, on, or near the drive enclosure. This includes equipment drawings and manuals.
- **Never** use fork trucks to lift cabinets that are not equipped with lifting tubes. Be sure that the fork truck tines fit the lifting tubes properly and are the appropriate length.

ESD Sensitive Equipment!
- Always be aware of electrostatic discharge (ESD) when working near or touching components inside the GenIV cabinet. The printed circuit boards contain components that are sensitive to static electricity. Handling and servicing of components that are sensitive to ESD should be done only by qualified personnel and only after reading and understanding proper ESD techniques. The following ESD guidelines should be followed. Following these rules can greatly reduce the possibility of ESD damage to PC board components.
- Always transport static sensitive equipment in antistatic bags.
- Always use a soldering iron that has a grounded tip. Also, use either a metallic vacuum-style plunger or copper braid when desoldering.
- Make certain that anyone handling the GenIV printed circuit boards is wearing a properly grounded static strap. The wrist strap should be connected to ground through a 1 megohm resistor. Grounding kits are available commercially through most electronic wholesalers.
- Static charge buildup can be removed from a conductive object by touching the object to a properly grounded piece of metal.
- When handling a PC board, always hold the card by its edges.
- Do not slide printed circuit boards across any surface (e.g., a table or work bench). If possible, perform PCB maintenance at a workstation that has a conductive covering that is grounded through a 1 megohm resistor. If a conductive tabletop cover is unavailable, a clean steel or aluminum tabletop is an excellent substitute.
- Avoid plastic, Styrofoam™, vinyl and other non-conductive materials. They are excellent static generators and do not give up their charge easily.
- When returning components to Siemens LD A, always use static-safe packing. This limits any further component damage due to ESD.

Additional safety precautions and warnings appear throughout this manual. These important messages should be followed to reduce the risk of personal injury or equipment damage.

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About This Manual

Separation of Manuals

This manual is one component of a series of manuals intended for use with the Robicon Perfect Harmony series of Medium Voltage (MV) Pulse Width Modulated (PWM) Variable Frequency Drives (VFD). Each part in this series is for use by individuals having unique job functions and qualifications. The manuals in this series are listed below:

- The *GenIV Product User Manual* (A5E01454341C)

- *GenIV Installation, Commissioning, and Maintenance Manual* (A5E01454341D)

- *NXG ToolSuite Software User Manual* (A1A902291)

- *NXG Communications Manual* (A1A902399)

- *NXG Control Manual* (A1A19001588)

The *GenIV Product User Manual* (A5E01454341C) defines the configuration and capabilities of the Perfect Harmony family of Medium Voltage Variable Frequency Drives and specifically addresses the GenIV configuration.

The *GenIV Installation, Commissioning, and Maintenance Manual* (A5E01454341D) provides a detailed description of how the system is transported, installed, and maintained at the customer's site.

The *NXG ToolSuite Software User Manual* (A1A902291) provides a detailed description of ToolSuite, a PC-based application that integrates various software tools used for NXG-based Drives. The NXG ToolSuite is a high-level GUI that runs on a PC that is equipped with the Microsoft Windows operating system. The NXG control and the PC running the NXG ToolSuite communicate using Ethernet and TCP/IP protocol.

The *NXG Communications Manual* (A1A902399) describes the NXG control communication board, which enables network communication via a variety of protocols and enables modem connection.

The *NXG Control Manual* (A1A19001588) describes the NXG control system. The Harmony family of drives is a collection of MV drives with different power topologies and cooling methods. The unifying factor with the drives is the NXG control system - a second generation control for the Harmony line.

All manuals contain a readers' comments form. Please complete these forms and return them to us. Monitoring your feedback allows us to continue to exceed your expectations and provide complete, effective, easy-to-use product documentation.

Reference Tools

Many steps have been taken to promote the use of this manual as a reference tool. Reference tools include the following:

- A thorough table of contents for locating particular sections or subsections

- Chapter number thumb nails in the outer margins for easy location of chapters

- Special text styles are applied to easily differentiate between chapters, sections, subsections, regular text, parameter names, software flags and variables, and test points

- A comprehensive index

If you have any comments or suggestions to improve the organization or increase the usability of this manual, please complete the Readers' Comments Form located at the end of this manual and return it to Siemens LD A Document Control.

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Conventions Used in this Manual

The following conventions are used throughout this manual:

- The terms "Perfect Harmony," "VFD," "variable frequency drive," and "drive" are used interchangeably throughout this manual.

Note: Hand icons in the left margin alert readers to important operational or application information that may have special significance. The associated text is enclosed in a border for high visibility.

Attention! Attention icons in the left margin alert readers to important safety and operational precautions. These notes warn readers of potential problems that could cause equipment damage or personal injury. The associated text is enclosed in a border for high visibility.

Caution - Electrical Hazard! Electrical hazard icons in the outer margins alert readers to important safety and operational precautions. These notes warn readers of dangerous voltages, potential safety hazards, or shock risks that could be life threatening. The associated text is enclosed in a border for high visibility.

ESD Warning! These icons in the left margin alert readers to static sensitive devices. Proper electrostatic discharge precautions should be taken before proceeding or handling the equipment.

- Chapter numbers are highlighted in the outer margins to facilitate referencing (see margin)

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1 Introduction

The Robicon Perfect Harmony series of Medium Voltage (MV) Pulse Width Modulated (PWM), Variable Frequency Motor Drives (VFD) are designed and manufactured by Siemens LD A, New Kensington, PA, USA with additional manufacturing facilities in Europe, Asia, and South America. The Harmony VFD is intended for use with standard medium-voltage three-phase AC induction, synchronous, wound rotor, permanent magnet, or super conducting motors. When any of these types of motor is connected to a utility supply at a fixed frequency (i.e., 60 or 50 Hz), the motor runs at a single speed. The Harmony series of drives allows variable speed motor operation without sacrificing any of the desirable properties of the motor.

1.1 Purpose

This manual defines the commissioning and maintenance of the Perfect Harmony family of Medium Voltage Variable Frequency Drives and specifically addresses the GenIV configuration. Detailed descriptions of the common features of the Harmony drive family are defined in the following manuals:

Companion Manuals:

- *GenIV Product User Manual* (A5E01454341C)

- *NXG ToolSuite Software User Manual* (A1A902291)

- *NXG Communications Manual* (A1A902399)

- *NXG Control Manual* (A1A19001588)

1.2 Perfect Harmony

The Perfect Harmony VFD is based on a patented (U.S. patent #5,625,545) multi-level output topology. Medium voltage levels are obtained by adding together the outputs of multiple low-voltage power cells. The low-voltage power cells are simplified variations of standard PWM motor drives for low-voltage service, which have been built in high volume for many years.

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1.3 GenIV

Refer to companion manual *GenIV Product User Manual* (A5E01454341C), Chapters 3 and 4, for an overview of the GenIV technology and specifications.

1.3.1 Cabinet Details

The GenIV core enclosure is Nema 1 Ventilated (IP 31 degree of protection) and is provided with top and bottom cable access plates (see Figure 1-1). The doors are hinged and mechanical key interlock provisions are provided.
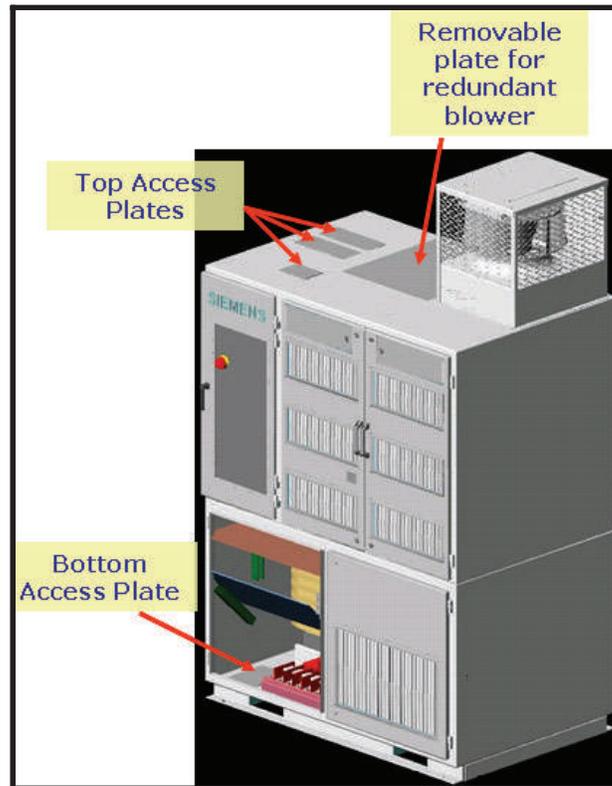
Figure 1-1: GenIV Enclosure (4160V Output, 200-1100 Hp)

1.4 Maintenance Earthing Procedure

☞ **Note:** The Perfect Harmony is a modular system that can be marketed into highly integrated applications. Therefore, these instructions do not cover all variations of equipment types or installations. Only qualified personnel should perform maintenance on these systems.

1. Stop drive operation either through remote or local controls.

2. De-energize input voltage by opening incoming switchgear and locking to OPEN position with mechanical interlock. Apply lock-out/tag-out principles as required by local code.

3. De-energize auxiliary control voltages and synchronous motor field/exciter controls.

4. Wait ten minutes to allow stored energy to dissipate from the Perfect Harmony drive.

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5.   If applicable, isolate motor connections by opening output switchgear using interlock key from input switchgear and locking to OPEN position using mechanical interlock.

TOP ACCESS
PLATES

REMOVABLE PLATE
for
REDNANT BLOWER

BOTTOM
ACCESS LTE
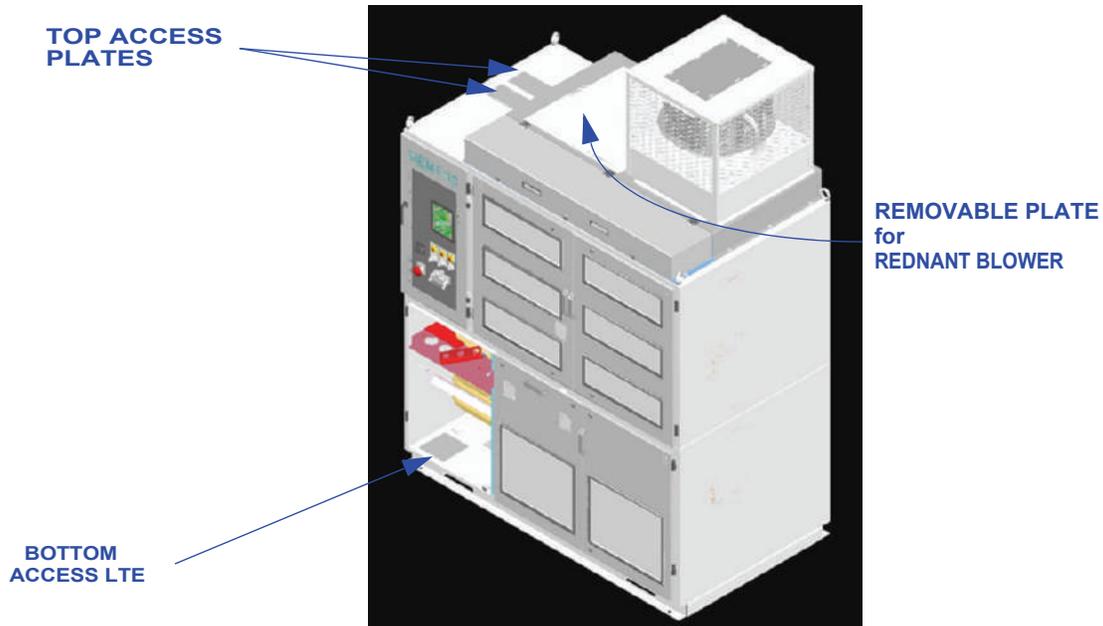
Figure 1-2: GenIV Enclosure (4160V Output, 1000-2500 Hp)

TOP ACCESS PLATES

REMOVABLE PLATE
FOR
REDUNDANT BLOWERS

REMOVABLE PLATE
FOR
REDUNDANT BLOWERS

BOTTOM ACCESS PLATES
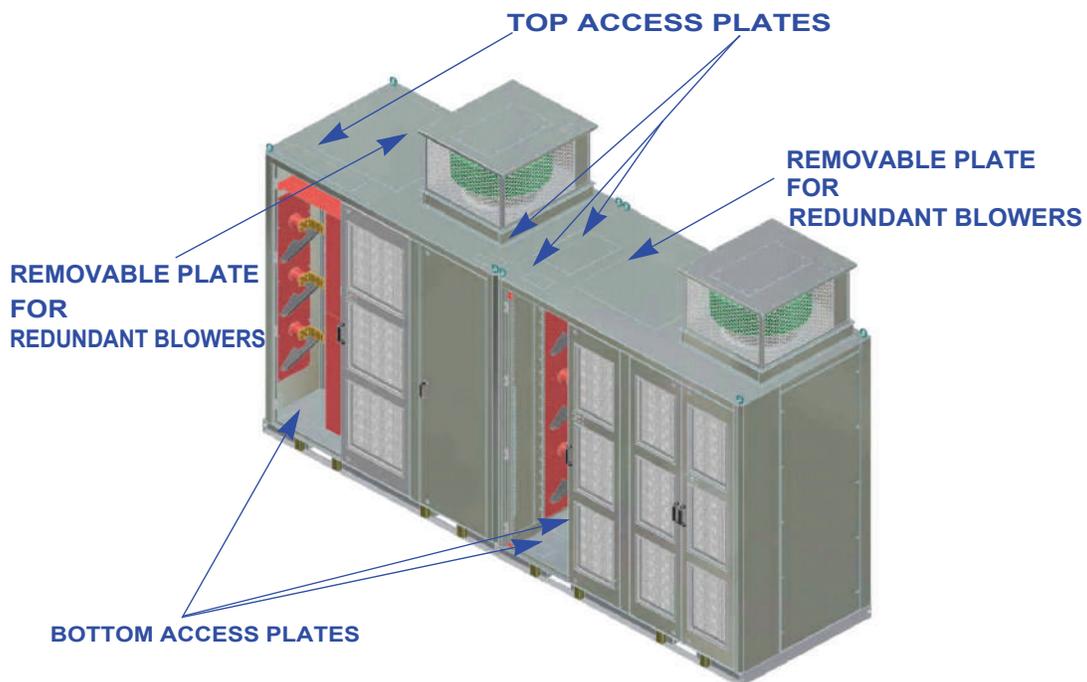
Figure 1-3: GenIV Enclosure (6600V Output, 300-3500 Hp)

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6. Observe the cell control board voltage LEDs by removing the interlock key from the input/output switchgear and opening the Perfect Harmony cell sections door(s).

7. The LEDs are an indication of stored energy within the power cell capacitors (see Figure 1-4). If all cell LEDs are not lit, remove polyglass plates located behind the swing-out control box. Where available, use ancillary AC voltage sensing devices to confirm the drive is de-energized.

8. Apply GREEN/YELLOW insulated ground cables from L1/L2/L3 and T1/T2/T3 to protective earth, P.E., with captive fasteners.

9. Perform maintenance as required.

10. Remove GREEN/YELLOW insulated ground cables from L1/L2/L3 and T1/T2/T3 to protective earth, P.E.

11. Close Perfect Harmony doors in reverse sequence, and replace interlock key into input switchgear.
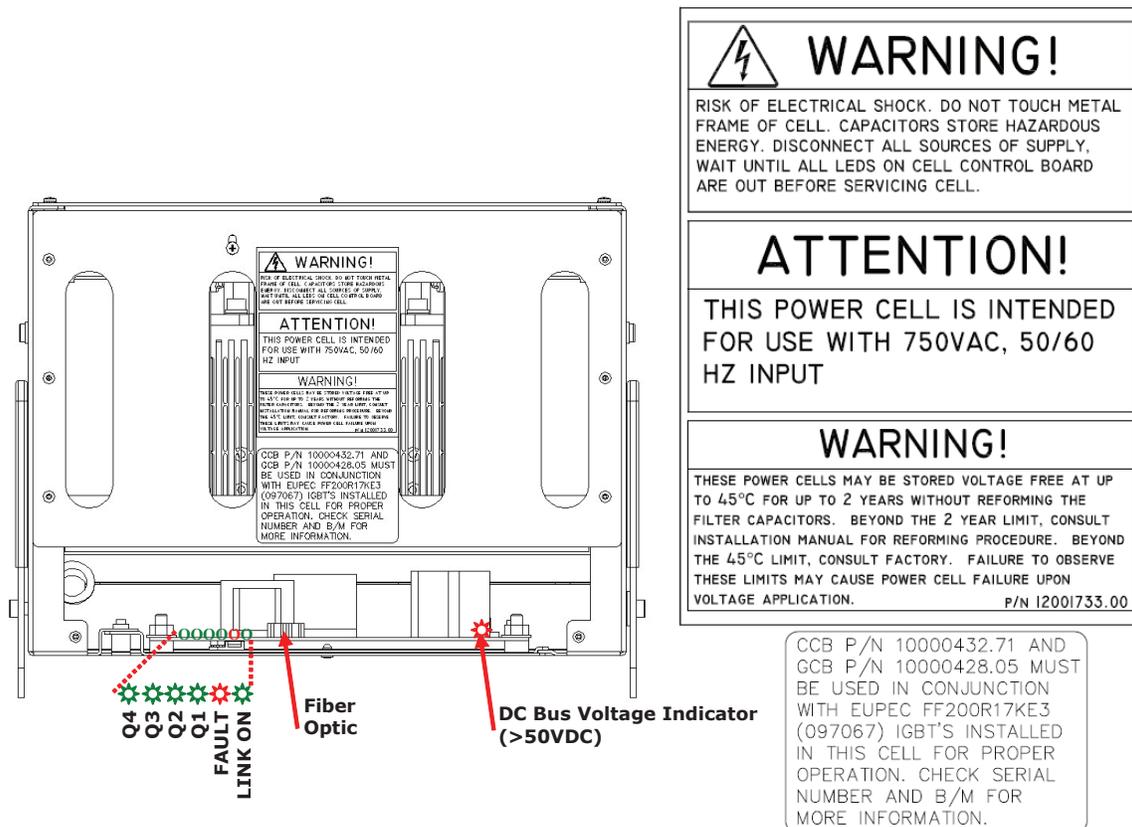
Figure 1-4: Indicators and Labels

Warning! The power cells include discharge resistors to dissipate stored energy after the input voltage is removed. The power cell DC bus voltage decays to less than 50 VDC in less than 5 minutes.

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CHAPTER

2   Installation

☞

> **Notes:**
> - 4160V drives consist of a single cabinet.
> - 6600V drives less than 2000kVA have two cabinets that are normally bolted together without a shipping split.
> - 6600V drives 2000kVA or greater have two cabinets with a shipping split.

⚠

> **Important!**
> Before installing the Perfect Harmony drive, be sure to read and understand the Installation as described in this chapter.

2.1 Installation

When installing Perfect Harmony drives, it is essential to understand the proper techniques associated with the following procedures:

- Receiving
- Shipping splits
- Off-loading
- Weight estimates
- Handling
- Placement and storage
- Anchoring
- Reconnecting wiring

Each of these procedures is discussed in the sections and subsections that follow.

2.2 Receiving

The proper receiving procedure consists of the following steps:

- Verify that the proper items have been shipped.
- Inspect all items for damage that may have occurred during shipping.
- File a claim with the shipping carrier if any damage is present.

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2.3 Shipping Splits

The GenIV has three standard configurations. Refer to Chapter 1of this manual.

4160V Drives with Frame -1 Cell

These drives are shipped in two parts:

- The Blower Assembly, which is shipped on a pallet, includes eyebolts for lifting and installation.

- The remainder of the GenIV drive (refer to Figure 1-1).

4160V Drives with Frame - 2 Cells

These drives are shipped in two parts:

- The Blower and Plenum Assembly, shipped with eyebolts for lifting and installation.

- The remainder of the GenIV drive (refer to Figure 1-2).

6600V Drives - Less Than 2MVa

These drives are shipped as follows:

- Two Blower Assemblies, shipped on pallets, each on pallets, each shipped with eyebolts for lifting and installation.

- The remainder of the GenIV drive (refer to Figure 1-3).

6600V Drives - 2MVa or Greater

These drives are shipped as follows:

- Two Blower Assemblies, shipped on pallets, each on pallets, each shipped with eyebolts for lifting and installation.

- Transformer section

- Cell cabinet.

☞ | **Note:** Cells may be shipped separately in some instances.

The separation point between the transformer and cell cabinet is shown in Figure 2-1.

2
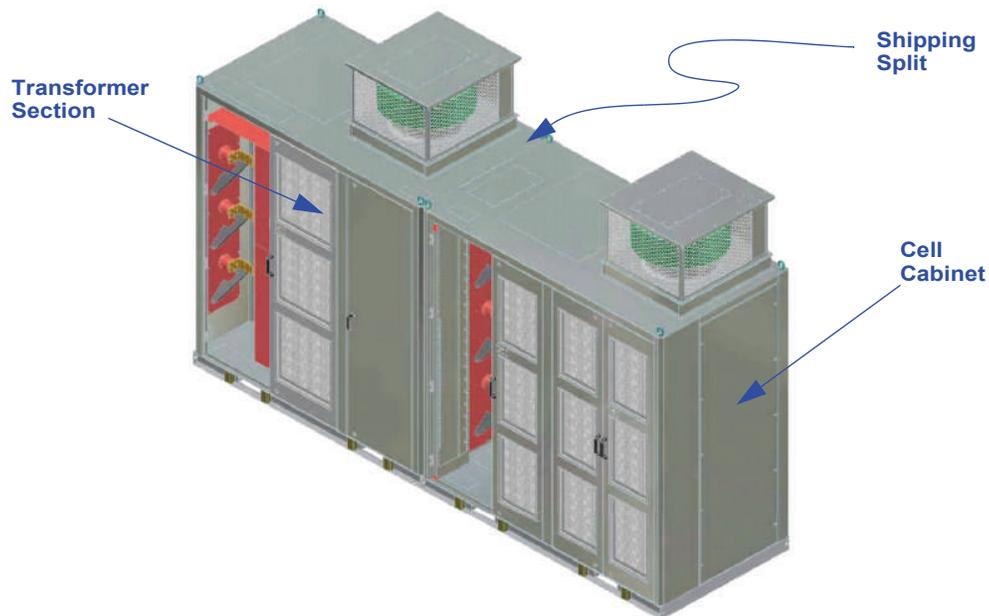
Figure 2-1: 6600V GenIV Drive with Shipping Split

2.4 Off-loading

Due to the size and weight of Perfect Harmony components, it is important to carefully plan all handling operations. Off-loading from the truck is often the most critical operation because of the limited access. Advance planning and coordination among the manufacturer, the carrier, the installation contractor, and the owner are vital. Prior considerations should be made for ceiling heights, door widths, and ease of installation.

> **Danger!**
>
> **Never use eye bolts for lifting any of the Perfect Harmony cabinets.** Eye bolts are used at the beginning of the manufacturing process when the cabinets weigh much less. Drives may be shipped with the eye bolts removed from certain cabinets.

Prior to moving the unit, ensure that:

- The unit doors are closed
- The unit is in an upright position
- The unit is stabilized to prevent tilting
- Each cell's locking latches are tie-wrapped in an upright position

2.5 Weight Estimates

Because the Perfect Harmony drive system is a customizable system, exact weights of systems will vary based on the ratings of the drive and included options. The approximate weights (refer to Table 2-1) of the GenIV core configuration are:

☞ | **Note:** For customized drives that include switchgear or transition cabinets, refer to the project drawings for weight estimates.

Table 2-1: Weight Estimates

Cell Frame Size	Motor Voltage[1]	Hp[2]	Weight (lbs)[3]
1 (40-140 amp)	4160	200	4352
1 (40-140 amp)	4160	300	4890
1 (40-140 amp)	6600	300	6980
1 (40-140 amp)	4160	400	5438
1 (40-140 amp)	6600	400	7330
1 (40-140 amp)	4160	450	5674
1 (40-140 amp)	4160	500	5900
1 (40-140 amp)	6600	500	7580
1 (40-140 amp)	4160	600	6374
1 (40-140 amp)	6600	600	7790
1 (40-140 amp)	4160	700	6760
1 (40-140 amp)	6600	700	8320
1 (40-140 amp)	4160	800	7108
1 (40-140 amp)	6600	800	8530
1 (40-140 amp)	4160	900	7467
1 (40-140 amp)	6600	900	9080
1 (40-140 amp)	4160	1000	7739
1 (40-140 amp)	6600	1000	9530
2 (200-260 amp)	4160	1000	8605
1 (40-140 amp)	4160	1100	7973
2 (200-260 amp)	4160	1250	9380
1 (40-140 amp)	6600	1250	11225
2 (200-260 amp)	4160	1500	10082
1 (40-140 amp)	6600	1500	11575
2 (200-260 amp)	4160	1750	10798
1 (40-140 amp)	6600	1750	13275
2 (200-260 amp)	4160	2000	11353
2 (200-260 amp)	6600	2000	13905
2 (200-260 amp)	4160	2250	11834
2 (200-260 amp)	6600	2250	14925
2 (200-260 amp)	4160	2500[4]	12242
2 (200-260 amp)	6600	2500	15565
2 (200-260 amp)	6600	3000	16685
2 (200-260 amp)	6600	3500	18250

[1]Motor Voltage and Hp will affect cell frame size
[2]Drive Rated Hp
[3]For redundant blower, add 160 lbs and for cell bypass add 75 lbs.
[4]Drive kVA when transformer must support de-rating.

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2.6 Handling

There are four possible methods of handling cabinets:

- Strap and Cradle
- Fork Lift Truck Lifting (4160V or 6600 drives with shipping split)
- Pipe Rollers
- Roller Dollies (4160V drives or 6600V drives with shipping split)

These methods are summarized in this section.

> **Important!**
> - Though lifting options are presented, the final lifting is the liability of those lifting the structures. Care and attention should be used while lifting to monitor the condition of the lift at all times. Low lifting heights and slow movements should be made where possible.
> - The actual lifting process must be monitored continuously. Also, the equipment used must be sized appropriately according to forces to which they will be subjected. This analysis has been prepared without knowing any of the equipment available on site, so tailored lifting descriptions cannot be made.

2.6.1   Overhead Crane Lifting Method Using Slings

If an overhead crane is available, the best method is to pass fabric slings through the base tubes and left as shown in Figure 2-2. The sling must be long enough that the crane hook is at least four feet above the top of the enclosure to prevent buckling of the drive cabinet. If this distance cannot be maintained, spreader bars of appropriate strength must be used. The strength of the sling must be adequate for the weight given in on the drawings, or for the weight estimated using date contained in Table 2-1 of this chapter.

> **Note:** 6600V drives less than 2MVa have an offset center of gravity requiring alternate strap placement. Refer to Figure 2-3

> **Attention!**
> •   Be sure to use slings that are strong enough to support the weight of the drive and long enough to prevent the cabinet from buckling.
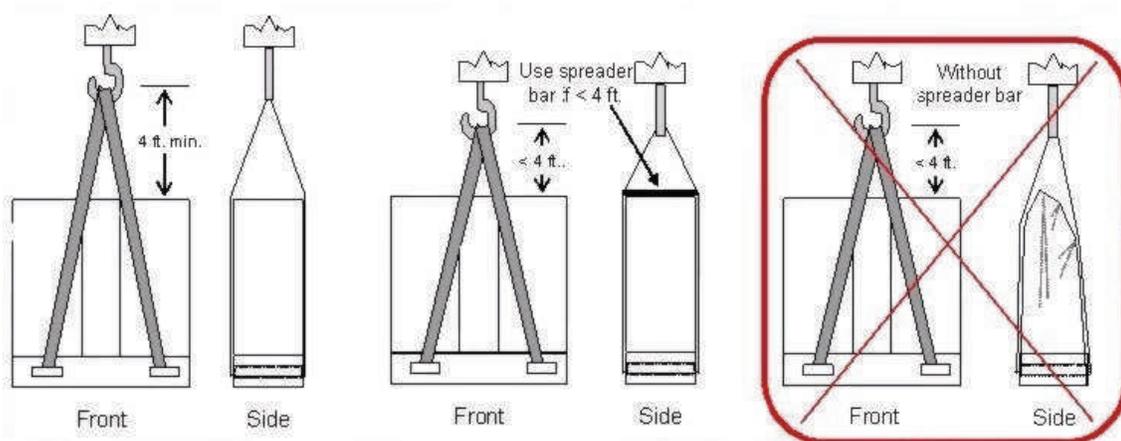
Figure 2-2: Proper Handling Using the Sling Lifting Technique and an Overhead Crane
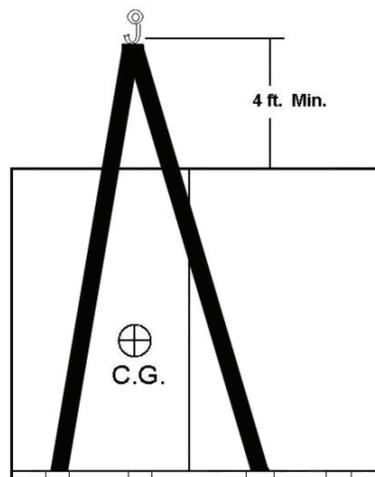
Figure 2-3: Sling Lifting with Offset Center of Gravity

2

Lifting Unit Containing Louvers

When lifting a unit that contains louvers, such as shown in the following photo, the louvers must be protected by placing blocks of wood between the unit and the straps. Two 2-by-4 pieces of wood, encased in bubble wrap, should be wedged between the bottom-front face of the unit and the straps, and two 2-by-4 pieces of wood, encased in bubble wrap, should be placed at the top front face of the unit, above the louvers, between the unit and the straps.

Figure 2-4: Lifting Unit Containing Louvers

2

2.6.2   Forklift Truck

A properly sized forklift truck may be used to lift the drives. The tines of the truck must be at least 40" long and no greater than 10" wide or 2.5" thick. Transformer cabinets will accept tines that are up to 2.75" thick. The tine spacing must be adjustable from 30" to 54".
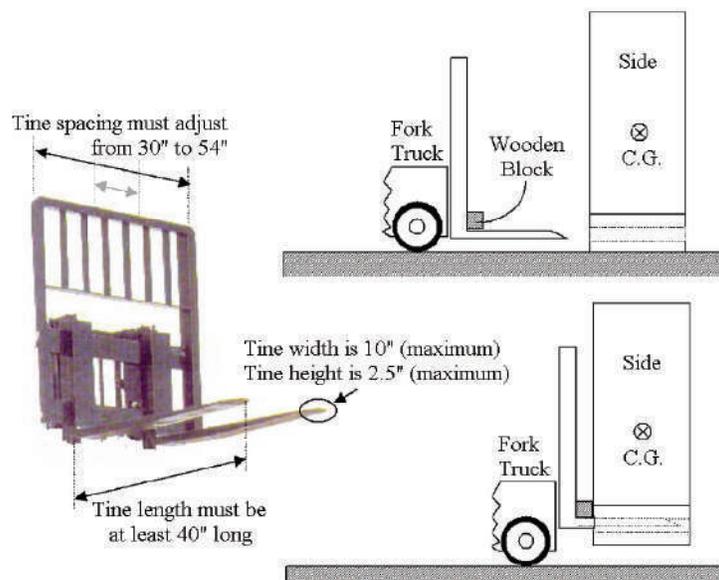
**Figure 2-5: Proper Handling of GenIV Enclosure Using a Fork Lift Truck
(Rear Insertion is Recommended)**

> **Important!**
> - Be sure that the fork truck is appropriately rated for the weight being lifted.
> - Be careful that the forklift does not damage the front surface of the enclosure.
> - It is a good idea to place a wooden stop block in the corner of the tines as shown in Figure 2-5.
> - The center of gravity of the Perfect Harmony enclosure is approximately midway between the front and back surfaces.

2.6.3   Pipe Rollers

The use of pipe rollers is the least preferred method of handling. However, it is possible to set the enclosure on many parallel pipe sections placed on the floor and move it by rolling. The pipes must be no less than 2" in diameter and at least 6" longer than the width of the cabinet (3" on each side). The pipes must be spaced no more than 18" apart. Refer to Figure 2-6.
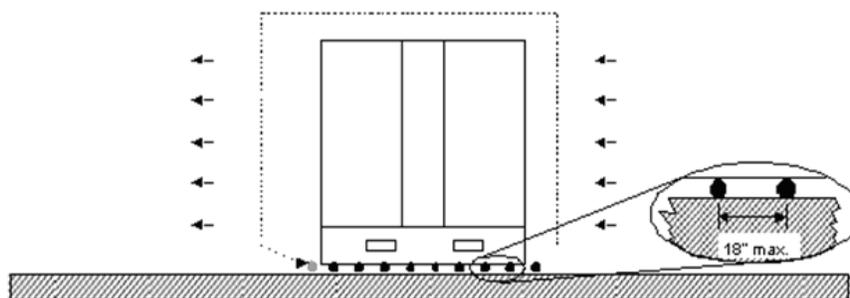
Figure 2-6: Proper Use of Pipe Rollers in Handling Perfect Harmony Cabinets

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2.6.4   Roller Dollies

If roller dollies are used, they should be placed under the front and rear channels of the base, just outside the fork tubes (as shown in Figure 2-7).
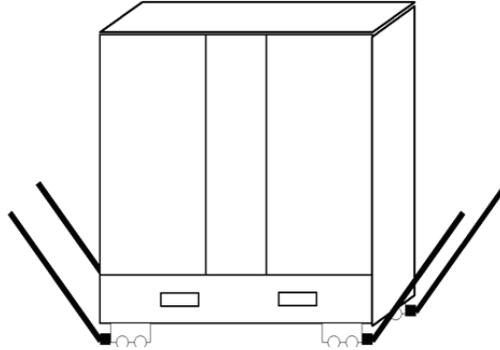
Figure 2-7: Proper Placement of Roller Dollies

⚠ **Warning:** Roller Dollies CANNOT be used for 6600V drives under 2MVa shipped as one section.

2.7 Placement Location and Storage

☞ **Notes:**

- Intake cooling air enters the drive through front-mounted ventilation grilles, and is exhausted through the cage mounted on top of the enclosure. Do not place the drive where the intake/exhaust paths could be blocked.

- Place the drive in a location where the removable access plates interface adequately with the cable termination to the drive.

After final inspection, move the drive promptly to its final position or dry indoor storage area. When choosing the location for the Perfect Harmony drive, be sure the area is clean, flat, dry, and **the front of the drive is easily accessible even when the drive doors are open**. Shims may be necessary to level the cabinet on uneven floors. Avoid extreme temperatures, such as below 0°C or above 55°C; avoid conditions as noted on the shipping labels. If it is necessary to temporarily store the drive in an outdoor area, heaters may be placed in the drive and operated to prevent moisture accumulation. A protective cover such as plastic or a tarp should be placed over the drive to reduce any problems due to the outside elements. This is especially important if the storage is for more than a few days.

⚠ **Warning!**
If the mounting surface is not flat, the metal cabinets of the Perfect Harmony drive may buckle, causing the cabinet doors to be misaligned and/or not open and close properly. Shims may be necessary to level the drive for proper door operation.

⚠ **Warning!**
If a drive is de-energized (or in storage) for 6 months or more, the Harmony cell electrolytic capacitors will need to be reformed. Contact Siemens about reforming procedures for the GenIV. Failure to follow reforming procedures and guidelines may result in cell or system damage.

2.8 Re-Connecting the Shipping Splits

Larger Perfect Harmony drives may be shipped in sections. Tie-bolts are used to connect the individual cabinets to each other. Figure 2-8 illustrates lifting points and cabinet connection points for GenIV drives shipped in two sections. Each section should be bolted to the next to prevent creating air gaps greater than 1/8".

The control wires are connected with plugs. These plugs are located in the front of the drive near the control terminals terminals located to the left of the control box.

Refer to Figure 2-8 for additional detail.

> ⚠️ **Note:** Before using hand tools, tie one end of a string to the tool and the other to your wrist. This will prevent loss of the hand tool if it is accidentally dropped into the drive.

2

2
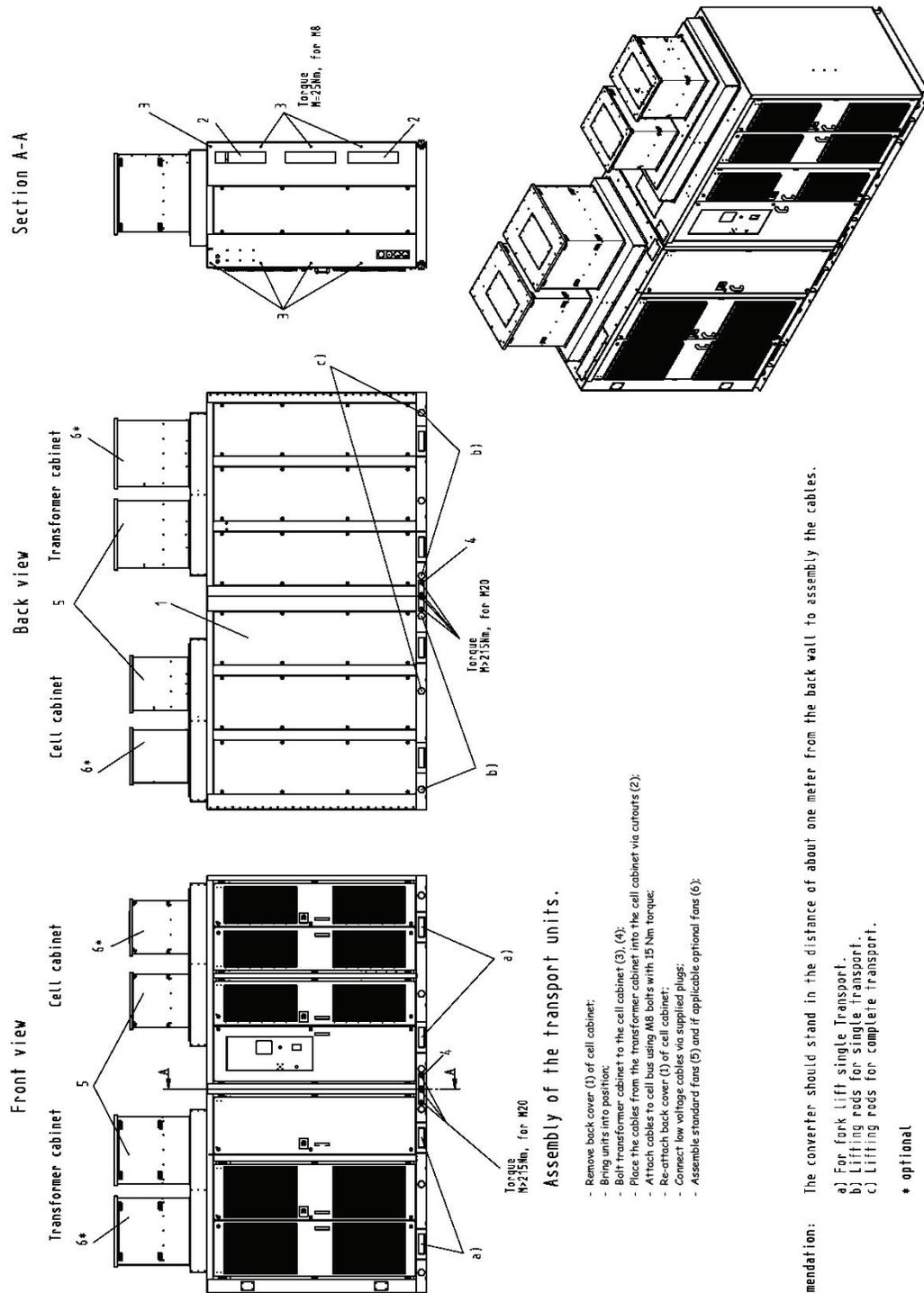
Figure 2-8: 6600V, 2000kVA and Higher Lifting Points and Assembly

2.9 Anchoring Cabinets to Floors and Walls

Holes for anchor bolts are located on the base mounting channel typically 1" from front and back edges, and 4" from the sides. Refer to supplied drawings for mounting details.

When anchoring the cabinets to the floor, we recommend that the installer use cemented J-bars on all corners. Holes in the base of the drive cabinets are 0.81" in diameter and easily accept 0.5" threaded J-bars. If the drive is mounted against a wall, top angles may be used to secure the drive to the back wall in lieu of the rear J-bar connections to the floor. Refer to Figure 2-9 for an overview. Exact dimensions are given in the drawings supplied with the drive.

> ☞ **Note:** Refer to System drawings for the type of base structure used with the cabinet as well as the exact connection locations.
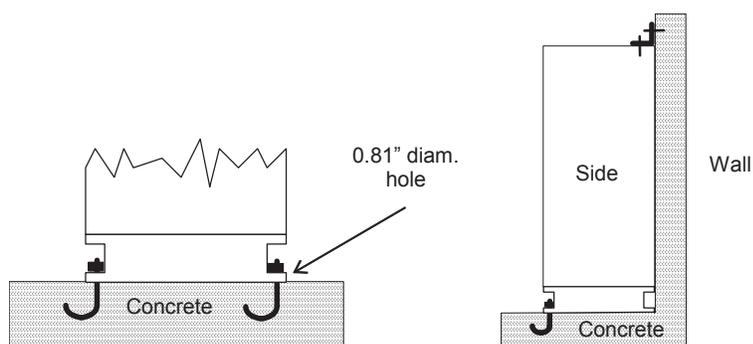
Figure 2-9: Proper Anchoring Technique for Cabinets

> ☞ **Note:** Given the location of the right blower assembly, wall anchoring may require enclosure drilling modifications.

2.10 External Wiring

The transformer has a set of +5%, nominal, -5% voltage taps for compensating the primary voltage source. The GenIV VFD (Variable Frequency Drive) is shipped with the nominal taps connected. This means that the VFD secondary cell voltages are at the nominal 750 VAC (for example) for rated primary input voltage. Customer-supplied medium voltage cables enter an access plate in the top (input/output section) or bottom (transformer section). See Figure 1-1 or project drawings for exact locations.

Customer-supplied low-voltage cables (#8 - #22 AWG) for the control enter an access plate in the top (input/output section) or bottom (transformer section). See Figures 1-1 through 1-3 or project drawings for exact locations.

> ⚡ **Danger!**
> Ensure that the entire system is earth grounded at its P.E. ground point.

> ⚠ **Attention!**
> The transformer primary winding neutral point is designed to operate floating (ungrounded). Do not bond the transformer primary winding neutral point to ground. Failure to adhere to this instruction will cause large, unbalanced currents to circulate in the ground/neutral path of the drive's input source system during drive energization.

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Attention!

To maintain EMC compliance, input medium voltage wiring MUST be installed in metallic electrical conduit and routed through the approved access plates. Customer supplied low voltage I/O cabling #12-#22 AWG MUST be routed separately from power cables / medium voltage cables. Shielded low voltage cables shall maintain shield integrity for the length of the cable including all inter-connections; and, the shield shall be grounded ONLY at the source. Refer to Appendix A of this manual to review EMC Installation Guidelines.

Note: Torque specifications for the Perfect Harmony drive are listed in Table 2-2.

Note: Conductor sizes for input medium voltage termination may vary based on the size of the drive and the dynamics of the system. The customized system schematic (included with your drive) shows the conductor size used on the main transformer taps. The size of the input conductors will usually match or exceed this size. However, be sure to size the input conductors appropriately for your particular application, taking into account the length of the input power feed and your local standards and electrical codes. Labels are applied near the connects recommending the use of 75 °C conductors.

The input and output medium voltage terminals (L1, L2, L3 and T1, T2, T3) are offset from one another and have two NEMA one-hole pattern configurations (vertical and horizontal) to facilitate top or bottom cable termination. MV terminations are provided for 3/8" fasteners.

Note: The GenIV design is best accommodated for single-conductor single-core medium voltage cables. Three-conductor single-core cables **are not recommended** and may require special attention.

Note: Customer should not terminate MV cables at drive output until start of commissioning cycle.

Wire bending space has been allocated for 150 mm^2 (350 mcm) cable (one per terminal) for the MV input/output connections from the top entry.

If the output cable length approaches 7500 feet in length, the drive may require an output filter as described in Chapter 4 of the *GenIV Product User Manual* (A5E01454341C). When output filters are required, the drive voltage is limited as described in Chapter 4 of the *GenIV Product User Manual* (A5E01454341C).

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Table 2-2: Torque Specifications for the Perfect Harmony

Standard Torque Chart		
Fastener Size English (Metric)	Tightening Torque (in-lb)	Metric Equivalent Tightening Torque (N-m)
2-56 (M2)	3.0	0.34
4-40 (M3)	6.0	0.67
6-32 (M3.5)	12.0	1.34
8-32 (M4)	22.0	2.46
10-32 (M5)	36.0	4.03
1/4-20 (M6)	70.0	7.84
1/4-20 (M6) elec	100.0	11.20
1/4-28	70.0	7.84
5/16-18	155.0	12.92
(M8)	80.0	8.96
3/8-16, 3/8-24	275.0	30.80
(M10)	180.0	20.16
1/2-13 (M12)	672.0	75.26
	(lb-ft)	(N-m)
5/8-11	112.0	151.76
3/4-10	198.0	268.29
1	500.0	677.50

2.10.1 Protection Circuits

The input protection and E-Stop circuits described in the *GenIV Product User Manual* (A5E01454341C), Section 4.3.4, should be integrated to the external wire scheme prior to Siemens start-up (commissioning).

2.10.2 I/O External Wiring

Refer to the project drawing C set for the customer I/O connection interface (#12 - #22 AWG). All hardwired I/O cabling should be routed and terminated prior to commissioning.

Caution - Electrical Hazard!
Standard safety precautions and local codes must be followed during installation of external wiring. Protection separation must be kept between extra low voltage (ELV) wiring and any other wiring as specified in the CE safety standard IEC61800-5-1.

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CHAPTER
3   Commissioning

3.1 Pre-Commissioning

3.1.1   Description

Instructions for receiving, off-loading, handling, placement, anchoring, and external wiring, are defined by this manual. The Customer or Customer's Agent is responsible for these tasks.

After the location of the drive has been determined and the drive is in the installed location (including bolting and anchoring of the drive), Siemens can arrive at the site to commence the pre-commissioning process.

3.1.2   Process

1. Obtain site equipment information and verify it matches factory information.

2. Install lockouts and de-energize equipment (see Section 1.4).

3. Torque check the cabinet connections. Inspect the entire drive for shipping and/or installation damage, and verify each cell is properly engaged to its rear bus connectors.

4. Ensure that the enclosure is earth grounded at the P.E. point of the drive. Confirm what type of cable the customer is using for the motor connections. If it is a shielded cable, only one end of the shield can be grounded. It must be grounded at the drive. Inspect MV input cabling and hardwired I/O control wiring.

5. Check and note if the drive integral isolation transformer neutral is grounded. Is transformer neutral grounded? Note "yes" or "no" on form. Ohm check all secondary transformer connections to the chassis cabinet to ensure no damage has occurred during shipment.

> **Note:** Siemens strongly recommends no ground on transformer neutral conductor. However, the transformer iron core is routinely chassis-grounded to the enclosure by Siemens.

6. Inspect customer load.

7. Inspect internal routing of the fiber optic connections and their integrity.

8. Obtain permission to energize.

9. At this time, it is necessary to have an auxiliary control voltage source connected per the VFD schematics to allow the pre-commissioning process to continue. A temporary source can be utilized.

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10. Remove lockouts and energize LV controls.

11. Power is required to test the cooling system and control. Energize auxiliary 120 VAC and 3-phase power to the blowers to verify the rotation and phase sequencing of the cooling fans.

12. Confirm input and output voltage attenuator resistors and output Hall Effect current sensor burden resistors according to project drawings.

> **Note:**
> - The motor leads should not be connected to the drive when performing the following OLTM check.
> - The input MV switchgear should be locked and tagged out prior to OLTM checks in the next step.

13. In OLTM, backfeed the drive with a Variac connected to one of the Harmony transformer secondary windings. Verify all cell and the drive input line voltages are correct.

14. If the VFD has cell bypass, verify contactor operation by removing cell fiber optics at the NXG DCR.

15. De-energize and apply lockouts until start up and commissioning is performed.

16. At the end of the pre-commissioning, a copy of the pre-commissioning report should be left with the responsible site manager.

3.2 Start Up (Commissioning)

1. Initial inspection:

   o Obtain phase sequence of motor

   o Remove lockouts

   o Verify customer has not operated, altered, or energized equipment since pre-commissioning was done by Siemens

   o Verify hardwired I/O per system drawings

   o Ensure blower is running prior to applying input MV

2. Energize MV input with motor disconnected. Leave the power on the drive for at least 1 hour; if possible leave the power on over night.

3. Verify control is working in OLTM as per Table 6-2 in the *NXG Control Manual* (A1A19001588).

4. Where applicable, verify cell bypass on each cell:

   o Remove fiber optic link. Contactor will close.

   o Very all cells bypass correctly.

5. De-energize and apply lockouts. See Section 1.4.

6. Connect motor to VFD output (T1, T2, T3) with proper phase sequence.

7. Remove lockouts and energize VFD.

8. Operate motor at 1% speed and verify proper direction of rotor rotation.

9. Run motor uncoupled from load, and verify speed ranges and feedbacks per Section 6.3, Table 6-3, of the *NXG Control Manual* (A1A19001588).

10. Couple motor and operate according to Section 6.4, Table 6-4, of the *NXG Control Manual* (A1A19001588).

☞ | **Note:** If motor parameters are loaded in parameter list, do not use auto-tune feature. Otherwise, reference Section 6.6.1 of the *NXG Control Manual* (A1A19001588).

11. Complete speed loop and spinning load tuning. See Section 6.6.1 of the *NXG Control Manual* (A1A19001588).

12. Verify DCS address across serial link, and verify DCS operation where applicable.

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13. Establish application manual parameters with customer. See Section 6.7 of the *NXG Control Manual* (A1A19001588).

14. Once system has reached the process design operating condition, utilize Siemens ToolSuite to record the following VFD data:

  o Plant Load At Test Point

  o Voltage VFD Input

  o Current VFD Input

  o Power Factor VFD Input

  o Voltage VFD Output

  o Current VFD Output

  o Speed Demand

  o Motor Speed (RPM)

  o VFD Efficiency

> **Note**: If plant is operated across a load range, take load data at incremental load points to obtain a profile of the VFD operation as part of the process.

15. Complete the cell identification page (Table 3-1) before leaving site.

16. Test spares where applicable

17. Review six-month maintenance procedures with end user, as described in Section 4.2.

18. The commissioning process is now complete. Acquiring customer's signature provides acceptance of the Siemens equipment.

  o Customer's signature (required)

  o Print name

  o Title

  o Company

  o Phone number

  o E-mail address

> **Note**: For output filters, encoders, synchronous motors, synchronous transfer applications, and start-up criteria, refer to Chapter 6 of the *NXG Control Manual* (A1A19001588).

3.2.1 Nomenclature ID

Please record the following information at the end of the commissioning process.

Table 3-1: Customer Drive Nomenclature ID

A5 Serial Number Goes Here _____	A4 Serial Number Goes Here _____	A3 Serial Number Goes Here _____	A2 Serial Number Goes Here _____	A1 Serial Number Goes Here _____
B5 Serial Number Goes Here _____	B4 Serial Number Goes Here _____	B3 Serial Number Goes Here _____	B2 Serial Number Goes Here _____	B1 Serial Number Goes Here _____
C5 Serial Number Goes Here _____	C4 Serial Number Goes Here _____	C3 Serial Number Goes Here _____	C2 Serial Number Goes Here _____	C1 Serial Number Goes Here _____

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4   Maintenance

4.1 General Maintenance

Siemens has designed, built and tested the Perfect Harmony variable speed drive for long, trouble-free service. However, periodic maintenance is required to keep the drive working reliably, to minimize system down time, and to maintain safety.

> **DANGER-ELECTRICAL HAZARD!**
> Always switch off the main input power to the equipment before attempting inspection or maintenance procedure. See Section 1.4 of this manual.

> **Warning:**
> Only qualified service personnel should maintain Perfect Harmony equipment and Systems.

4.2 Six Month Inspection

1. Check operation of fans in the blower assembly:

    o While in operation, listen for audible noises that may indicate that impeller imbalance may be present.

    o De-energize the MV input to the drive (see Section 1.4) and low voltage to the blower.

    o Wipe off any accumulated dust.

    o Verify mounting bolt torque (M10).

    o Inspect electrical connections for stray wire strands or insulation failures.

    o Check that the impeller rotates freely without obstruction.

    o Record any ALARMS issued by the drive. If these alarms are persistent, a Siemens field service engineer can analyze the blowers with OEM software.

2. Use touch-up paint as required on any rusty or exposed parts on the enclosure exterior.

3. For drive internal inspection, contact Siemens about a preventative maintenance service agreement.

4. Verify replacement part stock and contact Siemens for additional spares.

5. Replace door filters on the enclosure (reference Table 4-1 for P/Ns) as described next.

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The front view of the cell door filter during normal operation is as shown in the following photograph:

A. To remove the filter, lift up on the filter retainer until its bottom is free from the door:
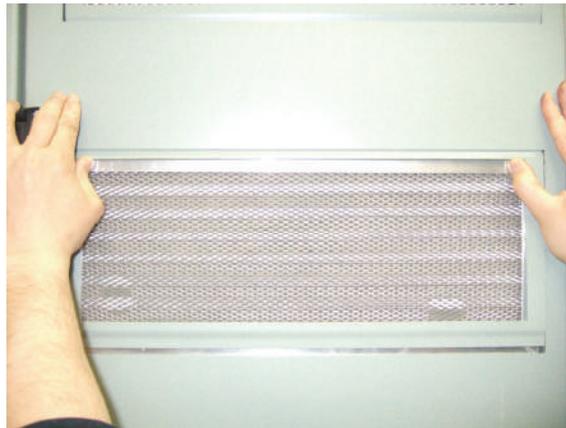
B. Pull out the bottom of the filter retainer, which will release it from the door:
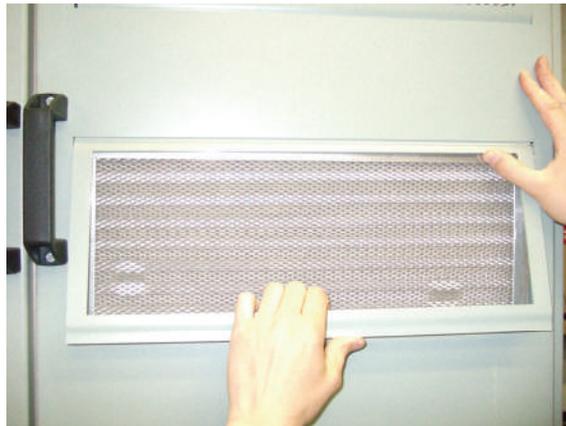
C. Remove the filter and replace it with a spare.

☞ | **Note:** If the filter is removed but not replaced, make sure to use the same orientation upon reinsertion.

⚡ | **DANGER-ELECTRICAL HAZARD!**
The cell door includes partially expanded metal, which holds the filter captive and provides protection against accidental contact with the electrical components.

D. Reverse Steps A and B to reinstall the filter retainer.

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4.3 Replacement of Parts

Replacement of component parts may be the best method of troubleshooting when spare parts are available. When any sub-assembly is to be replaced, always check that the part number of the new unit matches that of the old unit (including the revision letter).

> **Note:** Companion manual *NXG Control Manual* (A1A19001588) includes a Troubleshooting section in Chapter 7.

- Failures traced to individual PC boards within the Control Cabinet are best serviced by replacement of the entire board.

- Failures traced to individual power cells are best serviced by replacement of the entire cell.

> **DANGER!**
> Failure to observe the following may result in severe injury or death:
> PT and CT secondary circuits are capable of generating lethal voltages and currents with their primary circuit energized. Follow standard safety precautions while performing any installation or service work (i.e. removing PT fuses, shorting secondaries, etc.)

> **Attention!**
> The disposal of any failed components (capacitors, etc.) must be done in accordance with local codes and requirements.

4.3.1 Spare Parts List

The following spare parts list is shown for reference and is subject to change without notice. Always contact Siemens about the latest information regarding spare parts.

> **Note:** For spare parts lists for **customized drives**, refer to the custom documentation package shipped with the drive or call Siemens LD A Customer Service Department at (724) 339-9501. When calling for spare parts information, please have your sales order number and drive part number readily available.

Table 4-1: GenIV Spare Parts (for Drives less than or equal to 140A Output, 4160V Output)

Spare Part	Item Part Number			
Power Cell*	40A Cell 10000424.040	70A Cell 10000424.070	100A Cell 10000424.100	140A Cell 10000424.140
Cell CCB Fuse	1000V, 1A Fuse A1A092604			
Cell Input Fuses	Refer to chart in Section			
Transformer Air Filters	Door Filter A1A11006180.01			
Cell Air Filters	Door Filter A1A11006180.00			
NXG	SBC & Keypad Adapter A1A10000623.000M	System I/O Board A1A10000423.00	BGA Modulator A1A10000350.00M	I/O Breakout Board → 120V I/O A5E01649325
	Signal Control Board A1A10000403.01	NXGII Power Supply A1A14000461.00	Keypad A1A460A68.23	24V I/O A5E01649374
Blower Fuses	8A, 600V AJT A1A089149			
Control Transformer Fuse	Secondary 6A, 600V A1A081099			
Control Transformer Fuse	Primary 3A, 600V A1A080752 (480V)	Primary 3.5A, 600V A1A089205 (400V)		
Fiber Optic	Fiber Optic Link, 2.9M A1A10000614.00			
Blower	EC Blower A1A098200 (EBM)			
Cell Bypass	Bypass Contactor A1A10000539.00	Fuse 2A 1200V A1A089592	PCA Bypass Control A1A3636601.01M	Power Supply A1A10000484.00
Communication Network	Profibus DP A1A252241.155	Devicenet Profile12 A1A252241.156	Modbus Ethernet A1A252241.157	Control Net A1A252241.158
	Modbus + A1A252241.159	Modbus A1A252241.160		
	GenIV Cell Lifter A1A163496.08			

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Table 4-2: GenIV Spare Parts (for Drives greater than 140A Output, 4160V Output)

4

Spare Part	Item Part Number			
Power Cell*	200A Cell A1A10000424.200	260A Cell 10000424.260		
Cell CCB Fuse	1000V, 1A Fuse A1A092604			
Cell Input Fuses	Refer to Table 4-4			
Transformer Air Filters	Door Filter (4160V) A1A11006181.01			
Cell Air Filters	Door Filter A1A11006181.00			
NXG	SBC & Keypad Adapter A1A10000623.000M	System I/O Board A1A10000423.00M	BGA Modulator A1A10000350.00M	120V I/O A5E01649325
	Signal Control Board A1A10000403.01M	NXGII Power Supply A1A14000461.00M	Keypad A1A460A26.23	I/O Breakout Board	24V I/O A5E01649374
	Communications Board A1A363818.00M			
Blower Fuses	8A, 600V AJT A1A089149			
Control Transformer Secondary Fuse	6A, 600V A1A081099			
Control Transformer Fuse	480V Primary	3A, 600V, A1A080752	400V Primary	3.5A, 600V A1A089205
Fiber Optic	Fiber Optic Link, 3.4m A5E01437712			
Blower	EC Blower A1A0100118			
Cell Bypass	Bypass Contactor Assembly A1A10000539.00	Fuse 2A 1200V A1A089592	Bypass Control PCA A1A363662.01M	Power Supply A1A10000484.00

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Spare Part	Item Part Number				
Communication Network	Profibus DP A1A252241.155	Devicenet Profile12 A1A252241.156	Modbus Ethernet A1A252241.157		Control Net A1A252241.158
	Modbus + A1A252241.159	Modbus A1A252241.160			
Hall Effect	500A HECT A1A089836				
Input CT	CT 50:5 A1A091705	CT 75:5 A1A091706	CT 100:5 A1A091707	CT 150:5 A1A091708	CT 200:5 A1A091709
	CT 250:5 A1A091710	CT 300:5 A1A091711	CT 400:5 A1A091712	CT 500:5 A1A091713	CT 600:5 A1A091714
Input Attenuator	2.4 kV A1A164877.00	3.0kV A1A164877.01	3.3kV A1A164877.02	4.16kV A1A164877.03	
	4.8 kV A1A164877.04	6.0 kV A1A164877.05	6.6 kV A1A164877.06	6.9 kV A1A164877.07	
	7.2 kV A1A164877.08	8.4 kV A1A164877.09	10.0 kV A1A164877.10	11.0 kV A1A164877.11	
	12.0 kV A1A164877.12	12.5 kV A1A164877.13	13.2 kV A1A164877.14	13.8 kV A1A164877.15	
Output Attenuator	4160V A1A164877.03				
Cell Lifter	GenIV Cell Lifter A1A163496.08				

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Table 4-3: GenIV Spare Parts (for Drives greater than 140A Output, 6600V Output

Spare Part	Item Part Number				
Power Cell*	40A Cell A1A10000424.040	70A Cell A1A10000424.070	100A Cell 10000424.100	140A Cell 10000424.140	200A Cell 10000424.200 · 260A Cell 10000424.260
Cell CCB Fuse	1000V, 1A Fuse A1A092604				
Cell Input Fuses	Refer to Table 4-4				
Transformer Air Filters	Door Filter A5E01679467				
Cell Air Filters	Door Filter (6600V) A5E01679468				
NXGII Control	SBC & Keypad Adapter A1A10000623.000M	System I/O Board A1A10000423.00M	BGA Modulator A1A10000350.00M	I/O Breakout Board	120V I/O A5E01649325
	Signal Control Board A1A10000403.01M	Power Supply A1A14000461.00	Keypad A1A460A26.23		24V I/O A5E01649374
	Communications Board A1A363818.00M		Fiber-Optic Link Board (FOLB) A1A461D85.00M		
Blower Fuses	8A, 600V AJT A1A089149		**OR**	10A, AJT A1A089150	
Blower Circuit Breakers (Optional)	3P, 10A, 600V A5E01459444				
Control Transformer Secondary Fuse	6A, 600V A1A081099				
Control Transformer Fuse	480V Primary	3A, 600V A1A080752		400V Primary	3.5A, 600V A1A089205
Control Transformer Primary Circuit Breaker (Optional)	2P, 3A,480V A1A0101400				
Fiber Optic	Fiber Optic Link, 10m A1A085868				
Blower	60" Transformer Cabinet	EC Blower A1A098200	Cell Section & 80" Transformer Cabinet		EC Blower A1A0100118
Cell Bypass	Bypass Contactor A1A260934.00	Fuse 2A 1200V A1A089592	Bypass Control PCA A1A363662.01M		Bypass Power Supply A1A10000484.00
Communication Network	Profibus DP A1A252241.155	Devicenet Profile12 A1A252241.156	Modbus Ethernet A1A252241.157		Control Net A1A252241.158
	Modbus + A1A252241.159	Modbus A1A252241.160			

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Spare Part	Item Part Number				
Hall Effect	200A, HECT A1A089834			500A, HECT A1A089836	
Input CT	CT 50:5 A1A091705	CT 75:5 A1A091706	CT 100:5 A1A091707	CT 150:5 A1A091708	CT 200:5 A1A091709
	CT 250:5 A1A091710	CT 300:5 A1A091711	CT 400:5 A1A091712	CT 500:5 A1A091713	CT 600:5 A1A091714
Input Attenuator	2.4 kV A1A164877.00	3.0kV A1A164877.01	3.3kV A1A164877.02	4.16kV A1A164877.03	
	4.8 kV A1A164877.04	6.0 kV A1A164877.05	6.6 kV A1A164877.06	6.9 kV A1A164877.07	
	7.2 kV A1A164877.08	8.4 kV A1A164877.09	10.0 kV A1A164877.10	11.0 kV A1A164877.11	
	12.0 kV A1A164877.12	12.5 kV A1A164877.13	13.2 kV A1A164877.14	13.8 kV A1A164877.15	
Output Attenuator	6600V A1A168477.06				
Cell Lifter	GenIV Cell Lifter A1A163496.08				

* Customer may request IGBTs, diode rectifiers, and Cell Control Boards rather than a complete spare cell. Contact Siemens for further information regarding individual cell P/Ns.

☞ **Note:** Unless notified differently by Siemens, ALWAYS replace components with the same P/N and revision level.

4.4 Basic Rules for Repairing Harmony Cells

Cell failures or component failures should be reported to both the Quality Group and Product Development at Siemens.

Always refer to the latest BOM and Assembly Drawings for approved component Part Numbers and procedures when repairing any cell. Failure to use components other than those listed in the BOM may result in poor cell performance or further failures.

⚠ **Warning!** It is imperative to follow these rules for repairing Harmony Cells.

1. Never parallel or series non-identical manufactures part numbers (or Siemens LD A MDIT Numbers) for IGBTs or Electrolytic Capacitors in the same power cell.

2. Never substitute a non-specified CCB/GCB/SMPS board (or any specified component or subassembly) without formal approval from the Product Development Group.

3. Never change an input power fuse(s) without first determining the root cause for the fuse operation. Fuses are not designed to protect components in the Power cell against overload. If a fuse(s) is open, there is

usually a component failure within the cell. Re-application of rated power may cause catastrophic damage. Always inspect the related transformer winding and cell before replacing fuses.

☞ **Note:** In cases where the latest BOM specifies obsolete components and the substitution of an alternative is not available, contact the **Siemens LD A Product Development Group** for assistance. In such events, Product Development may suggest alternative components, only after sufficient technical review and verification.

Refer to Table 4-4 to view which fuses are approved for GenIV use:

Table 4-4: Power Cell Fuses

Power Cell	Rating Volts, Cell Amps Siemens P/N					
	040	**070**	**100**	**140**	**200**	**260**
Bussman	1000V,100A A1A099725	1000,160A A1A099726	1000V, 200A A1A099727	1000V, 250A P/N 099728	1250V, 450A A1A0100500	1100V, 500A A1A0100503
Ferraz	1000V,100A A1A099717	1000,160A A1A099718	1000V, 200A A1A099719	1000V, 250A P/N 099720	1300V, 450A A1A0100502	1200V, 500A A1A0100505
Siba	1000V,125A A1A099721	1000,200A A1A099722	1000V, 225A A1A099723	1000V, 280A P/N 099724	1250V, 450A A1A0100501	1100V, 500A A1A0100504

4.4.1   How To Remove Harmony Power Cells

To Remove the Power Cell:

1. Power down the GenIV System, following the standard shut-down procedure shown in Section 1.4.

2. Open the doors to access the power cells.

3. Make sure that the DC bus LED (labeled "Charge LED" - see Section 1.4), located on the Cell Control Board (CCB), is off. Then wait an extra minute before proceeding.

4. Remove the fiber optic from the CCB as shown below.
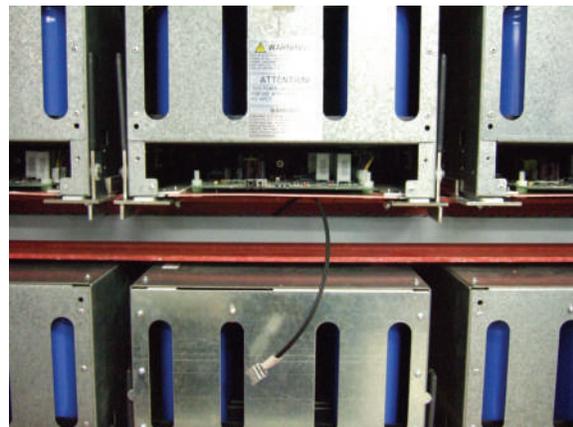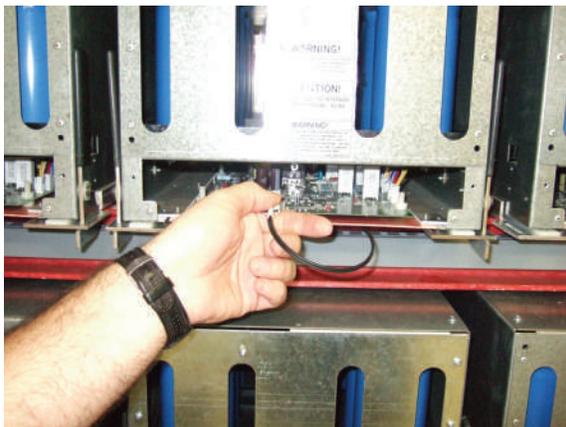
5. Grab the two locking latches and pull down to a horizontal position to release the power cell.

☞ **Note:** When the latches are pulled down to a horizontal position, the power cell will move forward approximately 1/2 inch.

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6. Still holding onto the latches, pull the power cell approximately one-third of the way out of its slot as shown next. Do not lift up or pull down on the cell, but rather let it slide on the polyethylene-coated mounting rails:

7. Using the Siemens cell lifter (Siemens P/N A1A163496.08)out of its slot and onto the lifter, as shown below:
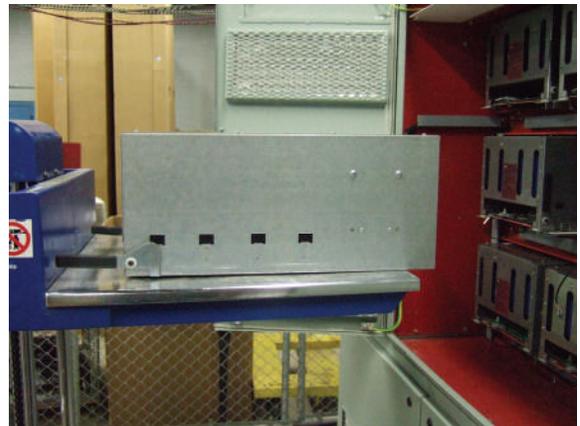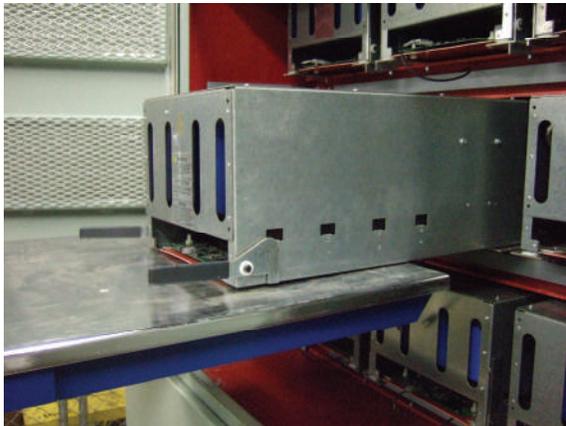
☞   **Note:** It is good practice to not run the system with one of the cells removed.

4.4.2   How to Return the Power Cell to Siemens

To ship the cell back to the factory, it should be packaged as shown below:

Fill bottom of box with Instapak sealed air foam in bag packaging material.

Place cell into box on top of foam. Be sure that the locking latches are pointed up.

Fill sides and top with Instapak sealed air foam packaging material. Before cooling, close box lid to form top. Check for air pockets and fill as needed. Seal box and ship.

4.4.3   How to Install Harmony Power Cells

To Install the Power Cell:

1.   Using the Siemens cell lifter (P/N A1A163496.08), line up the power cell with its slot.

2.   Push the cell into its slot. Do not lift up on the cell, but instead let it slide in on the polyethylene-coated mounting rails.

3.   Make make sure that the cell latches are above the ledge of the cell rail, and align the locking latches with the corresponding rail notches, as shown below:
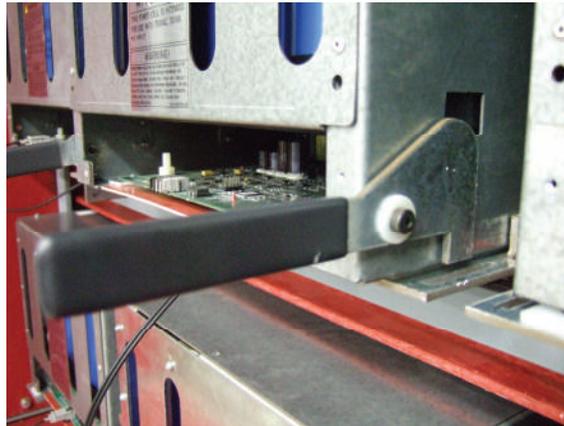
4. Push up on the latches until they are vertical:
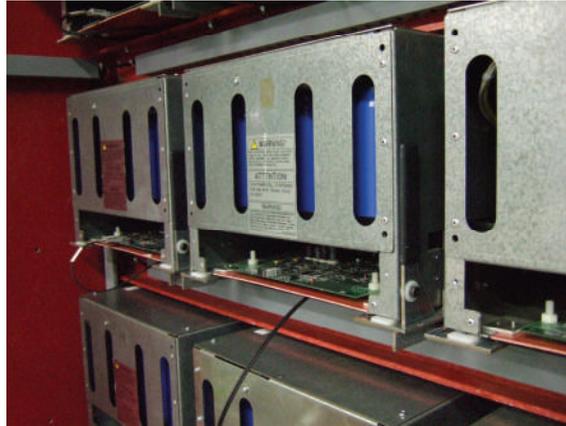
5. Reinstall the Fiber Optic:
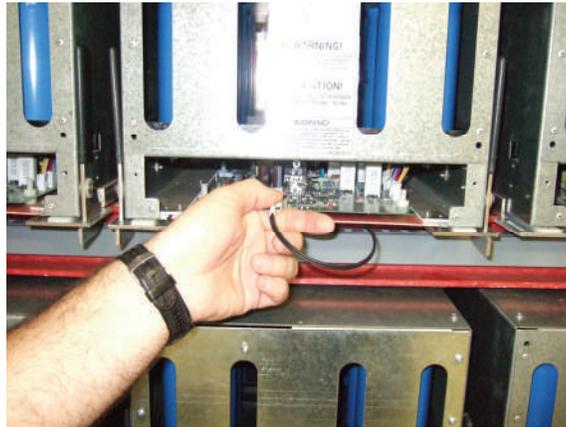
4.5 General Repair Hints and Procedures

1. Input fuse(s) or control fuse(s) opening is almost always an indication of component failure in a cell.

2. Damage to the cell chassis ground wire is always an indication of an insulation failure internal to the power circuit or its components, or the result of arcing between the power circuit and chassis. Always perform the appropriate HIPOT test or look for arc damage before re-using the subject cell.

3. An electrolytic capacitor failure that results in venting, bulging, or header expulsion, is usually caused by sustained over-voltage of 15 to 20% above its operating voltage rating.

4. If one or more electrolytic capacitors have failed, but only in a particular parallel group, and there this no indication of other component damage, look for a shorted or high leakage capacitor in the other parallel groups.

5. If capacitor damage is apparent in all parallel groups and if there is damage to the IGBTs or CCB, the cell was most likely exposed to over-voltage. Furthermore, failed input fuses may indicate that an over-voltage was generated from the transformer secondary.

6. An IGBT failure is usually a result of an over-voltage because the cell has system level over-current protection.

    In **non-catastrophic IGBT failures** (those which do not result in case rupture), the root cause can often be found by Product Development or the device manufacturer if the devices are returned for analysis. In most of these cases, the GCG and CCB are left unaffected and can be presumed functional.

    In **catastrophic IGBT failures** (those which result in case rupture), the root cause is more difficult to determine. Failures of this type usually result in collateral damage to adjacent IGBTs, especially those IGBTs in the same pole (for instance Q1/Q2 or Q3/Q4). These failures almost always cause damage to any connected GCB and CCB.

7. The following tests can be performed by qualified personnel to verify an IGBT's condition after a cell failure:

    G-E Check
    Short the collector to the emitter. Ohm check gate to emitter. Resistance should be 10M to infinite. A low resistance indicates device destruction. Device must be replaced.

    C-E Check
    Short the gate to the emitter. Ohm check collector to emitter. Resistance should be 10M to infinite. A low resistance indicates device destruction. Device must be replaced.

    A-K Check
    Use a diode checker to verify a small positive voltage drop (<1V) from emitter to collector (anode to cathode of the FWD) and blocking from collector to emitter (cathode to anode of the FWD). If a short, or if >1V is measured, the device must be replaced.

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A

A   EMC Wiring Installation Guidelines

A.1 General

These guidelines cover the basic points to be considered when installing a motor drive to achieve minimum Radio Frequency Interference (achieving Electromagnetic Compatibility, EMC). For motor drives, there are four key areas to be covered: Earthing, Screening, Filtering, and Wiring. Refer to Figure A-1.
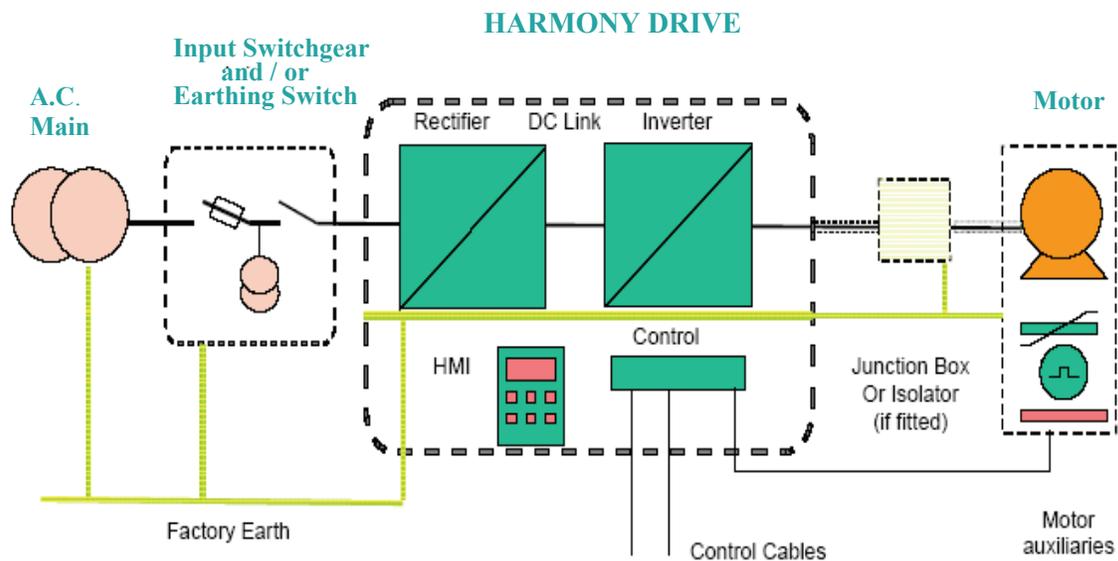
Figure A-1: Harmony Drive Installation to Achieve EMC

A.2 Key Areas for Consideration

A.2.1   Earthing

The Harmony series drive provides Customer grounding connections for PE (Protective Earth) identified by the symbol ⏚. The grounding connections are provided adjacent to each Power Input and Output connection terminals. All sections of the Drives are interconnected internally and identified by Green/Yellow conductors or Black conductors with Green and Yellow tape. Keep all ground connections as short as physically possible. Follow all local safety regulations with regard to earthing. All points with regard to low impedance earthing should be checked as part of the routine service or the maintenance checks.

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A.2.2   Screening

The purpose of screenings is to prevent any unwanted electromagnetic radiation escaping, or entering, a system. This implies that screening must be part of the cabinets or the enclosures as well as the connecting Input and Output cables. The Harmony Drive with switching elements and Microprocessor Clock frequencies are the main source of interference. The Siemens Harmony series have been engineered and tested such that the enclosures provide an effective "Faraday Cage". It is also necessary that the cables for the Input Main Power and Control Power to the Drive and the Output from the drive to the motor be screened; this for EMC and for mechanical reasons. The motor housing itself is a solid, effective EMC screen. The three screens – cabinet, cable screen, motor housing – must be connected together to effectively form one screen. To achieve the above, it shall be clear that no interruptions in the cable screen are permitted. The connections in the screening system must be designed to have low impedance in the Megahertz range. The use of special connectors for this purpose is recommended.

A.2.3   Filtering

When CE is specified, the Harmony series are fitted with internal EMC Filters. These EMC Filters are mostly used on the customer's Control power input. Siemens Engineering has selected the most appropriate EMC Filter based on the customer's input control voltage and current requirements. The only precautions that must be taken is that the Customer's Input Control Power connections must be in metallic tubing or flexible metallic tubing and must not be too long or come in close contact with the internal EMC Filter which has been pre-wired at the factory.

A.2.4   Wiring

Control Wiring - The control interfaces to a PDS are at least as important as the power connections. The control cabling is a part of the Faraday Cage as described in the section on screening.

  • Recommendations are to use shielded cables for all Analog and Digital control connections. As an alternate to shielded cables, twisted pairs are also effective if shielded cables are not used.

  • Analog signals and very low voltage digital I/O signals should always be made in twisted pairs, with the twist carried as close as possible to the appropriate terminals. If possible, avoid the use of a common return for different analog signals.

  • Digital Signals - Always separate digital and analogue signals. Never mix 110/230 V digital signals in the same cable as 24 V DC signals. A conventional screened or armored cable can be used for 110/230 V signals.

  • Double-shielded cables will give the best performance.

  • Control and signal cables must be separated from power cables.

  • Route control cables in separate cable trunks at least 200 mm (8") away from motor and power cables.

  • Where control cables must cross power cables, this should be done with angle as near to 90 degrees as possible. Refer to Figure A-2.

Serial Communications Signals - The appropriate cable will depend on the carrier medium, be it RS 232, RS 485, Ethernet, etc. Follow the system recommendations.

Ecoder Cables - Pulse encoders may be galvanically connected to the motor rotor; it is important that any bearing insulation is not bridged. The recommendations of the encoder and drive supplier should always be strictly followed. The correct cable type is also essential. It is also preferable to ensure that the cable run from the encoder is a continuous length and not interrupted by screw terminals.

I/O Breakout Board – This is a custom board created by Siemens for the Harmony series and general guidelines on control wiring should be followed.
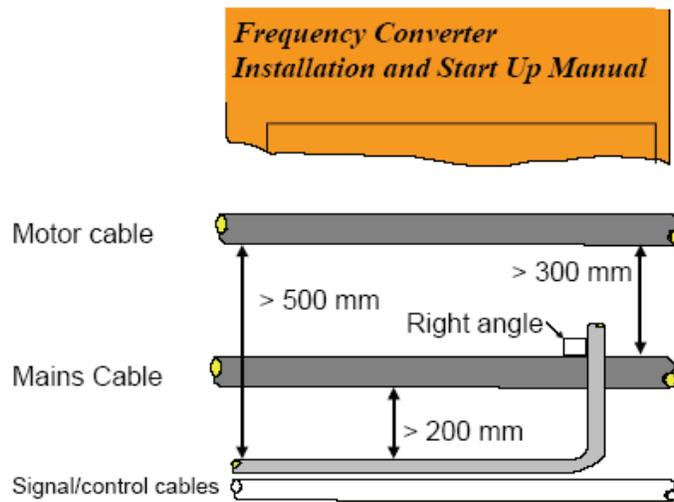
Figure A-2: Recommended Cable Segregation

Power Wiring - Many armored power cables are extremely intractable and difficult to bend; therefore allowing adequate bending radii is always important. In drive installations the armoring also forms an essential part of the electrical screening and the minimum bending radii detailed by the manufacturer must always be observed to prevent the wire armor spreading thus leaving slots to radiate HF emissions.

·   No other cables, neither power cables nor data/signal cables, should be included within the motor cable screen. Very high levels of electrical noise will be induced into such cables. Although it is possible to accommodate this by careful management, it is not recommended for general use.

·   Whenever screened cables are used, it is essential that they are "properly" glanded and terminated, that the screen/armor makes contact through 360 degrees to the gland and also that the gland is circumferentially grounded to the gland plate and to the main earth terminations.

For a complete guideline on EMC installation, please visit the Gambica website at:

http://www.gambica.org.uk/ and download the **VARIABLE SPEED DRIVES AND MOTORS – INSTALLATION GUIDELINES FOR POWER DRIVE SYSTEMS – USER GUIDE NO. 3** from the Publications Link.

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To assure timely technical updates on your equipment, please complete and return this form. This information is to be completed by the end user or equipment owner. For information on post sale service solutions, please check the appropriate boxes below before returning this form to **Siemens Energy & Automation,Inc.**

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E-mail	
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Sales Order Number (SO #) (see system door or system panel)	
Start-up Date	
Start-up Completed by	

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- Spare Parts Kits   ❒

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New Kensington, PA 15068

USA

SECTION 4

<u>**NXG CONTROL MANUAL**</u>
<u>**MANUAL NO. A1A19001588**</u>

Customer Name: PXP INC., Customers P.O.: **IR 68898 KK ALT1**
Project Name: PXP – IRENE 600HP, Siemens S.O. No.: 3001789510
Air Cooled Perfect Harmony Series, Adjustable Speed, AC Motor Drive
System Part Nos.: A5E02318880, A5E02320163 and A5E02320164

Siemens Energy & Automation, Inc. regrets that because of product liability issues, **edited, incomplete manuals may not be furnished**. Once the equipment is shipped from Siemens Energy & Automation, Inc., its ultimate application is outside of Siemens Energy & Automation, Inc. control, and allowance must be made for the possibility that the VFDs may be applied in ways that are not currently part of this contract. (For example, the Owner at some later date would decide to remove a VFD from service then sell it with its documentation.) To guard against the possibility of misapplication or misuse (and any possible attendant risk of injury) in the future, Siemens Energy & Automation, Inc. requires that "*complete*" User/Operation and Maintenance Manuals "must" be provided.

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NXG
CONTROL MANUAL

Manual Number: A1A19001588
Version 2.0
June 2007

Siemens Energy & Automation, Inc.

Large Drives A

This manual applies to all Perfect Harmony adjustable-speed AC motor drives.

This manual applies to NXG software up to and including version 3.1

For the support representative nearest you, please call Siemens main office at 724.339.9500.

Version History

Version 1.0 (original)	January 2007
Version 2.0 (12288)	June 2007

DECLARATION OF CONFORMITY

Manufacturer's Name:	SIEMENS ENERGY & AUTOMATION LD- A
Manufacturer's Address:	500 Hunt Valley Drive New Kensington, PA 15068 USA

declares that the product:

Product Name:	AC Variable Frequency Drives, WCIII , Liquid cooled Perfect Harmony Series, (Product models (3100XXXX.XX)
Product Description:	6,000 HP to 19,000 HP Input: 2.4 kV to 13.8 kV, 50Hz/60Hz, Output: 2.4 kV to 7.2 kV. Cells sizes 800 Amps and 1200 Amps, 50Hz/60Hz

Supplementary Information:

Directives and Standards:

The products herewith comply with the requirements of the **Low Voltage Directive 73/23/EEC** (as amended) and the **EMC Directive 89/336/EEC**

LVD Safety Standards: The product listed above conforms to IEC Standard IEC 61800-5-1 and Normative References including IEC 60529, IEC 61800-4, IEC60076-11, and IEC 60417.

EMC Directive and Standard: Siemens LD-A certifies that the apparatus to which this Declaration of Conformity relates conforms to the protection requirements of **Council Directive 89/336/EEC** on the approximation of the Laws of the Member States relating to electromagnetic compatibility. Testing performed under **IEC 61800-3:2004-8**.

Washington Labs, Ltd, Gaithersburg, Maryland, USA. Competent Body Assessment # SIM 9681/CBC and SIM9681/CBR dated April 7, 2007

Name: Tom Bierman, Director of Quality Signature:	Technical documentation holder: Ray Tomer, Staff Compliance Engineer
	ray.tomer@siemens.com

Perfect Harmony is a trademark of Siemens Energy & Automation

Date of issue: February 28, 2007

DECLARATION OF CONFORMITY

CE

Manufacturer's Name:	SIEMENS ENERGY & AUTOMATION LD- A
Manufacturer's Address:	500 Hunt Valley Drive New Kensington, PA 15068 USA

declares that the product:

Product Name:	AC Variable Frequency Drives, GenIV, Air cooled Perfect Harmony Series, (Product models (3100XXXX.XX)
Product Description:	200 HP to 1,100 HP Input: 2.4 kV to 13.8 kV, 50Hz/60Hz, Output: 2.4 kV to 7.2 kV. Cells sizes 40 Amps, 70 Amps, 100 Amps and 140 Amps, 50Hz/60Hz

Supplementary Information:

Directives and Standards:

The products herewith comply with the requirements of the **Low Voltage Directive 73/23/EEC** (as amended) and the **EMC Directive 89/336/EEC**

LVD Safety Standards: The product listed above conforms to IEC Standard IEC 61800-5-1 and Normative References including IEC 60529, IEC 61800-4, IEC60076-11, and IEC 60417.

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Name: Tom Bierman, Director of Quality
Signature:

Technical documentation holder:
Ray Tomer, Staff Compliance Engineer

ray.tomer@siemens.com

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Date of issue: February 28, 2007

Siemens Energy & Automation LD-A:	**Phone: 724-339-9500** **Fax: 724-339-8100**	**Customer Support Phone: 724-339-9501** **Customer Support Fax: 724-339-9507**

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Safety Precautions and Warnings

Perfect Harmony drives are designed with considerable thought to personal safety. However, as with any piece of high power equipment, there are numerous internal connections that present potentially lethal voltages. In addition, some internal components are thermally hot to the touch. Follow the warnings below when working in or near the Perfect Harmony System.

Danger - Electrical Hazards!
- **Always** follow the proper lock-out/tag-out procedures before beginning any maintenance or troubleshooting work on the drive.
- **Always** follow standard safety precautions and local codes during installation of external wiring. Protective separation must be kept between extra low voltage (ELV) wiring and any other wiring as specified in IEC61800-5-1.
- **Always** work with one hand, wear insulated or rubber safety shoes, and wear safety glasses. Also, always work with another person present.
- **Always** use extreme caution when handling or measuring components that are inside the enclosure. Be careful to prevent meter leads from shorting together or from touching other terminals.
- **Use** only instrumentation (e.g., meters, oscilloscopes, etc.) intended for high voltage measurements (that is, isolation is provided inside the instrument, not provided by isolating the chassis ground of the instrument).
- **Never** assume that switching off the input disconnect will remove all voltage from internal components. Voltage is still present on the terminals of the input disconnect. Also, there may be voltages present that are applied from other external sources.
- **Never** touch anything within the Perfect Harmony cabinets until verifying that it is neither thermally hot nor electrically alive.
- **Never** remove safety shields (marked with a HIGH VOLTAGE sign) or attempt to measure points beneath the shields.
- **Never** run the drive with cabinet doors open. The only exception is the control cabinet which contains extra low voltages (ELV).
- **Never** connect any grounded (i.e., non-isolated) meters or oscilloscopes to the Perfect Harmony system.
- **Never** connect or disconnect any meters, wiring, or printed circuit boards while the drive is energized.
- **Never** defeat the instrument's grounding.
- **Only** qualified individuals should install, operate, troubleshoot, and maintain this drive. A qualified individual is "one familiar with the construction and operation of the equipment and the hazards involved."
- **Hazardous voltages** may still exist within the Perfect Harmony cabinets even when the disconnect switch is open (off) and the supply power is shut off.

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Warning!
- **Always** comply with local codes and requirements if disposal of failed components is necessary (for example, CPU battery, capacitors, etc.).
- **Always** ensure the use of an even and flat truck bed to transport the Perfect Harmony drive system. Before unloading, be sure that the concrete pad is level for storage and permanent positioning.
- **Always** confirm proper tonnage ratings of cranes, cables, and hooks when lifting the drive system. Dropping the cabinet or lowering it too quickly could damage the unit.
- **Never** disconnect control power while medium voltage is energized. This could cause severe system overheating and/or damage.
- **Never** store flammable material in, on, or near the drive enclosure. This includes equipment drawings and manuals.
- **Never** use fork trucks to lift cabinets that are not equipped with lifting tubes. Be sure that the fork truck tines fit the lifting tubes properly and are the appropriate length.
- **Always** confirm proper parameter settings. The drive will not work properly if relevant parameters are not set correctly.

ESD Sensitive Equipment!
- Always be aware of electrostatic discharge (ESD) when working near or touching components inside the Perfect Harmony cabinet. The printed circuit boards contain components that are sensitive to static electricity. Handling and servicing of components that are sensitive to ESD should be done only by qualified personnel and only after reading and understanding proper ESD techniques. The following ESD guidelines should be followed. Following these rules can greatly reduce the possibility of ESD damage to PC board components.
- Always transport static sensitive equipment in antistatic bags.
- Always use a soldering iron that has a grounded tip. Also, use either a metallic vacuum-style plunger or copper braid when desoldering.
- Make certain that anyone handling the Perfect Harmony printed circuit boards is wearing a properly grounded static strap. The wrist strap should be connected to ground through a 1 megohm resistor. Grounding kits are available commercially through most electronic wholesalers.
- Static charge buildup can be removed from a conductive object by touching the object to a properly grounded piece of metal.
- When handling a PC board, always hold the card by its edges.
- Do not slide printed circuit boards across any surface (e.g., a table or work bench). If possible, perform PCB maintenance at a workstation that has a conductive covering that is grounded through a 1 megohm resistor. If a conductive tabletop cover is unavailable, a clean steel or aluminum tabletop is an excellent substitute.
- Avoid plastic, Styrofoam™, vinyl and other non-conductive materials. They are excellent static generators and do not give up their charge easily.
- When returning components to Siemens LD A, always use static-safe packing. This limits any further component damage due to ESD.

Additional safety precautions and warnings appear throughout this manual. These important messages should be followed to reduce the risk of personal injury or equipment damage.

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About This Manual

Separation of Manuals

This manual is one component in a series of manuals intended for use with the Perfect Harmony series of adjustable speed AC motor drives. Each part in this series is for use by individuals having unique job functions and qualifications. The manuals in this series are listed below:

- *NXG Control Manual* (Manual Number: 19001588)

- *NXG Communications Manual* (Manual Number: 902399)

- *NXG ToolSuite User Manual* (Manual Number: 902291)

- *Fault Reference for Harmony NXG* (Manual Number: 19000864)

The *NXG Control Manual* describes the NXG Control interface, applications, troubleshooting, maintenance, and system programming.

The *NXG Communications Manual* describes the communication board that enables network communication via a variety of protocols, and enables modem connection. The system supports up to two networks. Only the Modbus and Ethernet Modbus protocols are enabled with the communication board alone. All others require optional controller cards, called UCS modules or AnyBus modules, which plug into the communication board.

NXG ToolSuite User Manual describes the NXG ToolSuite, which is a PC-based application that integrates various software tools used for NXG based drives. With the ToolSuite, the operator can navigate through a drive's features using a PC and a mouse or touch screen, which makes the ToolSuite more convenient to use than a keypad. The NXG ToolSuite is a high-level GUI that runs on a PC equipped with the Microsoft Windows operating system.

The *Fault Reference for Harmony NXG Manual* describes the NXG faults, their causes, and corrective actions.

All manuals in this series contain a reader's comments form. Please complete this form and return it to us. Monitoring your feedback allows us to continue to exceed your expectations and provide complete, effective, easy-to-use product documentation.

Reference Tools

Many steps have been taken to promote the use of this manual as a reference tool. Reference tools include the following:

- A thorough table of contents for locating particular sections or subsections

- Chapter number thumb nails in the outer margins for easy location of chapters

- Special text styles are applied to easily differentiate between chapters, sections, subsections, regular text, parameter names, software flags and variables, and test points

- A comprehensive index

If you have any comments or suggestions to improve the organization or increase the usability of this manual, please complete the Reader's Comments Form located at the end of this manual and return it to Siemens LD A Document Control.

Conventions Used in this Manual

The following conventions are used throughout this manual:

- The terms "Perfect Harmony," "VFD," "variable frequency drive," and "drive" are used interchangeably throughout this manual.

Note: Hand icons in the left margin alert readers to important operational or application information that may have special significance. The associated text is enclosed in a border for high visibility.

Attention! Attention icons in the left margin alert readers to important safety and operational precautions. These notes warn readers of potential problems that could cause equipment damage or personal injury. The associated text is enclosed in a border for high visibility.

Caution - Electrical Hazard! Electrical hazard icons in the outer margins alert readers to important safety and operational precautions. These notes warn readers of dangerous voltages, potential safety hazards, or shock risks that could be life threatening. The associated text is enclosed in a border for high visibility.

ESD Warning! These icons in the left margin alert readers to static sensitive devices. Proper electrostatic discharge precautions should be taken before proceeding or handling the equipment.

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1 Overview

The Robicon Perfect Harmony series of Medium Voltage (MV) Pulse Width Modulated (PWM), Variable Frequency Drives (VFD) are designed and manufactured by Siemens LD A in New Kensington, PA, USA, with additional manufacturing facilities in Europe, Asia, and South America. The Harmony VFD is intended for use with standard and special three phase AC induction Motors (IM), and Synchronous Motors (SM). These motors were typically line started by means of a contactor or soft-starter and run at a single speed, based on the supplied frequency. The Harmony VFD allows these motors to run at variable speeds while maintaining the desirable properties of the motor over the full speed range.

The Harmony VFD adds many capabilities to these motors that could not be accomplished with a line connection: features such as synchronous transfer of the motor both to and from the line, Dual frequency breaking, Four Quadrant control (with specially equipped cells), output filters, long cable connections, torque mode, etc. to handle a wide range of applications not possible with line connected motors.

The Harmony series drives come in a wide range of power and size, and are available with air or water cooling, but all maintain a common control system. The NXG control is the second generation of control for these drives, adding a variety of new features not found on the original control. The NXG II control, also covered in this manual, adds additional features and capabilities.

1.1 Purpose

This manual covers many of the features of the Harmony drive in a generic fashion as it relates to the power platform. Specific configurations of the drive family are described in more detail in the specific product manuals pertaining to that hardware configuration. Detailed descriptions of the common features of the Harmony drive family are defined in the following manuals:

- *GenIV Product Manual* (19001591)

- *WCIII Product Manual* (19001590)

- *HV Product Manual* (19001751)

- *NXG Communications Manual* (902399)

- *NXG ToolSuite Manual* (902291)

1.2 Introduction to the Perfect Harmony

Perfect Harmony is a series of pulse-width modulated (PWM), variable frequency AC motor drives designed and manufactured by Siemens. The Perfect Harmony drive system provides the following to address power quality issues:

- Clean power input

- High power factor, nearly perfect sinusoidal input currents

- Nearly perfect sinusoidal output

- Four quadrant control on specially equipped drives

- Parallel drive operation on select drive applications from a systems control perspective (only the external control and power connections differ from a standard drive)

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1.2.1   Clean Power Input

The Perfect Harmony drive series meets the most stringent IEEE 519-1992 requirements for voltage and current harmonic distortion, even if the source capacity is no larger than the drive rating. This series protects other on-line equipment (such as computers, telephones, and lighting ballasts) from harmonic disturbances. Perfect Harmony also prevents "cross talk" with other variable speed drives. Clean power input eliminates the need for time-consuming harmonic/resonance analyses and costly harmonic filters. Figure 1-1 illustrates harmonic distortion waveforms for a typical 6-pulse, 12-pulse and Perfect Harmony series drive.

Source Current

Source Current

Source Current

Source Voltage

Source Voltage

Source Voltage

Typical 6-pulse
Input Waveform

Typical 12-pulse
Input Waveform

Perfect Harmony Series
Input Waveform
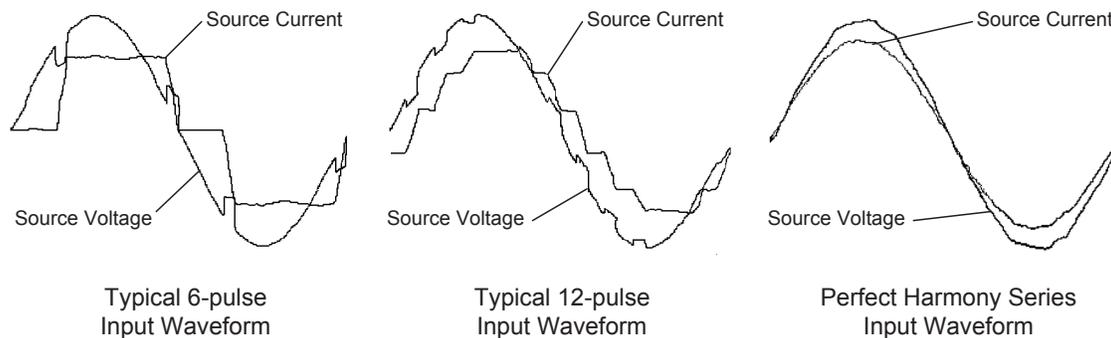
Figure 1-1: Harmonic Distortion Waveform Comparisons (6-pulse, 12-pulse and Perfect Harmony)

Total harmonic distortion of the source current is 25% for the 6 pulse, 8.8% for the 12-pulse and 0.8% for the Perfect Harmony. The corresponding voltage distortions with a typical source impedance are 10%, 5.9% and 1.2%, respectively.

> **Note:** The above comparisons were done using a typical 1,000 Hp current source drive (6-pulse and 12-pulse modes) and a Perfect Harmony series drive operating from a 1100 kVA, 5.75% impedance source.

1.2.2   High Power Factor, Nearly Perfect Sinusoidal Input Currents

Power factor is a measure of the fraction of current that produces real power to the load. Typically, power factor is given as a percentage. A high power factor VFD (e.g., 94%) makes much better use of its input line current demand in producing real power to the motor than a VFD operating at a low power factor (e.g., 30%). VFDs having low operating power factor often generate square-wave-shaped line currents containing harmonics and other associated resonance problems.

The Perfect Harmony series draws nearly perfect sinusoidal input currents, having a power factor that exceeds 94% throughout the entire speed range without the use of external power factor correction capacitors. This eliminates utility penalties for power factor and demand charges, and improves voltage regulation. In addition, feeders, breakers, and transformers are not overloaded with reactive power. Low-speed applications specifically benefit from the Perfect Harmony series, since a high and stable power factor is maintained throughout the entire speed range using standard induction motors. Figure 1-2 compares graphs of power factor versus percent speed for the Perfect Harmony series and a typical phase-controlled SCR drive.
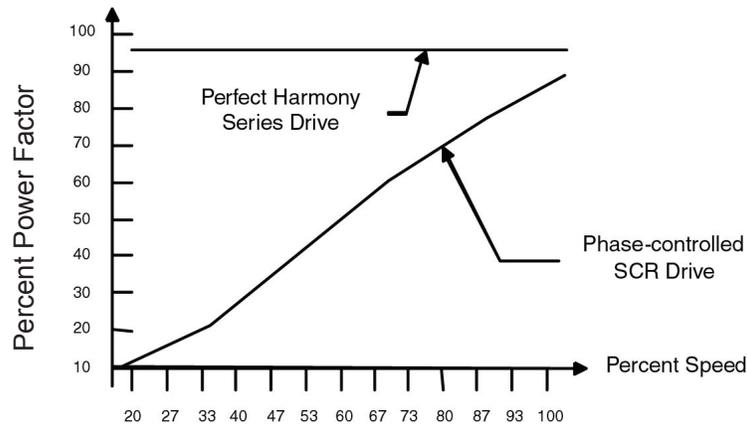
Figure 1-2: . Comparison of Perfect Harmony and a Typical Phase-controlled SCR Drive

1.2.3   Nearly Perfect Sinusoidal Output Voltage and Current

The design of the Perfect Harmony series of variable frequency drives inherently provides a sinusoidal output without the use of external output filters. This means that the drive provides a low-distortion output voltage waveform that generates no appreciable audible motor noise. In addition, there is no need to derate motors (the drive can be applied to new or existing 1.0 service factor motors). In fact, Perfect Harmony drives eliminate harmful VFD-induced harmonics that cause motor heating. Similarly, VFD-induced torque pulsations are eliminated (even at low speeds), thereby reducing the stress on mechanical equipment. Common mode voltage stress and dV/dt stress are also minimized. A typical graph of the output voltage and current from a Perfect Harmony drive is illustrated in Figure 1-3.

Figure 1-3: Nearly Sinusoidal Wave Form of the Output Voltage and Current from a Perfect Harmony Drive

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1.3 Cell Based Architecture

The Perfect Harmony Drives contain the patented interconnection of individually controlled power cells. Each cell consists of a three-phase input and a single-phase output. Since the original harmony series provided 2 quadrant operation, the three phase input consisted of a three phase diode front end connected to phase shifted secondary windings, unique to each cell. The output inverter section received PWM gating pulses across optic fibers from a common modulator board attached to the control rack. Only rudimentary diagnostics information was transmitted from the cells back to the control.

1.4 Advanced Protocol (AP) Cell Communications

The original Harmony Cells had a dedicated, simple protocol to communicate with the cells. While the drive was running, the information going to each cell consisted of a run enable, gating information, and a synchronizing bit for the temperature feedback engine. Coming from the drive was the cell temperature encoded in a single bit, the fault status, and a low cell voltage level warning. The fault information was "wir-or'd" at the modulator so that all cells could shut down within microseconds of a detected fault on a single cell. After the fault was detected, more sophisticated diagnostic routines ran to determine and identify the exact fault and cell location. Other specific information on the cell was only available during drive idle state, when each cell could be interrogated individually as to the cause of any fault.

The need for additional information communicated both from and to the cell during running status called for a new protocol, while maintaining backward compatibility with older style cells. The new protocol requires new cell control boards and new modulator, since this communication is handled completely in the firmware of both boards. The modulator is able to detect the presence of cell control boards supporting AP on an individual cell basis, and can dynamically fall back to original protocol for an older cell type. This capability is available in the control, but may not be feasible within the power electronics to mix cell types, unless running at the least common denominator of cell capability.

The AP provides additional feedback from cells equipped with this protocol capability, which is provided for NXG control while the drive is running, while still maintaining the fast legacy signals needed for control and fault handling.

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CHAPTER

2   Control Descriptions

2.1 Overview

The NXG control monitors input power connections, coordinates all power components, controls output power to the motor, performs special functions such as integration into a process, transferring motors synchronously to and from power lines, all the while protecting the drive, the connected system process, and the motor. With specially equipped cells, the control also allows the cells to cleanly regenerate power back into the input power feed (refer to Figure 2-1).
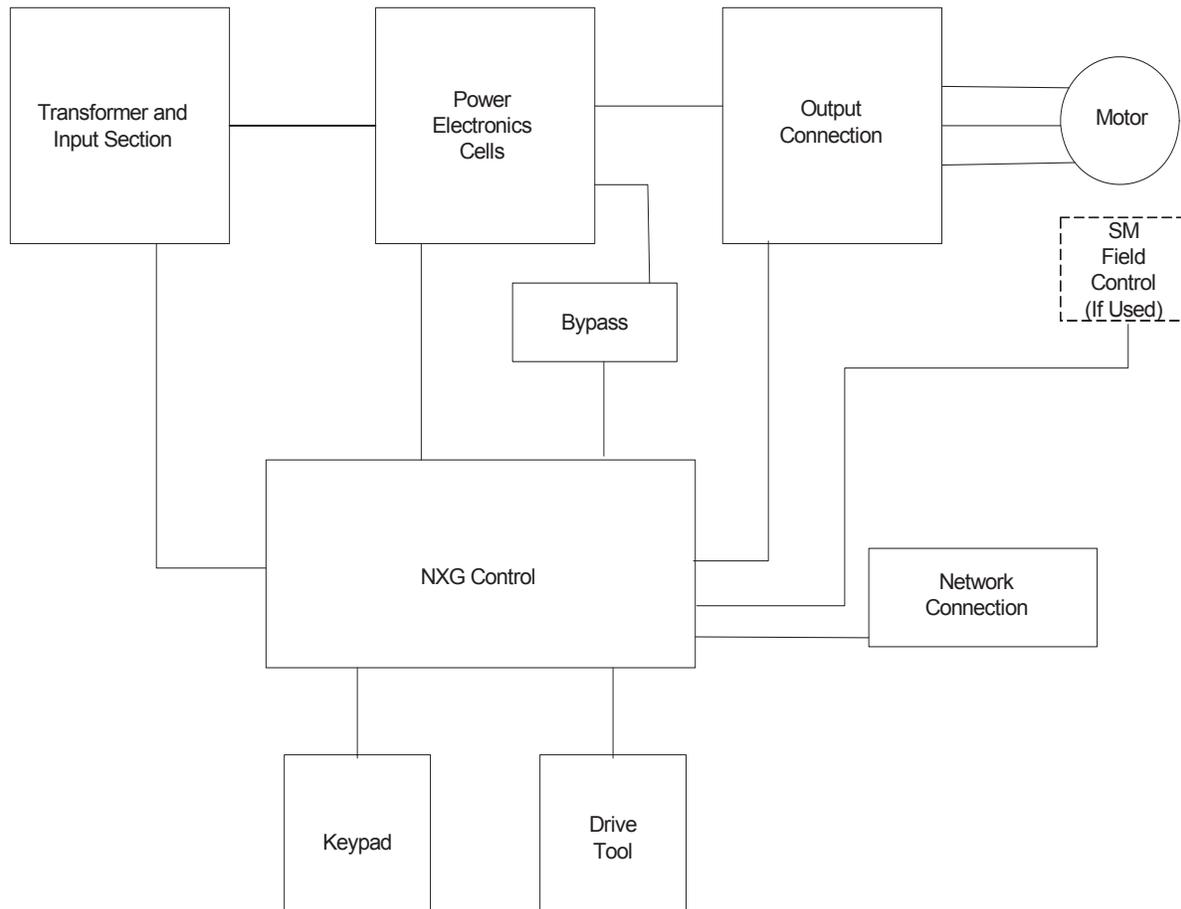
Figure 2-1: NXG Control In A Typical Drive System

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2.2 The NXG Control System

The NXG control was used in the first generation of Perfect Harmony Drives. A second generation Harmony control now extends the longevity of the control, and provides newer technology for further expansion of capability. The next iteration is known as NXGII. The NXGII control system has advantages over the NXG control such as a lower part count, a smaller footprint, and faster performance. Along with the hardware, the real-time operating system (RTOS) was also upgraded, just as operating systems on PCs are upgraded to improve performance and meet increasing processing or feature demands. The following diagrams shows the comparison of the NXG and NXGII control platforms.

The NXG Control System, located within the control cabinet, consists of a chassis and several control boards as shown in Figure 2-2. The NXG II Control System, located within the control cabinet, also consists of a chassis and several control boards as shown in Figure 2-3.
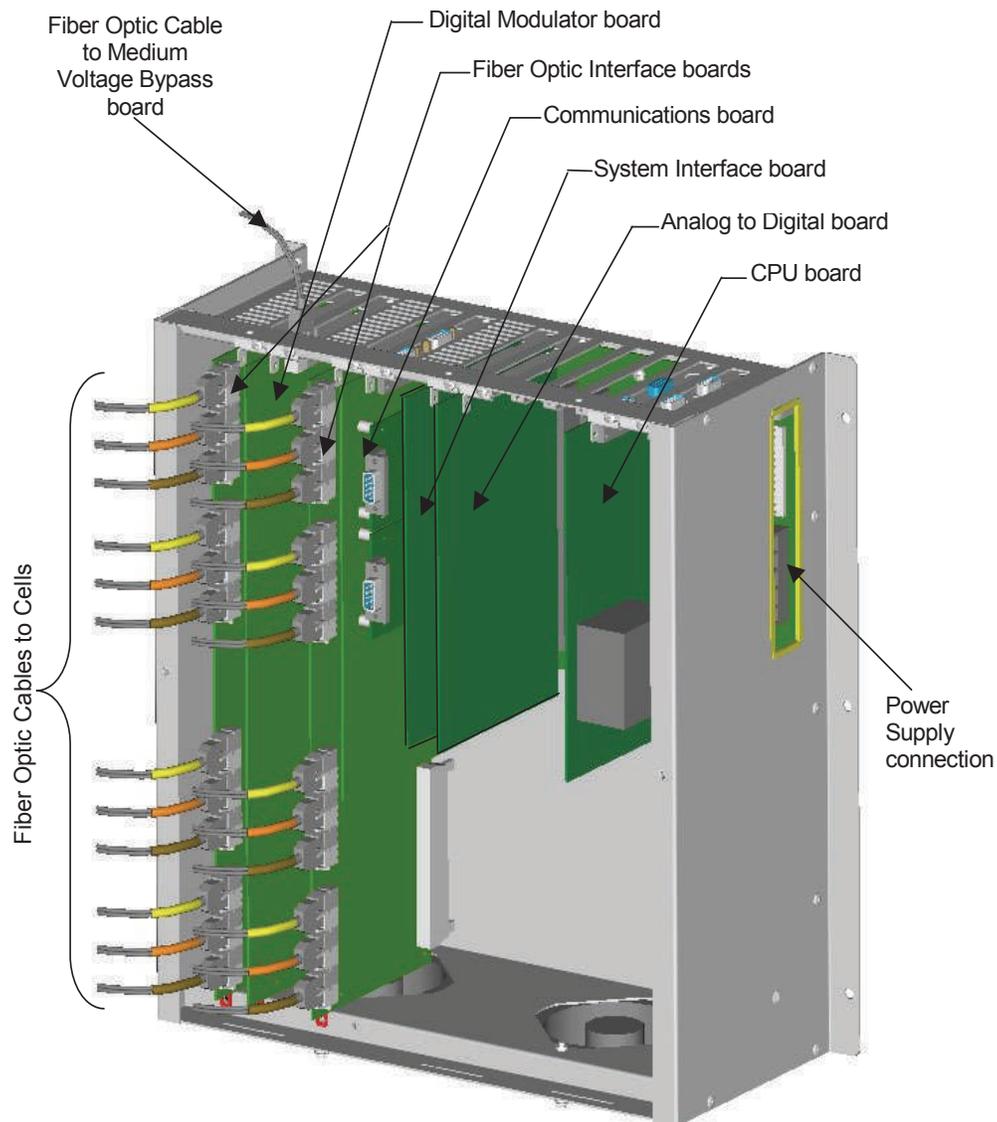
Figure 2-2: NXG Master Control Chassis
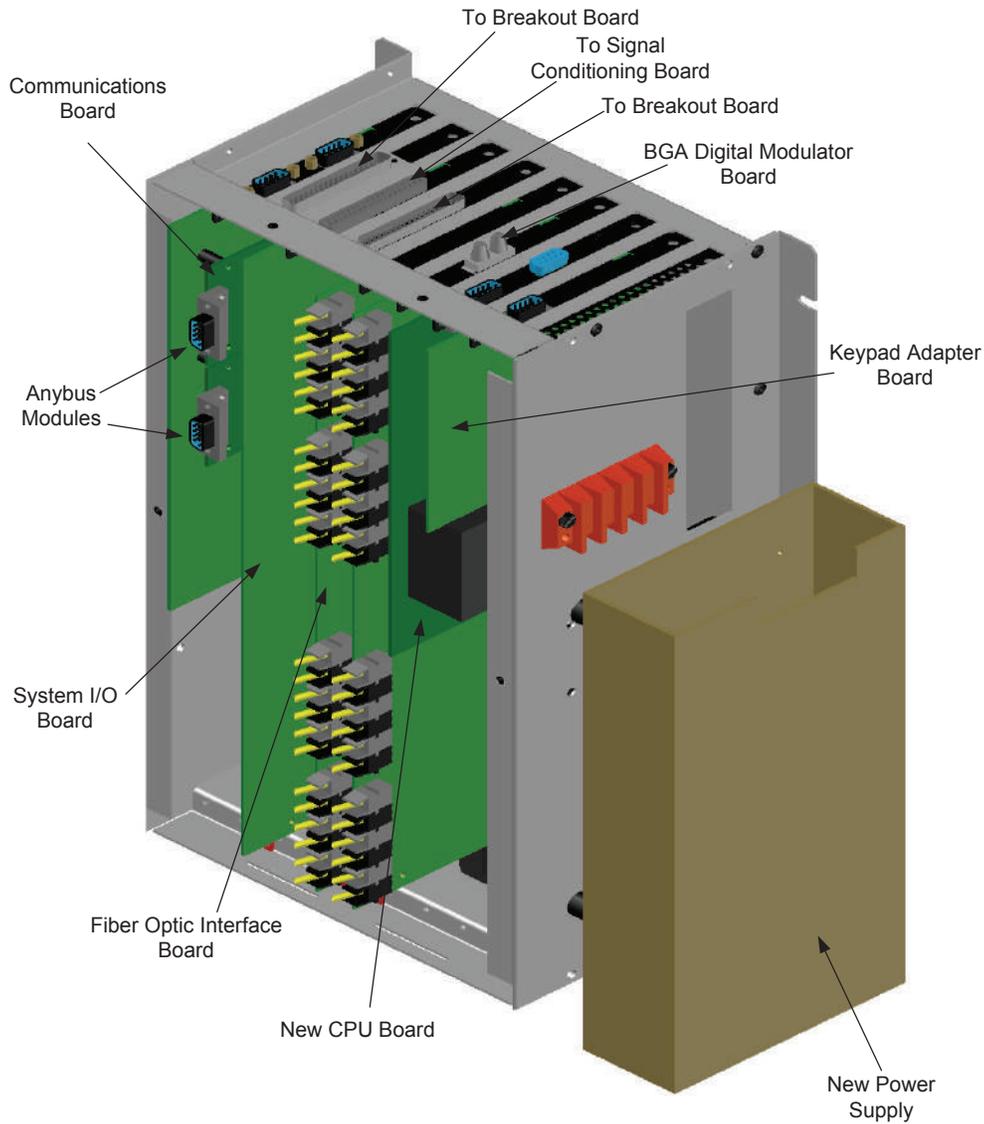
Figure 2-3: NXGII Master Control Chassis

The NXG Control uses four different power supplies. The four power supplies consist of 1 rack power supply +5V, ±12V, -5V, 2 Hall Effect power supplies +15V, -15V, and 1 WAGO power supply +24V. The NXG II Control uses one single integrated power supply with +5V, ±12V, ±15V, and +24V (-5V is not used).

The heart of the control is the Microprocessor board. This board is the master of the backplane bus and controls the operation of each board in the system.

The flash disk, which contains all of the specific parameter information and the system program for the VFD, is mounted on the microprocessor board. The flash disk may be disconnected and moved to a spare microprocessor board, without having to reprogram the VFD. See Figure 2-4 for the flash disk location on the microprocessor board for the NXG control. See Figure 2-5 for the flash disk location on the microprocessor board for the NXG II control.

2
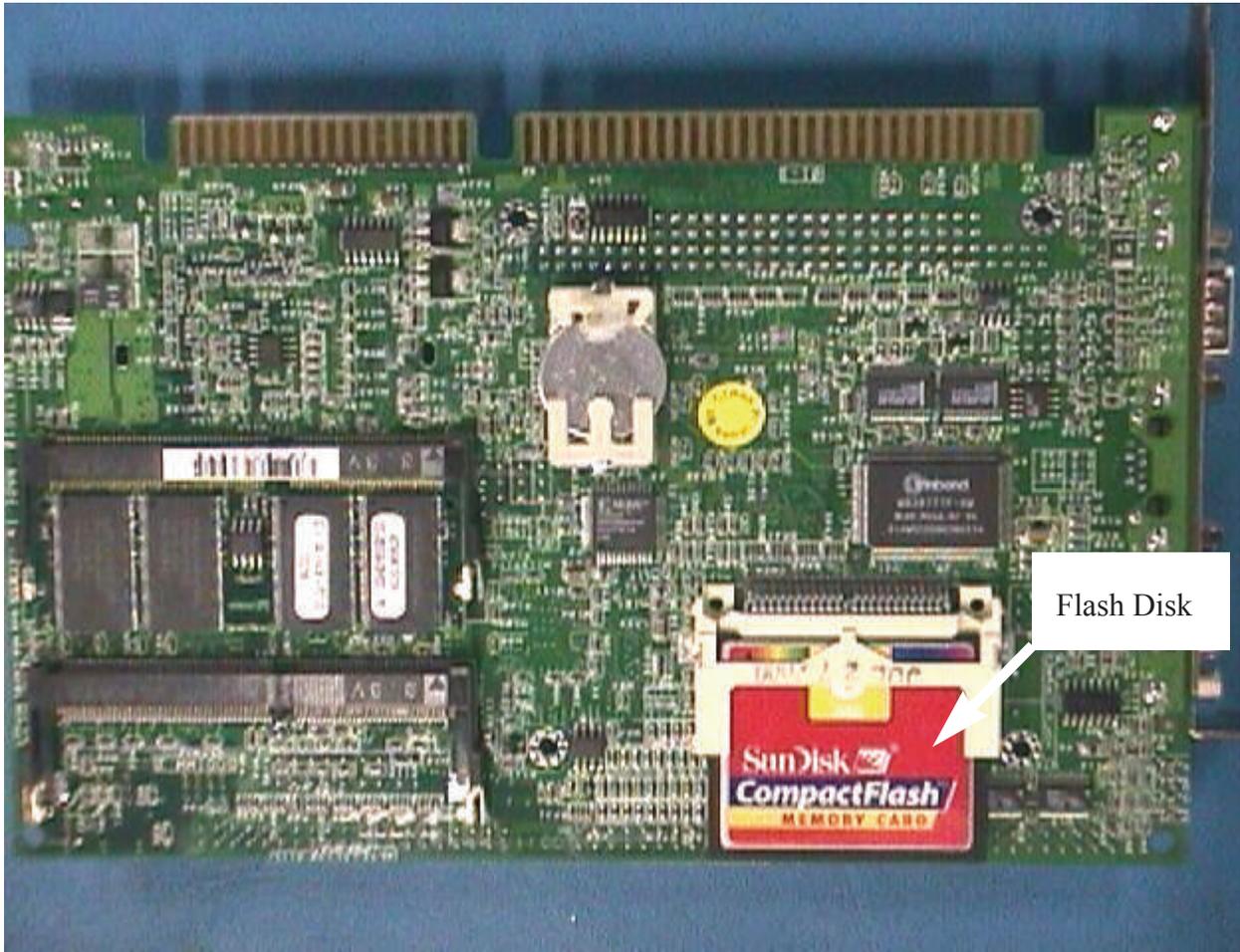
Flash Disk

Figure 2-4: Location of Flash Disk on the NXG Microprocessor Board

2
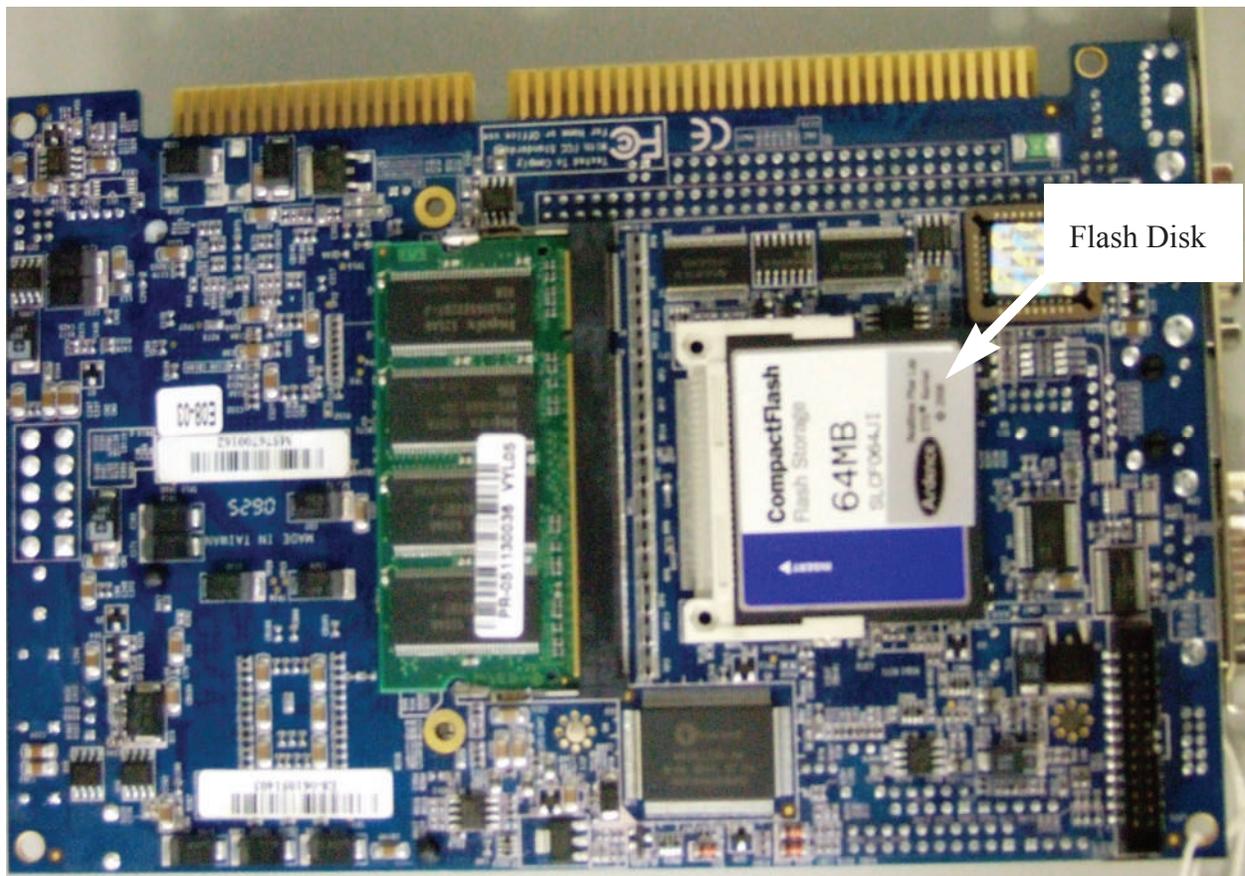
Flash Disk

Figure 2-5: Location of Flash Disk on the NXG II Microprocessor Board

The NXG control system interface board collects the drive input and output feedback signals and sends them to the analog-to-digital conversion board. The analog-to-digital conversion board executes the conversion at specified intervals and sends digital representations of the feedback signals to the microprocessor board. The microprocessor board then computes the next set of values to be sent to the digital modulator and sends them. The digital modulator sends specific commands or messages for each cell. These messages are sent through the fiber optic interface boards. Refer to Figures 2-2 and 2-3.

The NXGII control system combines the functionality of the system interface board with the analog-to-digital board and also provides additional I/O not available on NXG systems.The I/O provided by the system I/O board of NXG II consists of the following:

- 20 Digital Inputs - 24 VDC or 120 VAC arranged in 5 groups, with the first 4 groups having a single common per group, and the last group of 4 inputs being individually isolated

- 16 Digital Outputs - form C contacts capable of 1 A, 250 VDC or 30 VDC

- 3 Analog Inputs - two handle 0 to 20 mA or 0 to 10 VDC, and one that is 0 to 20 mA

- 2 Analog Outputs - 4 to 20 mA sources with a range of 200 μA to 22 mA

Note that the number of fiber optic interface boards and the number of fiber optic channels var depending on the number of cells in the drive.

Also shown in Figures 2-2 and 2-3 is a communications board. This board provides a direct interface to a Modbus network and allows network adapter boards for several other industrial networks to be connected to the drive control.

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2.3 Operating Interface Keypad

Figure 2-6 shows a typical operating interface keypad for the Perfect Harmony series VFD.
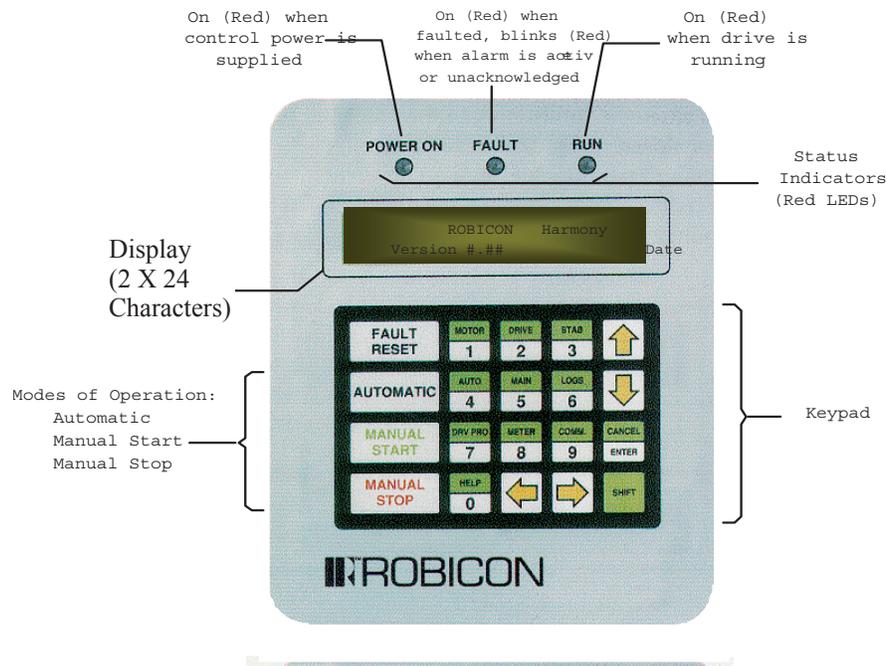
Figure 2-6: Typical Operating Interface Keypad

A detailed description of the Operating Interface Keypad along with all of its functions and modes of operation are described in Chapter 3.

2.4 Software Version Requirements and Limitations

The NXG requirements for software Versions 2.2 through 3.X, are a carrier frequency setting of 400 Hz with the following sampling rates:

- 3 ranks 4800 Hz

- 4 ranks 3200 Hz

- 5 ranks 4000 Hz

- 6 ranks 4800 Hz

The NXG II software Version 3.0 and above are compatible with NXG software Versions 2.2 and above, and do not have the sampling rate limitations.

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3   Hardware Interface

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3.1 Introduction

The NXG and the NXG II controls are structured differently, but essentially have the same interface, at least functionally. It is the purpose of this chapter to detail these interfacing components.

The scope of the interface, herein described, is from the control rack to the cell interface, and includes the hardware descriptions that make up the various components.

3.2 Signal Conditioning

All controls must have feedbacks from the system under control to function properly. The Harmony drive is no exception. Due to the wide range of input voltages and currents, and due also to the dangerously high levels of both input and output signals, interposing sensors must be utilized to scale the signals to a safe and usable level in the control cabinet, and present them to the controls. These are composed of input and output voltage attenuators, input CTs, and output Hall effect sensors. They are detailed in the individual product manuals for the model of the Harmony system addressed. It is beyond the scope of this manual to detail the values and locations of these sensors.

The control uses various direct signal levels. These signals are all scaled in such a way as to present the same control level signals independent of the source levels. This allows the control to be consistent in response from application to application, since the rated values are entered once for the inputs, and the drive responds in a similar fashion to all scaled per unit (PU) signals.

In the NXG control, an external (to the drive control rack) signal conditioning board provides connectivity of these signals while conditioning the signals for conversion into the control computer board. This board in turn connects via cable to the internal signal interface board, and finally to the Analog-to-Digital converter board.

3.3 System I/O Board

With the NXG II control, the system I/O board provides additional digital and analog I/O (see Figure 3-1), often adequate to eliminate the need for the Wago system. The system I/O provides the following capability to the system:

- 20 digital inputs arranged in 5 groups. They accept either 24 VDC or 120 VAC. The first 4 groups have a single "common" per group. The last group of 4 inputs are individually isolated.

- 16 digital outputs, all isolated from each other. They are form "C" contacts capable of 1 A (2 derated to 1 A) 250 VAC or 30 VDC, the same as the WAGO system.

- 3 isolated analog inputs. Two that handle 0 to 20 mA or 0 to 10 VDC and one that is 0 to 20 mA. The 0 to 10 VDC inputs also supply the source voltages for the potentiometers.

- 2 analog outputs. They are, essentially, 4 to 20 mA sources. Their actual range is ~200 µA to ~22mA, but not zero.

- The begin analog conversion signal comes from Modulator board. Then end of conversion goes out to CPU board as an interrupt for the control fast loop.

- Encoder interface for a typical quadrature, optical encoder.

- The following functions by the System I/O board provide a signal directly to the modulator to shut down all cells immediately:

    o Hall Effect Power Supply fail signal to Modulator

    o IOC level to Modulator (0-10VDC)

    o Control Power Supply Fail signal to Modulator

    o Inhibit or CR3 signal to Modulator
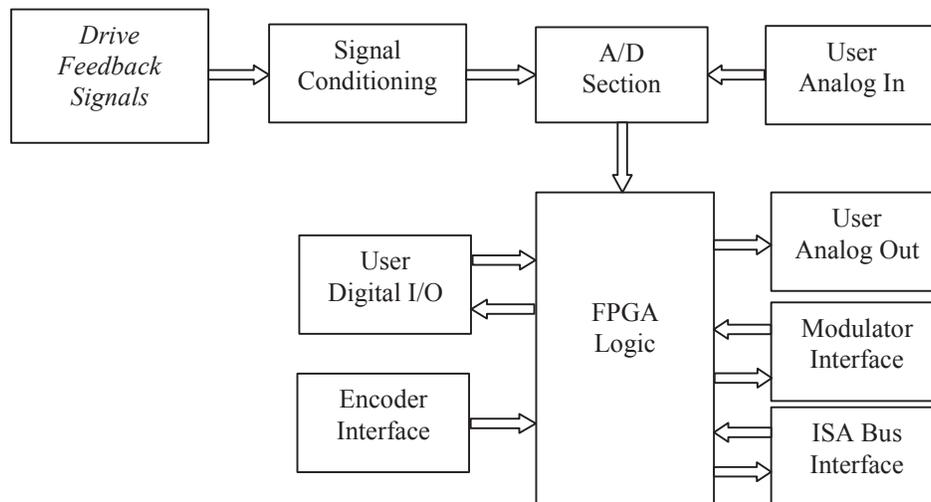
Figure 3-1: System I/O Board Block Diagram

Since this I/O resource is consistent with every system of this board, and to improve consistency of usage, the I/O has been given standard assignments used and assigned by the Drive core code. This improves response time, and prevents changes in the SOP from affecting the drive protection measures assigned to the discrete I/O.

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3.4 Breakout Board

In the NXGII control, the Break-out board is attached with a cable to the card mounted System I/O board. The connections are made off of the card rack via the system Break-out board. This is mounted on the same panel as the control rack and is connected to the rack via a multi-conductor cable. This is the point to which customer connections are made to the control system (refer to Figure 3-1).

The following I/O assignments are dedicated, and are controlled via the NXG code, not requiring SOP intervention. If not mentioned, the I/O point is mapped by SOP flag as is all Wago "External" Digital I/O.

For Cell type 750V AP

Dedicated Inputs:

Input	Function	Description
14	PrechargeRequest	Request to start precharge
15	M2CloseACK	feedback of M2 contact
16	M3CloseACK	feedback of M3 contact
17	M4CloseACK	feedback of M4 contact
18	M1CloseACK	feedback of M1 contact
19	DSPInputProtectACK	Latch Fault Relay (LFR) status

Dedicated Outputs:

Output	Function	Description
9	PrechgCompleteM1Close	Command to close M1
10	M2Close	Command to close M2
11	M3Close	Command to close M3
12	M4Close	Command to close M4
13	BreakerTrip	Command to open (trip) precharge supply breaker
14	M1ClosePermit	M1 close permissive
15	DSPInputProtect	Command to set LFR (1 sec pulse)

For GenIV type cells

Dedicated Inputs:

Input	Function	Description
19	DSPInputProtectACK	Latch Fault Relay (LFR) status

Dedicated Outputs:

Output	Function	Description
14	M1ClosePermit	M1 close permissive
15	DSPInputProtect	Command to set LFR (1 sec pulse)

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All other cell types

There are no dedicated I/O assignments in the code. All Internal Digital I/O are mapped to system program flags. The flags are entirely controlled via the SOP.

Inputs	SOP flags
0	InternalDigitalInput0a_I
1	InternalDigitalInput1a_I
2	InternalDigitalInput2a_I
3	InternalDigitalInput3a_I
4	InternalDigitalInput0b_I
5	InternalDigitalInput1b_I
6	InternalDigitalInput2b_I
7	InternalDigitalInput3b_I
8	InternalDigitalInput0c_I
9	InternalDigitalInput1c_I
10	InternalDigitalInput2c_I
11	InternalDigitalInput3c_I
12	InternalDigitalInput0d_I
13	InternalDigitalInput1d_I
14	InternalDigitalInput2d_I
15	InternalDigitalInput3d_I
16	InternalDigitalInput0e_I
17	InternalDigitalInput1e_I
18	InternalDigitalInput2e_I
19	InternalDigitalInput3e_I

Outputs	SOP flags
0	InternalDigitalOutput0_O
1	InternalDigitalOutput1_O
2	InternalDigitalOutput2_O
3	InternalDigitalOutput3_O
4	InternalDigitalOutput4_O
5	InternalDigitalOutput5_O
6	InternalDigitalOutput6_O
7	InternalDigitalOutput7_O
8	InternalDigitalOutput8_O
9	InternalDigitalOutput9_O

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10	InternalDigitalOutput10_O
11	InternalDigitalOutput11_O
12	InternalDigitalOutput12_O
13	InternalDigitalOutput13_O
14	InternalDigitalOutput14_O
15	InternalDigitalOutput15_O

3

3.5 Modulator and Fiber Optics

The Harmony series drives are unique in that the cell power units that compose the power section of the drive, also present a challenge to the control. They must be controlled to act in unison to provide a clean, three-phase, sinusoidal output source to the motor.

The control system inputs the desired control reference signals, and regulates the outputs to provide the cells with the appropriate PWM information needed to operate the "H" transistor bridge in each of the cells. These signals are sent from the modulator to the cells via a fiber optic cable, which provides needed electrical isolation from the high cell voltages. These signals are sent nominally every 10 µs to each cell.

The drive enable is also sent to each cell to enable the transistors, and the cell responds with status information that is monitored with every transmission. In particular, the cell fault bit is used at the modulator level to disable all drive cells in a fast manner (2 cell transmission periods - nominally about 20 secs.) to protect the cells. The modulator is also programmed to shut down the cells in the case of a link fault, which is generated if the cell doesn't respond before the next message is sent, or if a hardware inhibit signal (CR3) is present.

The modulator synchronizes the control software with the carrier signal to provide accurate voltage sampling. This is done by providing a "start of sampling" signal called Fsamp to the analog-to-digital converters (ADC) to begin sampling the output signals of the drive. At the end of the sampling conversion of the ADCs, the analog system generates a hardware interrupt to the control processor board to read the converted signals with minimum delays. This interrupt spawns a processing thread known as the fast loop cycle to sample and filter the signals. The control reads the signals, filters them, and then calculates the next set of signal commands to the modulator to be converted into PWM signals.

Another protection in the modulator is to shut the cells down if the drive doesn't update the modulator in four fast loop cycles. This is the modulator watchdog, which is enabled automatically anytime the drive enable is true, allowing the transistors in the cells to gate or turn on.

3.6 Bypass Control

The modular configuration of the power section provides a robust power system. Should a device or cell fail in any manner, the cell can be bypassed at the output

Another part of the Modulator board functionality is the ability to control the activation of the bypass contactors through a fiber optic link between the modulator board and the Medium Voltage bypass board, which contains pilot relays to interface to the cell-based output contactors. By this means, the control can trip on a cell fault, immediately isolate the faulted cell, compensate for the neutral shift to equalize the three output phase voltages, and re-enable the drive output within 250 msec. This fast bypass feature provides maximum availability by making the cell trip transparent to the system process.

3

3.7 Parameter Interface

To tune and monitor the drive performance, a means must be provided to input data to the control. The standard interface for the Harmony drive is the Keypad, which is detailed in the following chapter on human interface.

In addition, a PC-based tool can optionally be connected for remote configuration and monitoring via an Ethernet connection. This Drive Tool includes most of the functionality of the keypad plus provides graphing capability for a number of internal control signals. This Drive Tool is part of a collection of tools known collectively as the Tool Suite. These are addressed separately in the *ToolSuite Manual* (902291).

3.8 Discrete Inputs and Outputs

The drive provides a means to connect both analog and digital control signals to the drive. The system is flexible in the amount of I/O needed by and provided to the system. This is referred in the literature as external I/O.

3.9 Wago Controller

Both the NXG and NXG II controls can provide this capability. A dedicated serial port is used to communicate with the Wago brand flexible I/O system via Modbus protocol. Configuring the Wago into the system is accomplished by menu parameters describing the Wago configuration (number of different types of modules used). Accessing the digital I/O is accomplished via the SOP, whereas the analog I/O is utilized by selecting inputs or outputs through menu configuration assignments. See the section on the menu hierarchy in Chapter 4 for setup and usage.

3.10 User I/O

3.10.1 Introduction

The I/O modules (Digital In/Out, Analog In/Out) allow user-customization of the system for the application requirements. The Next Gen control uses the Wago$^{©}$ I/O system. This system consists of DIN rail mounted modules that can be easily expanded by simply inserting modules into the existing modules (see photo below). The Configuration of the I/O is handled through the External I/O Menu (2800) see Section 3.10.4.

☞ | **Note:** Like modules must be grouped together. Refer to the Wago literature for specifics on limitations and power equipment.
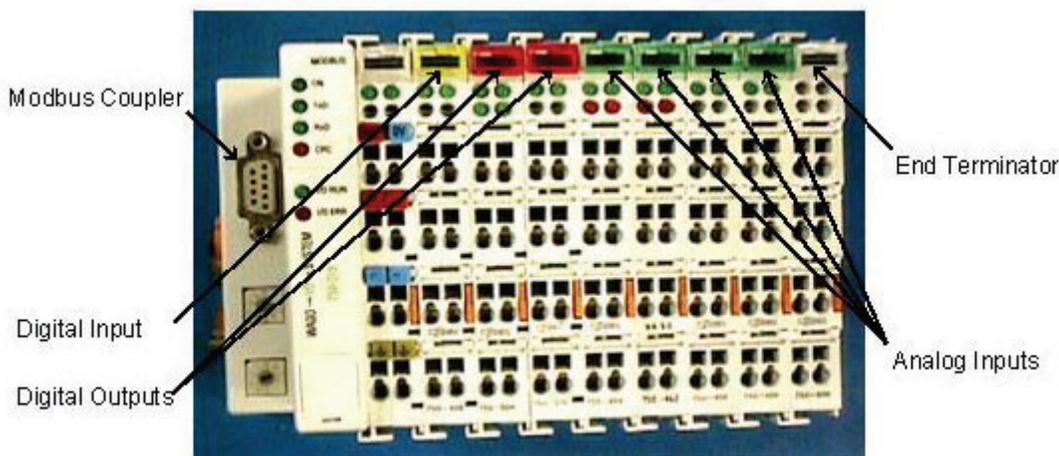
Figure 3-2: Wago I/O System Photo

3

Table 3-1: Wago I/O Module Color Codes

Module Function	Color
Digital Outputs	Red
Digital Input	Yellow
Analog Input	Green
Analog Output	Blue
Special Modules	Colorless

3.10.2 Wago Modbus Coupler Settings

This section covers the settings of the MODBUS coupler used for communications between the NXG control and the Wago I/O system. Normally this coupler is configured at the factory and there is no need to make changes.

Figure 3-3 shows the bottom of the WAGO Fieldbus coupler case. To access the DIP switches, you have to remove the cover. To do so, you must pry with just a little pressure on the bottom of the unit where there is a little "bump" on either side. You can then start applying pressure from the top where the DB9 connector is, pushing down.
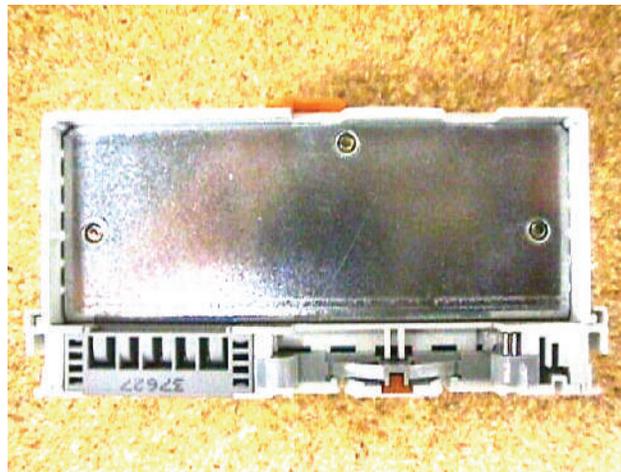
Figure 3-3: Wago MODBUS Coupler Bottom

Figure 3-4 shows how the cover should lift off of the WAGO Fieldbus Coupler to give access to the DIPswitches.
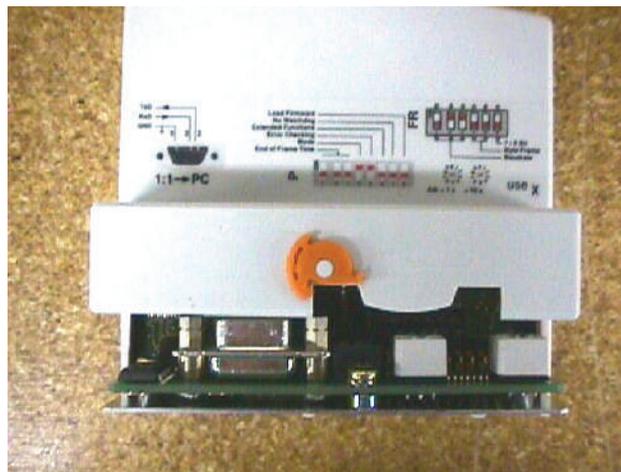
Figure 3-4: Wago MODBUS Coupler with Cover lifted

SIEMENS

3

Figure 3-5 shows the actual DIP switches in the WAGO Fieldbus Coupler. The first three switches of the top DIP switches, labeled FR on the cover plate, are to set the baud rate. Switch 1 is off, switch 2 is on, and switch 3 is off. The correct settings are shown here and are different than the picture displayed on the outside cover that is removed to access the DIP switches.
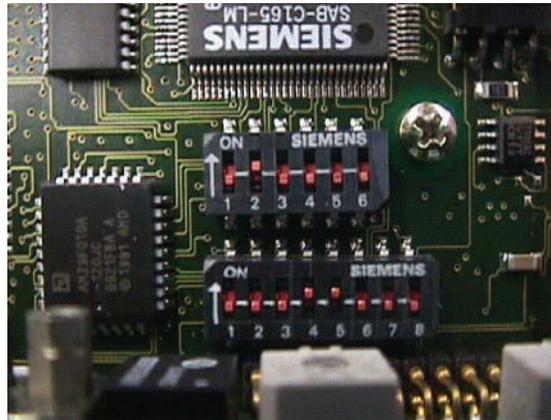
Figure 3-5: Wago MODBUS Coupler DIP switch settings
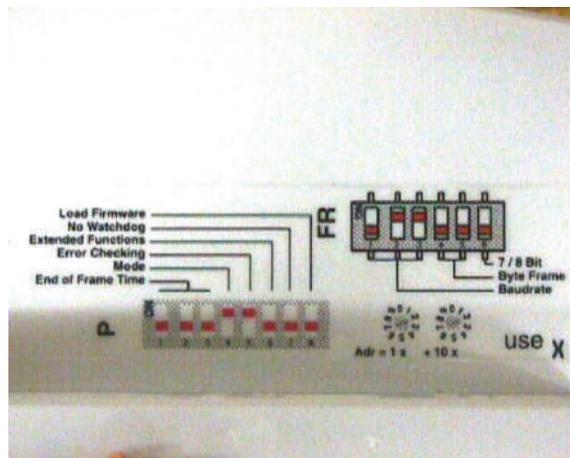
Figure 3-6: Wago MODBUS Coupler DIP switch settings label

3.10.3   External I/O Menu (2800)

The External I/O is configured from the External I/O Menu (2800). The user must define the total number of I/Os per the Table below for each type of I/O (Analog I/O and Digital I/O). If the I/O count is incorrect, the drive will indicate a "Wago Configuration Fault." Once the correct number of I/O is entered, the fault can be cleared by a Fault Reset.

Table 3-2: External I/O Menu (2800)

Parameter	ID	Units	Default	Min	Max	Description
Analog Inputs	2810		0	0	24	Sets the quantity of analog inputs in the attached external I/O.
Analog Outputs	2820		0	0	16	Sets the quantity of analog outputs in the attached external I/O.
Digital Inputs	2830		0	0	96	Sets the quantity of digital inputs in the attached external I/O.
Digital Outputs	2840		0	0	64	Sets the quantity of digital outputs in the attached external I/O.

3.10.4   Digital I/O

The Digital I/O data is only available and usable within the System Program. The System Program has predefined variable names for External Digital Inputs and Outputs. You may write a system program and make use of these I/O for whatever functionality or logic is required. The I/O is assigned system program variable names, based on the location or order that the module is inserted into the Wago I/O system. For example, if a single Digital input module and a single Digital Output module are inserted into the Wago system, the system program would define them as follows:

Digital Input Module #1: (assuming the module is a 4 input module)

`ExternalDigitalInput01a_I through ExternalDigitalInput01d_I`

Digital Output Module #1: (assuming the module is a 2-output module)

`ExternalDigitalOutput01a_I through ExternalDigitalOutput01b_I`

If there are additional modules added they would be defined as follows:

Digital Input Module #2: (assuming the module is a 4 input module)

`ExternalDigitalInput01e_I through ExternalDigitalInput01h_I`

Digital Output Module #2: (assuming the module is a 2-output module)

`ExternalDigitalOutput01c_I through ExternalDigitalOutput01d_I`

3.10.5   Analog Output Menu (4660)

The analog outputs are set up via the pick list parameters in the Analog Output menus (4661 through 4721). First a pick list is presented to allow selection of the variable to be output to the Analog Output module. To complete the setup, select the type of output (bipolar or unipolar) and the percent of the value to provide scaling of the variable.

☞ **Note:** A set of standards has been established for the use of certain I/O. Please refer to these standards as a beginning point to establish wiring and system program creation. See Chapter 8 on System Programming for details.

Table 3-3: Analog Output #1 (4661)

Parameter	ID	Units	Default	Min	Max	Description
Analog variable	4662					This variable sets the input source for analog output #1.
Output module type	4663					Sets the output type for the module (Unipolar or Bipolar).
Full range	4664	%	0	0	300	Scales the output range of the variable selected.

3.10.6 Analog Input Menu (4090)

The analog inputs are set up to receive the converted data from the user modules selected as either 0 - 20mA, 4 - 20mA, 0 - 10V. The user defines the minimum and maximum values for scaling as well as the Loss of Signal (LOS) threshold and action. All Analog inputs are available to be used by the Comparators for additional control functionality (refer to the Comparator Setup Menu (4800) in Chapter 4).

Table 3-4: Analog Input #1 Menu (4100)

Parameter	ID	Units	Default	Min	Max	Description
Source	4105					This parameter sets the input source for analog input #1. Can be any one of 24 External Analog Inputs.
Type	4110		0 - 20mA			This parameter sets the operational mode for analog input 1. 0 - 20mA 4 - 20mA 0 - 10V
Min input	4120		0	0	200	Minimum Analog input
Max input	4130		100	0	200	Maximum Analog input
Loss point threshold	4140		15	1	100	Threshold where loss of signal action is activated.
Loss of signal action	4150		Preset			Select loss of signal action. Preset Maintain Stop
Loss of signal setpoint	4160		20	0	200	Loss of signal preset speed.

3.11 Calculating Voltage Attenuator Resistors

3.11.1 Resistor Calculation

Input and output voltages are attenuated to provide a low voltage signal for measurement. Typically, two resistors are used (on both the input and output sides) to support medium voltages. Use the calculations explained next if the resistor values are not available in the Perfect Harmony NXG Cookbooks. Note that even if the discrete value of

available resistors is not the same as the exact calculated value, no scaling is required; the NXG software automatically scales the voltages as needed.

> ☝ **Note:** The input attenuator resistors must be selected to match the input transformer nameplate rating. The output attenuator resistors must be selected to match the motor nameplate rating.

3

Figure 3-7 shows the attenuator circuit that is used to convert medium voltages to low voltage measurement signals. R_f represents the effective feedback resistance used in the System Interface Board (R_f = 4765 Ω in current versions, i.e., 461F53-00 and 461F53-02).

R₁, R₂ = Medium voltage resistors
R_f = Effective value of feedback resistance
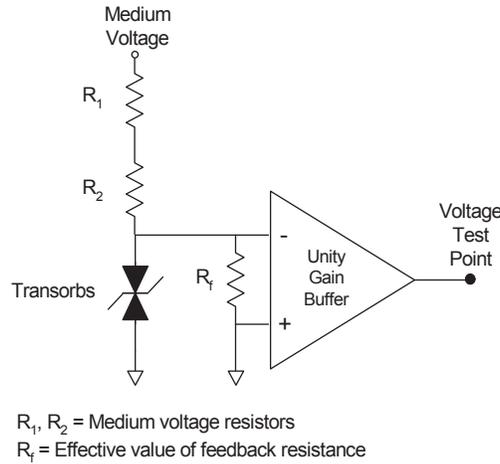
Figure 3-7: Attenuator Circuit

Calculate the resistor values as follows:

$$R_1 + R_2 = (722.3 * V_{mv}) - 4765$$

Where:

- V_{mv} is the nominal line-to-line input voltage in RMS

- 4765 is the value of R_f

- 722.3 is a combined constant equal to $(4765/5.3864) * (\sqrt{2} / \sqrt{3})$

- 5.3864 is the nominal voltage at the test point for 1 PU

- $\sqrt{2}$ is used to convert from L-L to L-N voltage

- $\sqrt{3}$ is used to convert from RMS to peak voltage

For example, for a V_{mv} of 4160 V, $R_1 + R_2 = 3.0$ MΩ. The Perfect Harmony NXG Cookbook yields values of $R_1 = 2.0$ MΩ and $R_2 = 1.0$ MΩ. In typical applications, R_2 is fixed at 1.0 MΩ and R_1 is selected based on the rated medium voltage level. Both resistors are 10 W, 1% medium voltage resistors.

For rated voltages below 1.0 kV, fix the value of R_2 at 120 kΩ.

> ⚠ **Warning:** Never place a third resistor inside the control cabinet in series with the medium voltage resistors to achieve the calculated values. Doing so will violate the protection of the transorbs in the attenuator circuit and introduce dangerous voltages into the control cabinet.

3.11.2   Software Supported Voltages

The following input and output voltages are supported by the NXG software and will be automatically scaled for measurement:

   2400, 3000, 3300, 3400, 4160, 4800, 6000, 6600, 7200, 8400, 10000, 11000, 12000, 12500, 13200, 13800, and 22000.

3.12 I/O Configuration

The Harmony series drive is known for its flexibility and configurability. This is due to the incorporated System Program interpreter built into the drive core software. In its simplest form, it is used to map the digital I/O points in the hardware to internal drive system flags. With the System I/O, this is also possible for inputs and outputs not specifically assigned.

In the more advanced format, simple Boolean relationships allow combinations of inputs, external or internal, to form a more complex purpose. In addition, timers, counters, and comparators allow great configurability to the logic. The design and use of the system program (SOP) is discussed in detail in chapter 8 of this manual, and in the SOP Utility chapter of the *ToolSuite Manual* (902291).

3.13 Communications

The drive provides, as standard, a serial port with Modbus protocol and an Ethernet port with which to communicate with the outside world. The communication board also allows the addition of two network adapters to cover all the other supported protocols. See the NXG Communications Manual (902399) for use and configuration of these features.

$$\nabla \ \ \nabla \ \ \nabla$$

4   User Interface

4.1 Introduction

All control systems provide a means to change and tune the controls. There are basically three ways to change parameters in the drive. Two of these are the standard keypad and the PC-based Drive Tool, which are introduced here. The third method involves changing the parameters by means of the networks, but is too complex to describe here, and is less commonly used. Since it involves programming on an interconnected platform, e.g. an external PLC, it is mentioned here only in passing. For more information, refer to the *NXG Communications Manual* (902399).

The remainder of this chapter will discuss, in detail, the navigation of the standard keypad, and will introduce a more advanced external interface in the PC-based Drive Tool.

4.2 Keypad

This section pertains to the standard keypad hardware and operation. The actual contents of the parameter menu system is discussed in detail in Chapter 5, *Applications and Advanced Features*.

Although the drive comes standard with this interface, and the menu system is secured with multiple, programmable password levels, for security or other reasons the drive is capable of running without the keypad. However, the keypad should never be added or removed with power applied to the control.

The Perfect Harmony series contains a user-friendly keypad and display interface. This keypad/display interface is located on the front of the Perfect Harmony Drive Control Cabinet. The Keypad and Display Interface is illustrated in Figure 4-1.

The Keypad and Display Interface is used to access the control parameters and functions of the Perfect Harmony drive. Parameters are organized into logical groups using a menu structure. To view or edit parameters, the operator must maneuver through the menu structure to the desired parameters. This is accomplished using navigation arrow keys or special key sequences as short cuts. A summary of these key sequences is given later in this chapter.

The [SHIFT] key (which is used in conjunction with the 10 numeric keys and the [ENTER] key) is provided to access nine common system menus, a help display function and a [CANCEL] key. The keypad is used to navigate through the menu system, activate control functions, reset the system after faults have occurred, edit parameter values, enter security access codes, and place the system in either automatic, manual, or stop (auto/hand/off) mode.

4
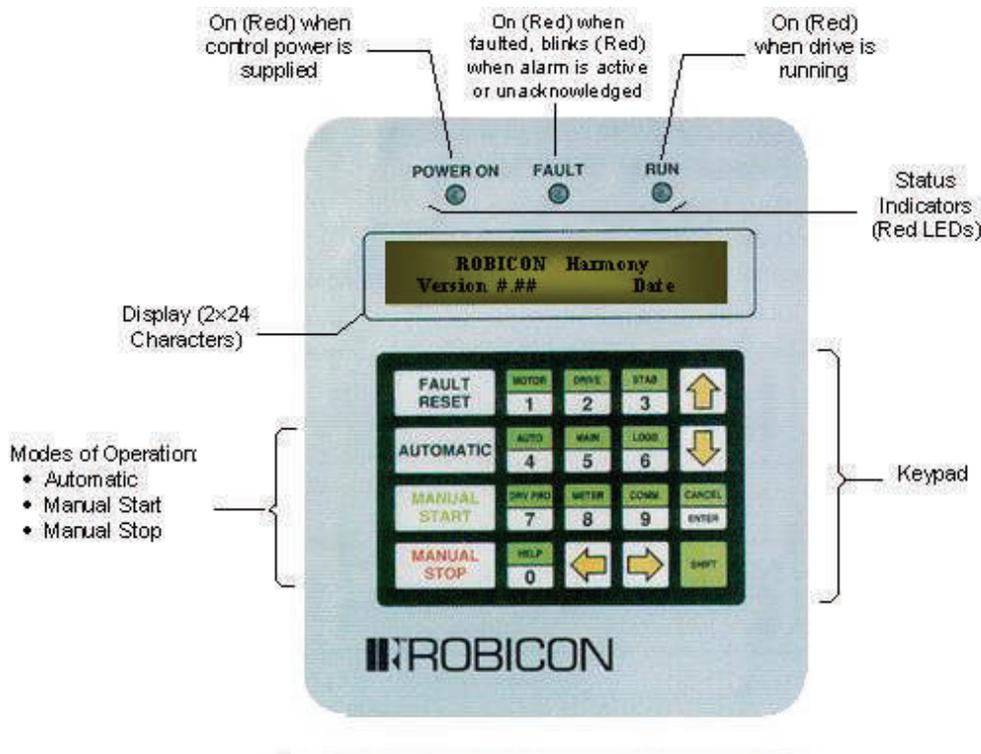
Figure 4-1: The Keypad Display Interface of the Perfect Harmony Series

The Perfect Harmony keypad contains 20 keys. Each of these keys has a least one function associated with it. Some keys are used for 2 or more functions. The following sections give descriptions and uses of each of the keys on the keypad, as well as the diagnostic LEDs and the built-in display.

4.2.1   Fault Reset and LED Indicator

The [FAULT RESET] key is located on the top left corner of the keypad and has a dual purpose. If a drive fault is present, the reset will attempt to clear the fault. If there is no drive fault but an active alarm is present, then the fault reset acknowledges the alarm.

The Fault LED can be flashing, continuously on, or off.

A flashing LED means that an alarm is either active or unacknowledged. An LED that is on continuously means that a fault condition exists. Table 4-1 details all of the LED conditions.

The [FAULT RESET] key is a programmable key that works in conjunction with the drive SOP. It is generally used as just a generic fault reset, but can also be changed to incorporate system logic specific to an application.

Table 4-1: Fault LED Conditions

Fault LED Condition	Display	Fault Condition	Alarm Condition	Alarm Acknowledged or Fault Reset?
Flashing	Toggles between alarm name(s) and normal display	N/A	Active	No
Flashing*	Toggles between alarm name and normal display	N/A	Cleared (not acknowledged)	No
Flashing	None	N/A	Active (acknowledged)	Yes
Flashing	Toggling between alarm name, normal display, next alarm, normal display, etc.	N/A	Multiple Active Alarms	No
On Continuously	Fault name	Active	N/A	No
On Continuously	Fault name within display**	Multiple Faults	N/A	No

After an alarm condition is cleared, the Fault LED will continue to flash until the alarm is acknowledged by pressing the [FAULT RESET] key.

**Use the down and up arrow keys to cycle through the active fault list.*

☞ **Note:** If an alarm condition occurs before or during a fault condition, the LED and display will not indicate the presence of an alarm until the fault condition is cleared and reset. The alarm conditions are recorded in the Alarm/Fault Log.

When a fault condition occurs, the fault indicator is red. The system can be reset by the following steps:

1. Determine the cause of the fault (see the display or check the Alarm/Fault Log).
2. Correct conditions that may have caused the fault, if appropriate.
3. Reset the system by pressing the [FAULT RESET] key on the keypad.

When there are no fault conditions but an alarm condition occurs, the fault indicator will flash red. The alarm condition can be acknowledged by the following steps:

1. Determine the cause of the alarm (see the display or check the Alarm/Fault Log).
2. Correct conditions that may have caused the alarm, if appropriate.

3. Acknowledge the alarm by pressing the [FAULT RESET] key on the keypad. Acknowledging an alarm will cause all alarms to no longer be displayed on the keypad display. However, if any alarm condition still exists, the Fault LED will flash red.

4. If there are both faults and alarms, press the [FAULT RESET] key twice to first reset the fault and then acknowledge the alarms

4.2.2   Automatic Key

The [AUTOMATIC] key is a programmable key located below the [FAULT RESET] key on the keypad, and can be used via the SOP to put the Perfect Harmony drive into automatic mode. In automatic mode, the standard speed setting for the drive is obtained from the 4-20 mA input and through speed profile parameters located in the Speed Profile Menu (4000).

☞ | **Note:** Automatic mode can be customized to suit particular application needs by modifying the appropriate I/O parameters from the keypad and display interface. Modification of the factory-supplied program of the Perfect Harmony is also a viable option, although it requires an understanding of the factory supplied program format, the compilation process, and downloading techniques.

4.2.3   Manual Stop Key

The [MANUAL STOP] key is a programmable key which can be used, via the SOP, to place the Perfect Harmony into stop mode. Stop mode shuts down the drive in a controlled manner, regardless of its current state (manual, remote, or automatic).

☞ | **Note:** Modification of the factory-supplied program of the Perfect Harmony requires an understanding of the factory-supplied program format, the compilation process, and downloading techniques.

4.2.4   Manual Start Key

The [MANUAL START] key is a programmable key located below the [AUTOMATIC] key on the left side of the keypad. [MANUAL START] can be used via the SOP to put the Perfect Harmony system into manual control mode.

There are two varieties of control mode: local and remote. These varieties are distinguished by the sources of the velocity demand. The sources of velocity demand, as well as operation of the drive via the various customer interfaces, are completely configurable through the SOP. Details of programming the SOP can be found in Chapter 8. An example, which will be referred to in the remainder of the chapter, is illustrated in Figure 4-2.

4


```
                                                    Local manual mode is activated
                                                    pressing the Manual Start key
                                                    keypad and setting the velocit
                                                    using the up and down arrow ke
```

```
              Perfect Harmony Keypad


                    ⬆

    MANUAL                        Velocity Demand
     START                        Set Manually
                                  From Arrow Keys
                    ⬇



                                              Drive Output
                                                to Motor


  Remote Digital Input (120 VAC Logic)
                                          Perfect
    Manual/Remote                         Harmony
                                           Drive
    External Reference                            Remote manual mode is activate
                                                  pressing the momentary input a
                                                  the velocity demand using the
  Velocity Demand from an external                potentiometer.
        speed reference
```

Figure 4-2: Example of Two Programmed Control Modes

4.2.5   The 0 - 9 Key

Numeric keys are centrally located on the keypad of the Perfect Harmony system. These 10 keys (labeled 0 through 9) provide the following functions:

- Entry of security access codes.

- Speed menu functions as a shortcut menu (direct access to 10 basic menus according to assigned menu names [in green text above each numeric key]).

- Speed menu has direct access to all menus, submenus, and parameters and pick lists (with proper security) based on ID number.

- Speed menu function: press [SHIFT][RIGHT ARROW], then enter ID for parameter or menu; press [ENTER] to go there directly.

- Ability to change the values of parameters.

One function of the numeric keys of the Perfect Harmony keypad is to enter a 4-digit security access code. The security code consists of any combination of digits 0 through 9 and hexadecimal digits "A through F."

☞ **Note:** *Hexadecimal* (or hex) is a method of representing numbers using base 16 (digits 0-9, A, B, C, D, E, and F) rather than the more common base 10 (digits 0-9). Hex digits "A through F" can be entered from the keypad by pressing the [SHIFT] key followed by the numbers [1] through [6], respectively. The keystrokes required to enter hex values "A through F" are listed in Table 4-2. Decimal equivalents are also listed.

Another function of the numeric keys is the shortcut menu that allows the operator to access 10 common menus within the system using the pre-programmed numeric keys. Each of the numeric keys has an associated menu name printed in green (on top of each numeric key). To access one of these 10 menus, the operator uses the [SHIFT] key followed by the appropriate numeric key (e. g., [SHIFT]+[1] to access the Motor menu, [SHIFT]+[2] to access the Drive menu, etc.).

See Table 4-2 and Figure 4-3 for clarification.

Table 4-2: Hexadecimal Digit Assignments on the Perfect Harmony Keypad

Key Combination	Hex Value	Decimal Equivalent
SHIFT MOTOR 1	A	10
SHIFT DRIVE 2	B	11
SHIFT STAB 3	C	12
SHIFT AUTO 4	D	13
SHIFT MAIN 5	E	14
SHIFT LOGS 6	F	15

SIEMENS

Number for Entering
Parameter Values, Security Codes,
or Menu Numbers

MOTOR
1

Speed Menu Name (Use with Shift Key
From the Default Meter Display)
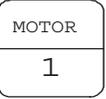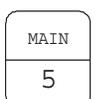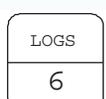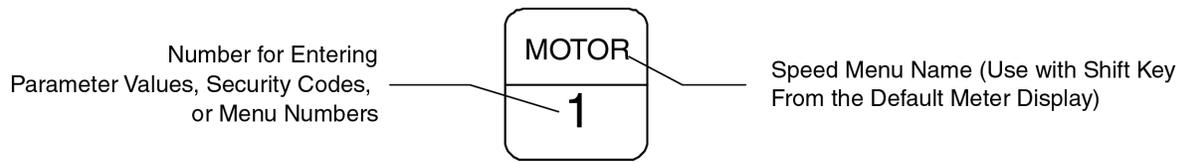
Figure 4-3: Anatomy of a Numeric Keypad Key

In addition to the shortcut menu feature, a second menu-access feature is available for all remaining menus in the Perfect Harmony system. The shortcut menu feature is available only from the main meter display on the LCD. The hexadecimal entry feature is available only during security code entry. Therefore, the results of [SHIFT]+[1] through [SHIFT]+[6] key combinations depend on the context in which they are used. This second method is the speed parameter feature, which cannot only be used on menus, but can also be used to go directly to a particular parameter or pick list. While this second method requires more keystrokes to access target menus, parameters, or pick lists, the operator can gain access to *all* security-approved items rather than just the 10 most common menus. Accessing items in this manner requires that the operator know the item ID number. This item number will be a four-digit number. This number is listed on the display each time the item is displayed, and is also listed in the menu reference charts later in this chapter.

In using the speed parameter feature, the operator enters an item using its ID number by pressing the [SHIFT] key followed by the right arrow key [⇨]. The display prompts the operator for the desired ID number. Using the numeric keys on the keypad, the operator enters the desired ID number, then presses the [ENTER] key. If the number is a valid ID number, and the current security level permits access to that item, then the desired item will display. Refer to Figure 4-4.

☞ **Note:** Any menu, parameter, or pick list can be accessed by ID. To do this press, [SHIFT]+[⇨]. The display will read "Enter Param ID:." Simply enter the ID number of the item you wish to access, and hit [ENTER].

The menu, parameter, or pick list ID can be found in the menu tables later in this chapter, or is listed on the display in ( ) when the item is displayed.

If the operator requests access to a menu number that is assigned a higher security level than the current security level, the drive will prompt the operator for the appropriate security level code.

Finally, the numeric keys on the keypad can also be used to change the value of system parameters. Once a parameter is selected for modification, the left-most digit of the parameter value is underlined and is called the *active* digit. Pressing a numeric key can change the active digit. This method automatically advances the underline to the next digit to the right. The operator continues pressing numeric keys until the desired value is displayed. The [ENTER] key is used to accept the new value.

☞ **Note:** When editing parameter values, be sure to pad significant digit fields with zeroes where appropriate. For example, to change the value of a 4-digit parameter from 1234 to 975 the operator must enter 0975.
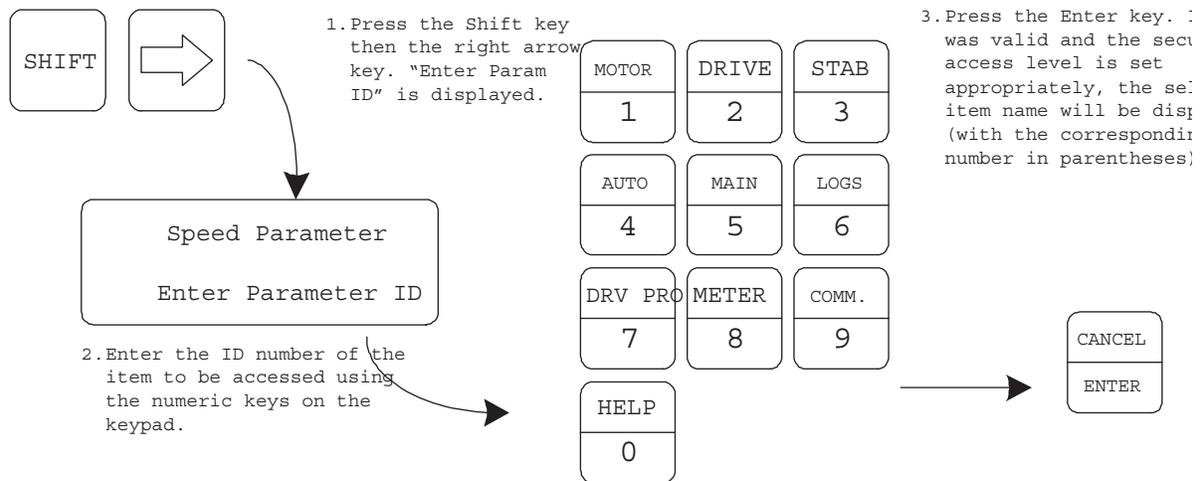
Figure 4-4: Accessing Items Using ID Numbers

> **Note:** In the case of signed parameters (parameter values that can be either positive or negative), the first active digit is actually the sign of the value. The sign is changed by using the up and down arrow keys when the left most (sign) position of the value is underlined (i.e., that is the active "digit"). Either a "+" or "-" will be displayed during the editing process. After the new value is accepted (using the [ENTER] key), positive values are displayed without the "+" sign. Negative values always show the "-" sign unless the negative sign is implied in the parameter name itself.

4.2.6 The Enter/Cancel Key

The [ENTER] key is located below the up and down arrow keys on the right side of the keypad. This key is similar to the Return or Enter key on a standard PC keyboard. It is used to choose/accept a selection or confirm an operation. For example, after locating and displaying a parameter within the Perfect Harmony menu structure, the operator may use the [ENTER] key to edit the parameter's value. Common functions of the [ENTER] key include:

- Selecting a submenu
- Entering edit mode for a selected parameter value
- Accepting a new parameter value after editing
- Initiating a function within the menu system

By using the [SHIFT] key, the [ENTER] key can be used as a cancel function. The secondary function [CANCEL] is listed on the upper portion of the [ENTER] key. The [CANCEL] function is used to abort the current operation or return to the previous menu display. Common functions of the [CANCEL] key include:

- Returning out of the menu system
- Rejecting any modifications to a parameter value in edit mode

4.2.7 Shift Function Keys

The [SHIFT] key is located in the bottom right corner of the keypad on the Perfect Harmony system. This key is used to access a second set of functions using existing keys on the keypad. Keypad keys that can be used with the [SHIFT] key have two labels (one on top and one on the bottom of the key). The standard (un-shifted) function of the key is listed on the bottom half of the key and has a white background. The shifted function of the key is shown on the top of the key and has a green background (matching the green background of the [SHIFT] key to identify that they are used together).

When the Perfect Harmony prompts the operator for a numerical value (e.g., during entry of the security access code, parameter modification, etc.), the [SHIFT] function of numerical keys 1 through 6 changes from quick menus to hexadecimal numbers "A" through "F" respectively. Refer to Table 4-2 for more information.

☞
> **Note:** It is not necessary to simultaneously press the [SHIFT] key and the desired function key. The operator must press the [SHIFT] key first, release it, and then press the desired function key. When the [SHIFT] key is pressed, the word "SHIFT" appears in the lower right corner of the interface display (indicating that the Perfect Harmony is waiting for the second key to be pressed). After a key is pressed, the word SHIFT is removed from the LCD. Refer to Figure 4-5. This Shift Function is a toggle, pressing [SHIFT] again before pressing any other key removes the pending SHIFT and clears the indicator.

Figure 4-5: Location of Shift Mode Indicator on the Perfect Harmony Display

Common functions of the [SHIFT] key include:

- Entering "speed menus" ([SHIFT] plus appropriate "speed menu" key from main meter display).

- Using the [CANCEL] function ([SHIFT] + [ENTER] sequence).

- Entering hex values "A" through "F" ([SHIFT] + [1] through [SHIFT] + [6] when editing values or entering security code).

- Accessing menus, parameters, or pick lists based on ID numbers ([SHIFT] + [⇨]).

- Returning to the top of the current menu/submenu ([SHIFT] + [⇧]).

- Going to the bottom of the menu or submenu ([SHIFT] + [⇩]).

- Resetting the current security level to 0 ([SHIFT] + [⇦] + [SHIFT] + [⇦] + [SHIFT] + [⇦] from the main meter display).

- Setting a parameter value back to its factory default ([SHIFT] + [⇦]), while in the parameter edit function.

A summary of [SHIFT] key sequences is listed in Table 4-3.

4.2.8   Arrow Keys

There are four yellow arrow keys on the Perfect Harmony keypad. The up and down arrow keys ([⇧] and [⇩]) are located in the upper right corner of the keypad. The left and right arrow keys ([⇦] and [⇨]) are located on the lower row of the keypad. Common uses of the arrow keys include:

- Navigating through the menu structure

- Scrolling through lists of parameters

- Incrementing/decremented parameter values (when in edit mode)

- Manually advancing to the next digit (when in edit mode)

- Increasing (up arrow [⇧]) and decreasing (down arrow [⇩]) the desired velocity demand of the drive (when in local manual mode)

- Clearing security level (press [SHIFT] + [⇦] 3 times from the default meter display)

- Entering speed parameter mode ([SHIFT] + [⇨]).

The left and right arrow keys ([⇦] and [⇨]) can be used to navigate through the menu structure of the Perfect Harmony system. In general, the right arrow [⇨] is used to advance to a submenu structure or enter parameter edit mode, and the left arrow [⇦] is used to back out of the menu structure. For example, from the main display the operator can press the right arrow key [⇨] to access the Main menu ([SHIFT]+[5] is a shortcut to the Main menu).

The up and down arrow keys ([⇧] and [⇩]) can be used to scroll through lists of items. For example, after using the right arrow key [⇨] to reach the Main menu, the operator may select the down arrow key [⇩] to scroll through the list of options within the Main menu. These options may be parameters, pick lists, or submenus. Refer to the next section for information about the structure of the menu system.

The up and down arrows ([⇧] and [⇩]) can be used to increment or decrement the desired velocity demand when the system is in local manual mode (refer to section 4.2.4). As the up and down arrow keys are pressed, the changes in desired velocity demand can be viewed from the main display on the LCD. Refer to Figure 4-6.

> **Note:** The velocity demand field (DEMD) on the front panel display is assigned by default. This display assignment (and the other three) can be changed from the menu system.

The menu system can be thought of as a "tree" with the main menu as the trunk. Submenus would then be branches from either the trunk (main menu) or another branch (submenu). Parameters can be thought of as leaves on the trees. For example, while inside a parameter or pick list, selecting [CANCEL] exits to the menu, but inside any menu, selecting [CANCEL] exits to the main display.

Table 4-3: Summary of Common [SHIFT] Key Sequences

Key Combination	Description
SHIFT MOTOR 1	Speed menu to the Motor menu (from the default meter display). Enters hexadecimal "A" (from value edit and security prompts).
SHIFT DRIVE 2	Speed menu to the Drive menu (from the default meter display). Enters hexadecimal "B" (from value edit and security prompts).
SHIFT STAB 3	Speed menu to the Stability menu (from the default meter display). Enters hexadecimal "C" (from value edit and security prompts).
SHIFT AUTO 4	Speed menu to the Auto menu (from the default meter display). Enters hexadecimal "D" (from value edit and security prompts).
SHIFT MAIN 5	Speed menu to the Main menu (from the default meter display). Enters hexadecimal "E" (from value edit and security prompts), [⇨] (right arrow) also enters at this point from outside of the menu system.
SHIFT LOGS 6	Speed menu to the Logs menu (from the default meter display). Enters hexadecimal "F" (from value edit and security prompts).
SHIFT DRV PRO 7	Speed menu to the Drive Protect menu (from the default meter display).
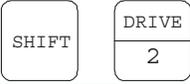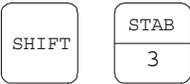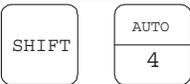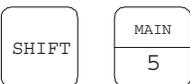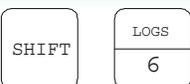
4

Key Combination	Description
[SHIFT] [METER 8]	Speed menu to the Meter menu (from the default meter display).
[SHIFT] [COMM. 9]	Speed menu to the Communications menu (from the default meter display).
[SHIFT] [HELP 0]	Speed menu to a context sensitive Help menu (from anywhere except the default meter display).
[SHIFT] [CANCEL ENTER]	Cancels/aborts the current action/keystroke or exits menu system.
[SHIFT] [⇨]	Enters "numerical menu access mode". The operator is then prompted to enter the 1, 2, or 3 digit number for the associated menu.
[SHIFT] [⇧]	Returns to the top of the current menu or submenu.
[SHIFT] [⇦] [SHIFT] [⇦] [SHIFT] [⇦]	Restores the security level back to 0. The [SHIFT] + [⇦] key sequence must be entered three times in succession from the default meter display to restore the security level back to 0.

Key Combination	Description
SHIFT ⬇	Going to the bottom of the menu or submenu.
SHIFT ⬅	When editing a value that has been changed from its factory default, this key sequence will return the value to its factory default.

4

2. Use the up and down arrow
keys to increase and
decrease the velocity
demand.

The velocity demand is d
dynamically on the front
panel of the Perfect Har

1. Place the drive in
local Manual mode.

```
MANUAL
START
```

```
MODE  DEMD  FREQ  RPM   ITOT
OFF    50    30   890    40
```

Figure 4-6: Using the Up and Down Arrow Keys to Control Velocity Demand

Another feature of the arrow keys is that they can be used to edit the values of parameters. To edit a parameter value, the operator must first navigate through the menu structure (using the arrow keys) and locate the parameter to be changed. With the parameter displayed on the LCD, the operator must press the [ENTER] key. This places the selected parameter into edit mode. Once in edit mode, an underscore is displayed beneath the first (i.e., the most significant) position of the parameter value. Changing the value of that position can be accomplished by pressing the desired numeric key, or by using the up and down arrow keys ([⇧] and [⇩]) to scroll (and wrap around) through the numbers 0 through 9 for that position and also to change the sign of signed number values. When the up and down arrow keys are used, the operator must press the right and left arrow keys ([⇦] and [⇨]) to move to the next (or previous) position in the number to be edited (unlike using the number keys which automatically shift the underscore to the next digit in the number). The operator must press the [ENTER] key to accept the new value or press the [SHIFT] + [ENTER] (i.e., [CANCEL]) to abort the change.

A feature unique to the left arrow key (with the [SHIFT] key) is its ability to cancel the current security mode and return to level 0. An operator can increase the security access level (by entering the appropriate security codes), but cannot lower the security access level using the standard "Change Security Code" option of the Main menu. If an experienced user enters level 7 (or any other security level) and then wishes to return to level 0 when he is finished (for security reasons), he may reset the drive by toggling power to the drive or using the [SHIFT] + [⇦] sequence three times from the main display (i.e., [SHIFT] + [⇦] + [SHIFT] + [⇦] + [SHIFT] + [⇦]). The latter method is a convenient way to reset the security level to 0 without interrupting the operation of the drive. When the security level is reset, the display shows a "Security Level Cleared" message. Refer to Figure 4-7.
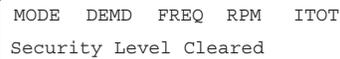
```
MODE  DEMD  FREQ  RPM   ITOT
Security Level Cleared
```

Figure 4-7: Security Level Cleared Message on the Perfect Harmony Display

Note:
- Security will return automatically to level 0 after 15 minutes of inactivity.
- The [SHIFT] + [⇦] + [SHIFT] + [⇦] + [SHIFT] + [⇦] key sequence is valid only when performed from the default meter display.

The speed parameter function is activated by selecting the right arrow key [⇨] used in conjunction with the [SHIFT] key to jump immediately to a menu, parameter, or pick list access feature. The operator can gain access to *all* security approved menus parameters or pick lists. Accessing items in this manner requires that the operator know the ID number associated with the target item. This ID number can be a one, two, three, or four digit number. To access an item using its ID number, press the [SHIFT] key followed by the right arrow key [⇨]. The display prompts the operator for the desired ID number. Using the numeric keys on the keypad, the operator enters the desired ID number and then presses the [ENTER] key. If the number was a valid ID number and the current security level permits access to that item, then the desired item will be displayed. Refer to Figure 4-7. Some common arrow key sequences are listed in Table 4-4. Within the menu structure (not in edit mode), the right arrow acts like the "ENTER" key upon the menu item displayed, while the left arrow climbs the menu hierarchy.

Table 4-4: Summary of Common Arrow Key Sequences
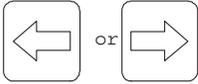
Key Combination	Description
← or →	Used individually to navigate through the menu structure. Also used to change the cursor position in the edit field of a parameter value (when in edit mode). It automatically jumps over a decimal point or field delimiter.
↑ or ↓	Used individually to scroll through lists of menu options, lists, and parameters. Used to change velocity demand (from default meter display). Increments/decrements digits under cursor and changes sign (when in edit mode).
SHIFT →	Enters "speed parameter mode." The operator is then prompted to enter the 1 or 4 digit ID number for the associated item and press the Enter key.
SHIFT ↑	Jumps to the top item of the currently selected menu, submenu, or picklist.
SHIFT ← SHIFT ← SHIFT ←	Restores the security level back to 0. The [SHIFT]+[⇦] (left arrow) key sequence must be entered three times in succession from the default meter display to restore the security level back to 0.
SHIFT ↓	Jumps to the bottom item of the currently selected menu, submenu, or picklist.
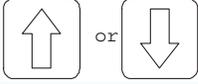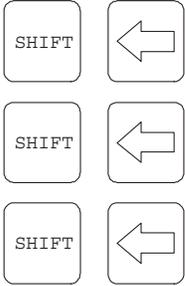
Key Combination	Description
SHIFT ⇐	When editing a value that has been changed from its factory default, this key sequence will return the value to its factory default.

4

4.2.9   Diagnostic Indicators

The standard keypad and display interface also contains 3 diagnostic LED indicators that are located above the display. These are Power On, Fault, and Run. The Power On indicator is lit when control power is supplied to the system. The Run indicator is illuminated when the drive is running. The Fault indicator is lit solidly when one or more system errors have occurred (e.g., boot-up test failure, over voltage fault, etc.). The Fault indicator blinks when one or more alarms are active or unacknowledged. The Fault Reset key must be pressed to clear any existing fault conditions and restore the system to normal operation. Refer to Figure 4-1 for the location of the 3 diagnostic indicators.

4.2.10   The Display

After power up or reset, the Siemens identification and software version number is displayed for 2-3 seconds. Afterwards, the meter display is shown on the LCD by default. The meter display is the starting point of the menuing system. This display remains on the LCD until keys are pressed. In order to re-display the version number, activate the "Display Version Number" function (8090) in the Master Menu (ID=8) (refer to Figure 4-8).
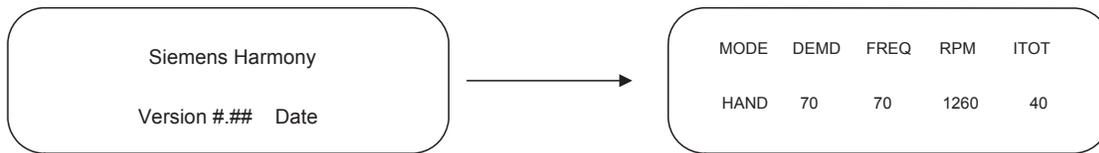
Figure 4-8: The Identification/Version Screen and Meter Displays

The meter display screen contains five fields that are monitored and updated dynamically. These fields are the MODE (the operational mode), DEMD (the velocity demand), RPM (calculated revolutions per minute), VLTS (motor voltage), and ITOT (total output current) fields. The value (or state) of each field is shown dynamically on the second line of the display. Refer to Figure 4-9. The MODE field is fixed. The last 4 fields on the display contain parameter values that can be defined by the operator.
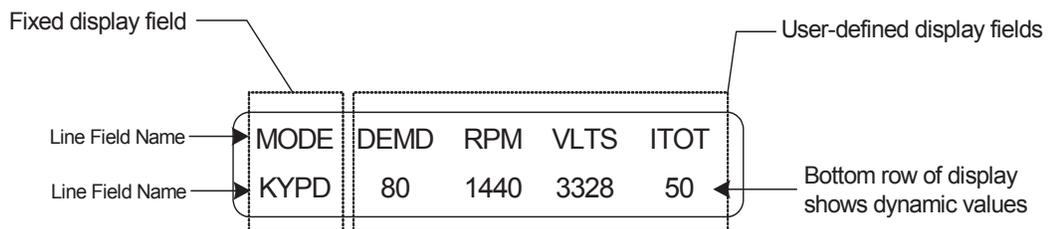
Figure 4-9: Dynamic Programmable Meter Display

The MODE field displays the current operational mode of the Harmony system. This field can have any one of the displays summarized in Table 4-5, depending on the current operational mode or the current state of the drive. Figure

4-10 depicts the display in rollback mode. Note that all four variable displays (from the right) can be selected from a pick list using the Display Parameters (8000).
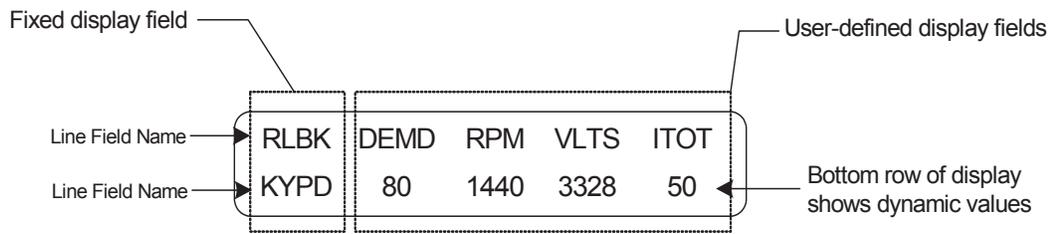
Figure 4-10: Dynamic Programmable Meter Display in Rollback Mode

The KYPD field displays the current operational mode of the Harmony system. This field can have any one of the displays summarized in Table 4-6, depending on the current operational mode or the current state of the drive. Figure 4-11 depicts the display in regeneration mode.
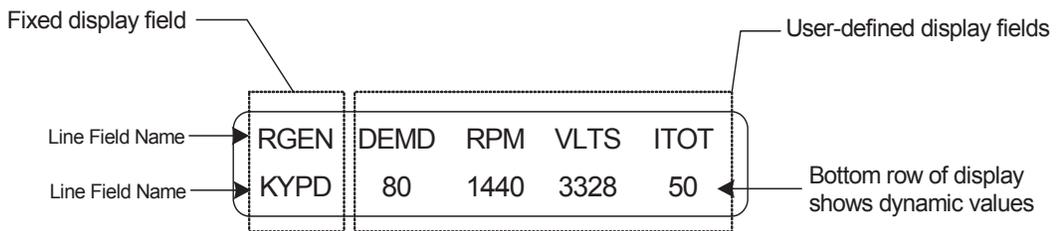
Figure 4-11: Dynamic Programmable Display in Regeneration Mode

The following illustrations depict the 2-line, 24-character display in various modes of access as the operator attempts to locate and change the Ratio Control and Motor Frequency parameters. The Metering display (refer to Figure 4-12) shows the "commanded speed reference" in percent. Figure 4-13 depicts the display following a [SHIFT]+[2] ([DRIVE]) key combination. From this point, the nine standard menus listed in Table 4-7 can then be selected using the up/down arrow keys ([⇧] and [⇩]). Figure 4-14 depicts the display after the down arrow key ([⇩]) is pressed twice and prior to the selection of the Speed Setup Menu (2060). If the [ENTER] or right arrow key ([⇨]) is pressed at this display, the Speed Setup Menu (2060) will be entered. Figure 4-16 depicts the display following a down arrow keystroke to the Ratio Control Parameter (2070). The down arrow key ([⇩]) was pressed once to obtain this display. Figure 4-17 depicts the display once the Ratio control parameter in the Speed Setup Menu (2060) is entered for edit. Note the word edit appears in the display when a parameter is in the edit mode. The left/right arrow keys ([⇦] and [⇨]) can be used to position the cursor under the desired digit (or sign) to be changed. The digit can be set by either using the number keys, or it may be incremented/decremented using the up/down arrow keys ([⇧] and [⇩]). The sign can be changed using the up/down arrow keys. The parameter is selected into memory once the [ENTER] or right arrow key ([⇨]) is pressed. Figure 4-18 depicts the display when a number in the range of the system is entered.

> **Note:** An asterisk (*) is used to denote when a parameter is changed from its current default value. This allows the user to quickly see which parameters have been changed. To return a parameter to its factory value, press [SHIFT] + [⇦] while in edit mode.

4

Figure 4-12: Status Display In Metering Mode
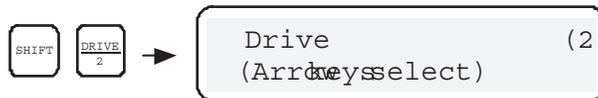
Figure 4-13: Status Display After [SHIFT] + [2] Sequence
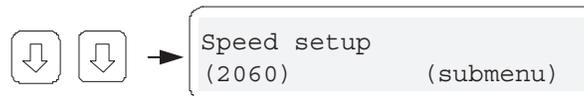
Figure 4-14: Status Display After [⇩] [⇩] Key Sequence
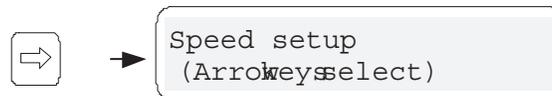
Figure 4-15: Status Display After [⇨] Key Sequence

Figure 4-16: Status Display After [⇩] Key Sequence
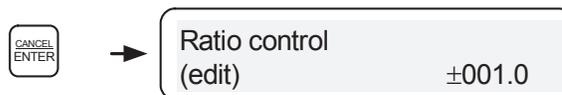
Figure 4-17: Status Display After [ENTER] Key to Change a Parameter

```
 ┌─────────────────────────────┐
 │ Ratio control               │
 │ *(2070)          -03.0       │
 └─────────────────────────────┘
```

Figure 4-18: Status Display Upon Entering a Value In the Range of the System

In the following example, press [SHIFT] [⇨] to get to the Parameter ID display. The parameter ID for Motor Frequency (1020) is entered. See Figure 4-19. The [ENTER] key is pressed once to show the Motor Frequency display, and then [ENTER] is pressed again to edit its value. Figure 4-21 shows the display if an out-of-range Motor Frequency value, such as 010, is entered. Since the range of the variable is 15 to 330, an error message will be displayed for approximately 4 seconds. Then the value shown before the attempted edit is displayed again.

```
┌───────┐  ┌───────┐       ┌─────────────────────────────┐
│ SHIFT │  │  ⇨   │  ──▶  │ Speed Parameter              │
└───────┘  └───────┘       │ Enter Param ID:           1  │
                           └─────────────────────────────┘
```
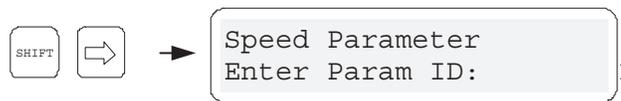
Figure 4-19: Status Display After [SHIFT] [⇨] and the Parameter ID 1020 is Entered

```
┌────────┐ ┌────────┐      ┌─────────────────────────────┐
│ CANCEL │ │ CANCEL │  ──▶ │ Motor Frequency             │
│ ENTER  │ │ ENTER  │      │ (edit)              010     │
└────────┘ └────────┘      └─────────────────────────────┘
```

Figure 4-20: Status Display After [ENTER] [ENTER]

```
 ┌─────────────────────────────┐
 │ Motor Frequency             │
 │    OUT OF RANGE             │
 └─────────────────────────────┘
```
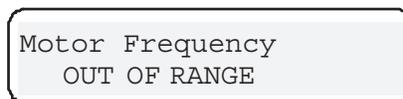
Figure 4-21: Status Display Upon Entering a Value Beyond the range of the System

Table 4-5: Summary of Operation Mode Displays: Line 1 of Mode Display in Order of Precedence

Order	Code	Meaning	Description
1	FRST	Fault reset	Displayed after the [FAULT RESET] button is pressed. *Note*: **This may not be visible** because of the speed of response to a Fault Reset.
2	TLIM	Menu setting rollback	Drive is being limited by a menu setting.
3	SPHS	Single phasing rollback	A Single phasing condition of the input line is limiting drive torque.
4	UVLT	Under voltage rollback	A Under Voltage condition of the input line is limiting the drive torque.
5	T OL	Thermal overload rollback	The drive has limited the amount of torque produced to prevent thermal overload of the input transformer.
6	F WK	Field weakening rollback	This condition exists when the motor flux is low and the application requires high torque. This prevents "motor pull-out," an unstable operating condition of the motor.
7	C OL	Cell overload rollback	A Cell current overload model has calculated a thermal overload condition of the drive cells and the drive has limited the amount of torque produced.
8	NET1	Network 1 limit	Torque limited by network 1 setting.
9	NET2	Network 2 limit	Torque limited by network 2 setting.
10	ALIM	Analog torque Limit	Torque limited by analog input.
11	EALM	External analog Limit	Drive is in speed rollback limit due to external analog limit
12	ENLM	External network Limit	Drive is in speed rollback limit due to external network limit
13	EMLM	External menu Limit	Drive is in speed rollback limit due to external menu limit

Order	Code	Meaning	Description
14	RLBK	Roll back	Appears during acceleration if drive has reached its torque limit setting.
15	RGEN	Regeneration	During normal deceleration, this message will be displayed when the drive is operating in regen torque limit.
16	BRKG	Dual frequency braking	Appears while drive is decelerating with dual frequency braking enabled.
17	BYPS	Cell bypassed	Indicates that one or more cells is in bypass.
18	PRCH	Pre-charge	The Pre-charge mode is rest and micro-voltage is low. The drive will require pre-charge to re-apply the micro-voltage.
19	OLTM	Open loop test mode	Appears if drive control algorithm is set to open loop test mode.
20	MODE	Normal mode display	This is the typical display message during normal operation.

4

Table 4-6: Summary of Operation Mode Displays: Line 2 of Mode Display in Order of Precedence

Order	Code	Meaning	Description
1	NOMV	No medium voltage	No input line voltage detected.
2	INH	CR3 inhibit	The CR3 or "Drive inhibit" input is asserted.
3	OFF	Idle state	The drive is ready to run but is in an idle state.
4	MAGN	Magnetizing motor state	The drive is magnetizing the motor.
5	SPIN	Spinning load state	The drive is trying to detect the speed of the motor to synchronize the drive frequency.
6	UXFR	Up transfer state	The drive is in the "Up Transfer State" preparing to transfer the motor to the input line.
7	DXFR	Down transfer state	The drive is in the "Down Transfer State" preparing to transfer the motor from the input line to the drive.
8	KYPD	Keypad speed demand	The drive speed demand source is the keypad.
9	TEST	Speed/Torque test	The drive is in a Speed or Torque test mode.
10	LOS	Loss of Signal	The drive 4-20mA analog input signal has dropped below a predefined setting.
11	NET1	Network 1	Indicates drive is being controlled from Network 1.
12	NET2	Network 2	Indicates drive is being controlled from Network 2.
13	AUTO	Automatic mode	The SOP flag AutoDisplayMode_O is set true usually to indicate drive is receiving its speed demand from a source other than the keypad or network. Typically used with an analog input speed source.
14	HAND	Hand mode	Appears if the drive is running under normal conditions.

Order	Code	Meaning	Description
15	BRAK	Dynamic Braking	Indicates that dynamic braking is enabled.
16	DECL	Decelerating (no braking)	The drive is decelerating normally.
17	COAS	Coasting to stop	The drive is not controlling the motor and it is coasting to a stop due only to friction.
18	TUNE	Auto Tuning	The drive is in an "Auto Tuning" mode used to determine motor characteristics.

4.3 NXG ToolSuite Overview

The NXG ToolSuite is a PC-based application that integrates various software tools used for NXG-based Drives. With the ToolSuite, you can navigate through a drive's features using a PC and a mouse or touch screen, allowing you to monitor and control that drive's functions quickly and easily. This makes the ToolSuite more convenient to use than a keypad. The NXG ToolSuite is a high-level GUI that runs on a PC equipped with the Microsoft Windows operating system. The NXG control and the PC running the NXG ToolSuite interface with each other using Ethernet and TCP/IP protocol.

The structure of the menu hierarchy is slightly different with this tool than with the Keypad described above. For full coverage of the Drive Tool, refer to the *ToolSuite Manual* (902291).

The ToolSuite contains the following:

   o Drive Tool

   o Debug Tool

   o SOP Utilities

   o Configuration Update Utility

4.3.1   The Drive Tool

The Drive Tool is the main graphical interface to the Drive. Its purpose is to manage all of the drive features and provide the user with a user-friendly view of the drive. The main features of the NXG Drive Tool are:

   o Drive Configuration

   o Drive Variable Graphing

   o Drive Status

   o Drive Control

4.3.2   The Debug Tool

The Debug tool is PC-based application software that provides a remote graphical user interface. The Debug Tool examines Drive variables using a PC and a mouse, allowing the user to monitor a drive's functions quickly and easily. The Debug Tool is a high-level GUI that runs on a PC equipped with the Microsoft Windows operating system.

4.3.3   The SOP Utilities

The SOP Utilities is a group of utilities under the ToolSuite umbrella program. It is launched much the same as the other Tools. It performs most of the functionality on the PC running the ToolSuite, but has serial communications capability for uploading and downloading the system program directly to the drive via an RS232 interface between the drive and the PC.

The purpose of the SOP Utilities Tool is to convert logic statements in the form of Sum-Of-Products (SOP) notation into a form of machine-recognizable code that is run under the built-in drive SOP interpreter. The mechanics of this operation are described in the drive manual and not discussed in this context.

4.3.4   The Configuration Update Utility

The Configuration Update Utility allows updating and configuration of software via the NXG CompactFlash card and the NXG ToolSuite. This utility is intended for use by trained Siemens trained personnel only.

The Configuration Update Utility is a Microsoft Windows based application for creating or updating CompactFlash and ToolSuite software for the NXG Control. When purchased, a CompactFlash memory card needs to be configured and made "bootable" for the real-time operating system that the NXG control uses.

4

4.4 Menu Descriptions

The following sections contain a condensed description of all parameter items available in the Perfect Harmony menu structure. Table 4-7 depicts main menus and submenus of the system. Each menu and submenu is associated with an ID shown in the ID column. The key sequence [SHIFT]+[⇨] ([SHIFT] plus the right arrow key) and up/down arrow keys ([⇧] and [⇩]), as described above, can be used to directly access each menu item

.

> **Note:** To prevent the unauthorized changes to the parameters, you can set a software flag, *KeySwitchLockOut_O*, to true. You will be able to display all parameters as usual. See Chapter 8 for information about setting software flags.

> **Note:**
>
> A help feature for all parameter settings is available by pressing the [SHIFT] + [0] ([HELP]) key sequence on the keypad. This feature provides a text description of the desired selection, plus the parameters minimum and maximum value if applicable. If more than 2 lines of help text are available, the operator may use the up and down arrow keys ([⇧] and [⇩]) to scroll through the entire help message.
>
> Parameters are always hidden in the menu display when there is insufficient security clearance to edit the parameter.
>
> Menu items may be hidden if they do not apply to the current drive configuration. Example: if Spinning load mode (ID 2430) is set to "Off," IDS 2440 through 2480 (spinning load parameters) are not displayed.
>
> Table 4-7 lists menus with associated "Off" submenu names only. Parameters and functions found in these menus are described in the sections that follow. Use the associated table number from Table 4-7 to quickly locate the table in the chapter that explains all of the associated items.
>
> Note that menu items change with new releases of software. Hence the menu system described here may be slightly different than the menu system on your drive. Your drive has help functions for every parameter, and these can be used if the function is not described here.

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Table 4-7: Perfect Harmony Menu and Submenu Summary

Menu	ID	Submenu Names	ID	Table	Description
Motor Menu	1	Motor Parameter	1000	Table 4-8	Used to enter motor-specific data.
		Limits	1120	Table 4-9	
		Autotune	1250	Table 4-11	
		Encoder	1280	Table 4-12	
Drive Menu	2	Drive Parameter	2000	Table 4-13	Used to configure the VFD for various load conditions and drive applications.
		Speed Setup	2060	Table 4-14	
		Torque Reference	2210	Table 4-15	
		Speed Ramp Setup	2260	Table 4-16	
		Critical Frequency	2340	Table 4-17	
		Spinning Load	2420	Table 4-18	
		Conditional Time Setup	2490	Table 4-19	
		Cells	2520	Table 4-20	
		Sync Transfer	2700	Table 4-22	
		External I/O	2800	Table 4-23	
		Output Connection	2900	Table 4-36	
		High Starting Torque	2960	Table 4-37	
		Watchdog	2970	Table 4-38	
Stability Menu	3	Input Processing	3000	Table 4-40	Used to adjust the VFD's various control loop gains, including current and speed regulator gains.
		Output Processing	3050	Table 4-42	
		Control Loop Test	3460	Table 4-48	
Auto Menu	4	Speed Profile	4000	Table 4-50	Used to configure various speed setpoint, profile, and critical speed avoidance and comparator parameters.
		Analog Inputs	4090	Table 4-51	
		Analog Outputs	4660	Table 4-59	
		Speed Setpoints	4240	Table 4-61	
		Incremental Speed Setup	4970	Table 4-62	
		PID Select	4350	Table 4-63	PID Select Menu contains PID setup parameters.
		Comparator Setup	4800	Table 4-64	Used to configure the analog comparators controlled through the SOP.

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Menu	ID	Submenu Names	ID	Table	Description
Main Menu	5	Motor	1	see Motor Menu, above	
		Drive	2	see Drive Menu, above	
		Stability	3	Table 4-39	
		Auto	4	see Auto Menu, above	
		Logs	6	see Logs Menu, below	
		Drive Protect	7	Table 4-75	
		Meter	8	Table 4-78	
		Communications	9	Table 4-83	
		Security Edit Functions	5000	Table 4-68	Configures security features.
Logs Menu	6	Event Log	6180	Table 4-71	Used to configure and inspect the event, alarm/fault, and historic logs of the VFD.
		Alarm/Fault Log	6210	Table 4-72	
		Historic Log	6250	Table 4-73	
Drive Protect Menu	7	Input Protection	7000	Table 4-76	Adjusts setpoint limits for critical VFD variables.
Meter Menu	8	Display Parameters	8000	Table 4-79	Set up Variables for display to LCD.
		Hour Meter Setup	8010	Table 4-81	
		Input Harmonics	8140	Table 4-82	
		Fault display override	8200	Table 4-78	
Communications Menu	9	Serial Port Setup	9010	Table 4-84	Used for configuring the various Communications features of the VFD.
		Network Control	9943	Please refer to *NXG Communications Manual* (number 902399)	
		Network 1 Configure	9900		
		Network 2 Configure	9914		
		Display Network Monitor	9950	Table 4-83	
		Serial echo back test	9180	Please refer to *NXG Communications Manual* (number 902399)	
		Sop & serial functions	9110	Table 4-85	
		TCP/IP Setup	9300	Table 4-86	

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4.4.1 Motor Menu (1) Options

The Motor Menu (**1**) consists of the following menu options:

- Motor Parameter Menu (**1000**)
- Limit Protection Menu (**1120**)
- Autotune Menu (**1250**)
- Encoder Menu (**1280**)

The contents of these menus are explained in the following tables.

Table 4-8: Motor Parameter Menu (1000)

Parameter	ID	Units	Default	Min	Max	Description
Motor frequency	1020	Hz	60	15	330	Enter the rated or base frequency of the motor from the nameplate.
Full load speed	1030	RPM	1780	1	19800	Enter the full load speed of the motor from the nameplate. Full load speed is base or rated speed minus slip.
Motor voltage	1040	V	4160	380	13800	Enter the rated voltage for the motor from the nameplate.
Full load current	1050	A	125.0	12.0	1500.0	Enter the rated nameplate full load current of the motor.
No load current	1060	%	25.0	0.0	100.0	Enter the no load current of the motor, if it is provided, or use the Auto-tune function.
Motor kW rating	1010	kW	746.0	120.0	20000.0	Enter the motor kW (0.746 * Hp) from the nameplate.
Leakage inductance	1070	%	16.0	0.0	30.0	Enter the leakage inductance of the motor if it is provided, or use the Auto-tune function.
Stator resistance	1080	%	0.10	0.00	25.00	Enter the stator resistance of the motor, if it is provided. To convert from ohms to % use the formula: [%Rs = 100 * ÷3 * Rs(*in ohms*) * Motor Current/Motor Voltage], or use the Auto-tune function.
Inertia	1090	Kgm^2	30.0	0.0	100000.0	Enter the rotor inertia of the motor if known ($1Kgm^2$ = 23.24 $lbft^2$), or use the Auto-tune function.
Saliency Constant	1091	%	1.4	0.0	2.5	Ratio of total q-axis 'L' to d-axis mutual 'L'
Max DC Exciter Curr	1105		0.25	0.00	1.00	Max allowed exciter stator current.
Initial Mag Current	1106		0.04	0.00	1.00	Initial mag current for starting SM with DC exciter.

Table 4-9: Limits Menu (1120)

Parameter	ID	Units	Default	Min	Max	Description
Overload select	1130		Constant			Selects the overload trip algorithm: Constant (fixed current-based TOL). Straight Inverse Time (motor temperature-based TOL). Inverse Time with speed derating (motor temperature-based TOL). **Note**: Selecting "constant" here, and setting the next two parameters (1139 & 1140) to max, effectively disables this function.
Overload pending	1139	%	100.0	10.0	210.0	Sets the overload level at which a warning is issued (constant mode).
Overload	1140	%	120.0	20.0	210.0	Sets the overload trip level at which the timeout counter is started (constant mode).
Overload timeout	1150	sec	60.0	0.01	300.0	Sets the time for the overload trip (constant mode).
Speed Derate Curve	1151	Submenu				This menu sets allowable motor load as a function of speed. See Table 4-10.
Motor trip volts	1160	V	4800	5	20,000	Sets the motor over-voltage trip point.
Maximum Load Inertia	1159	Kgm^2	0.0	0.0	500000.0	Sets the maximum load inertia that the motor can line start without exceeding maximum temperature.
Overspeed	1170	%	120.0	0.0	250.0	Sets the motor overspeed trip level as a percentage of rated speed.
Underload enable	1180		Disable			Enables or disables underload protection.
I underload	1182	%	10.0	1.0	90.0	Sets the current underload level based on the rated motor current.
Underload timeout	1186	sec	10.0	0.01	900.0	Sets the time for underload trip.
Motor torque limit 1	1190	%	100.0	0.0	300.0	Sets the motoring torque limit as a function of the rated motor current.
Regen torque limit 1	1200	%	-0.25	-300.0	0.0	Sets the regenerative torque limit as a function of rated motor current at full speed. The limit is allowed to increase inversely with speed.
Motor torque limit 2	1210	%	100.0	0.0	300.0	Sets the motoring torque limit as a function of the available motor current.
Regen torque limit 2	1220	%	-0.25	-300.0	0.0	Sets the regenerative torque limit as a function of rated motor current at full speed. The limit is allowed to increase inversely with speed.

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Parameter	ID	Units	Default	Min	Max	Description
Motor torque limit 3	1230	%	100.0	0.0	300.0	Sets the motoring torque limit as a function of the available motor current.
Regen torque limit 3	1240	%	-0.25	-300.0	0.0	Sets the regenerative torque limit as a function of rated motor current at full speed. The limit is allowed to increase inversely with speed.
Phase Imbalance Limit	1244	%	40.0	0.0	100.0	Sets the current threshold level for the output phase current imbalance alarm.
Ground Fault Limit	1245	%	5.0	0.0	100.0	Sets the threshold of voltage for the output ground fault alarm.
Ground Fault Time Const	1246	sec	0.017	0.001	2.000	Sets the filter time constant for averaging the ground voltage and delaying the response of the ground fault detection.
H/W Ground Fault Enable	1247		Disabled			Enables and disables hardware ground fault detection.
Loss of field level	1141	%	40	5	50	Sets the loss of field (Ids) level.
Loss of field timeout	1142	sec	10	0.5	25	Sets the loss of field timeout period.

Table 4-10: Speed Derate Curve Menu (1151)

Parameter	ID	Units	Default	Min	Max	Description
0 Percent Break Point	1152	%	0.0	0.0	200.0	Sets the maximum motor load at 0% speed.
10 Percent Break Point	1153	%	31.6	0.0	200.0	Sets the maximum motor load at 10% speed.
17 Percent Break Point	1154	%	41.2	0.0	200.0	Sets the maximum motor load at 17% speed.
25 Percent Break Point	1155	%	50.0	0.0	200.0	Sets the maximum motor load at 25% speed.
50 Percent Break Point	1156	%	70.7	0.0	200.0	Sets the maximum motor load at 50% speed.
100 Percent Break Point	1157	%	100.0	0.0	200.0	Sets the maximum motor load at 100% speed.

Table 4-11: Auto-tune Menu (1250)

Parameter	ID	Type	Description
Autotune stage 1	1260	Function	This function determines the stator resistance and leakage inductance of the motor. The motor does not rotate during this stage. If this function is not used, the menu-entered values are used. If the function is used, the parameters will be updated with the calculated values.
Autotune stage 2	1270	Function	This function determines the no-load current and rotor inertia of the motor. The motor rotates during this stage. If this function is not used, the menu entered values are used. **Note:** This should be used in only very special circumstances requiring high response rates, and should only be used under engineering guidance.

Auto-Tuning provides motor information that optimizes the Output Processing Control. Both stages of Auto-Tuning are optional. The user can enter the motor information if available (see Table 4-11). The process is performed in two stages.

Table 4-12: Encoder Menu (1280) (Closed Loop Vector Control Only)

Parameter	ID	Units	Default	Min	Max	Description
Encoder 1 PPR	1290		720	1	10000	Rated number of pulses per revolution delivered by the encoder. (Nameplate value).
Encoder filter gain	1300		0.0	0.0	0.999	Sets the gain of the filter for encoder feedback. This parameter can have a value between 0.0 (no filtering) and 0.999 (maximum filtering).
Encoder loss threshold	1310	%	0.0	0.0	75.0	Sets the level for the error between encoder output and calculated motor speed to determine encoder loss.
Encoder loss response	1320		Open Loop			Sets the drive response to a loss of encoder event. Stop (on Fault) Open Loop (control)

4.4.2   Drive Menu (2) Options

The Drive Menu (**2**) consists of the following submenus:

- (**2000**) Drive Parameter Menu
- (**2060**) Speed Setup Menu
- (**2210**) Torque Reference Menu
- (**2260**) Speed Ramp Setup Menu
- (**2340**) Critical Frequency Menu
- (**2420**) Spinning Load Menu
- (**2490**) Conditional Timer Menu
- (**2520**) Cell Menu
- (**2700**) Sync Transfer Menu
- (**2800**) External I/O Menu
- (**2805**) Internal I/O Menu
- (**2900**) Output Connection Menu
- (**2960**) High Starting Torque Menu
- (**2970**) Watchdog Menu

Contents of these menus are explained in the tables that follow.

Table 4-13: Drive Parameter Menu (2000)

Parameter	ID	Units	Default	Min	Max	Description
Rated input voltage	2010	V	4160	200	125000	Rated RMS input voltage of the drive. Set according to the input transformer primary voltage rating. **Note:** The input attenuator kit should always correspond to the rated primary voltage of the transformer.
Rated input current	2020	A	100.0	12.0	3000.0	Rated RMS input current of the drive. Set according to input transformer nameplate kVA rating as noted below.*
Rated output voltage	2030	V	4160	200	23000	Rated drive output voltage RMS. Set according to the rating of the output attenuator kit. **Note:** This value is typically equal to or higher than the motor voltage rating.
Rated output current	2040	A	100.0	12.0	1500.0	Rated drive output current RMS. Set equal to the cell (output) current rating. **Note:** The output Hall Effects and burden resistors should be sized for the cell current rating.
Rated Leading Vars	2042	%	50	0	75	Rated leading VARs (%)
Rated Lagging Vars	2043	%	50	0	75	Rated lagging VARs (%)
Control loop type See Note below.	2050		OLVC			Control loop algorithm type selection.Volts per Hertz (V/Hz) for parallel motors. Open Loop Vector Control (OLVC) for single induction motors. Closed Loop Vector Control (CLVC) for single induction motors with speed sensor(s). Open Loop Test Mode (OLTM) for checking cell modulation and testing Hall-effect transducer. Synchronous Motor Control (SMC) without speed sensor. Closed Loop Synchronous Motor Control (CSMC) with speed sensor. Synchronous Motor Brushless DC exciter mode (SMDC) which automatically sets High Starting Torque.
Parallel system	2051		Disable			Enable parallel system.

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Parameter	ID	Units	Default	Min	Max	Description
Drives/motor winding	2052		1	1	99	Number of drives connected to a single motor
Number of windings	2053		1	1	99	Number of motor windings
Drive index	2054		0	0	255	Drive sequence number determined by PLC
Node Id	2055		0	0	255	Shared memory card unique node ID.
Service Mode	2056		0	0	99999	Service mode register.
Aux storage	2057					This menu holds PLC storage registers.

☞ **Note:** Changing the control loop algorithm type to open loop test mode (OLTM) or Volts/Hz (V/Hz) disables fast bypass and turns off spinning load by changing those parameters (2600 and 2430 respectively).

* The calculation is derived as follows:

Rated Input Current   =   [(kVA rating) x (802)] ÷ [($\sqrt{3}$) x (Rated nominal primary voltage) x (0.96) x (0.94)]

                    =   [(kVA rating) ÷ (Rated nominal primary voltage)] x 513.11

☞ **Note:** The parameters discussed are based on hardware used within the drive and on the design limits of drive components. These settings should not be changed in the field to match the conditions on the site unless hardware modifications have been made and approval from applications engineering has been obtained.

Table 4-14: Speed Setup Menu (2060)

Parameter	ID	Units	Default	Min	Max	Description
Ratio control	2070		100.0	-250.0	250.0	Used to adjust the scaling of the speed reference value.
Speed fwd max limit 1	2080	%	100.0	0.0	200.0	The forward max speed reference limit 1.
Speed fwd min limit 1	2090	%	0.0	0.0	200.0	The forward min speed reference limit 1.
Speed fwd max limit 2	2100	%	100.0	0.0	200.0	The forward max speed reference limit 2.
Speed fwd min limit 2	2110	%	0.0	0.0	200.0	The forward min speed reference limit 2.
Speed fwd max limit 3	2120	%	100.0	0.0	200.0	The forward max speed reference limit 3.
Speed fwd min limit 3	2130	%	0.0	0.0	200.0	The forward min speed reference limit 3.
Speed rev max limit 1	2140	%	-100.0	-200.0	0.0	The reverse max speed reference limit 1.
Speed rev min limit 1	2150	%	0.0	-200.0	0.0	The reverse min speed reference limit 1.
Speed rev max limit 2	2160	%	-100.0	-200.0	0.0	The reverse max speed reference limit 2.
Speed rev min limit 2	2170	%	0.0	-200.0	0.0	The reverse min speed reference limit 2.
Speed rev max limit 3	2180	%	-100.0	-200.0	0.0	The reverse max speed reference limit 3.
Speed rev min limit 3	2190	%	0.0	-200.0	0.0	The reverse min speed reference limit 3.
Zero speed	2200	%	0.0	0.0	100.0	The zero speed threshold value. This is used for the threshold of the "Minimum Speed Trip" (or alarm).

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Table 4-15: Torque Reference Menu (2210)

Parameter	ID	Units	Default	Min	Max	Description
SOP / Menu control	2211					Control using SOP flags or through menus.
Torque setpoint	2220	%	0	-125	125	Sets the desired torque setpoint
Holding torque	2230	%	0	-100	100	Additional torque that is added to the output of the speed regulator for holding.
Torque ramp increase	2240	sec	1	0.01	10	Time to ramp torque.
Torque ramp decrease	2250	sec	1	0.01	10	Time to ramp torque.
Torque command scalar	2242		1	-1.25	1.25	Scalar used for torque command.

Table 4-16: Speed Ramp Setup Menu (2260)

Parameter	ID	Units	Default	Min	Max	Description
Accel time 1	2270	sec	5.0	0.0	3200.0	Acceleration time 1 in second.
Decel time 1	2280	sec	5.0	0.0	3200.0	Deceleration time 1 in second.
Accel time 2	2290	sec	5.0	0.0	3200.0	Acceleration time 2 in seconds.
Decel time 2	2300	sec	5.0	0.0	3200.0	Deceleration time 2 in seconds.
Accel time 3	2310	sec	5.0	0.0	3200.0	Acceleration time 3 in seconds.
Decel time 3	2320	sec	5.0	0.0	3200.0	Deceleration time 3 in seconds.
Jerk rate	2330		0.1	0.0	3200.0	Jerk rate in time to reach an acceleration rate that will achieve rated velocity in 1 sec.

Table 4-17: Critical Frequency Menu (2340)

Parameter	ID	Units	Default	Min	Max	Description
Skip center freq 1	2350	Hz	15.0	0.0	360.0	Enter the center of the first critical frequency band to be avoided.
Skip center freq 2	2360	Hz	30.0	0.0	360.0	Enter the center of the second critical frequency band to be avoided.
Skip center freq 3	2370	Hz	45.0	0.0	360.0	Enter the center of the third critical frequency band to be avoided.
Skip bandwidth 1	2380	Hz	0.0	0.0	6.0	Enter the bandwidth of the first critical frequency band to be avoided.
Skip bandwidth 2	2390	Hz	0.0	0.0	6.0	Enter the bandwidth of the second critical frequency band to be avoided.
Skip bandwidth 3	2400	Hz	0.0	0.0	6.0	Enter the bandwidth of the third critical frequency band to be avoided.

The critical frequency feature (sometimes called resonance avoidance) is accomplished using skip frequencies and skip bands as defined in Table 4-17. This is illustrated in Figure 4-22.
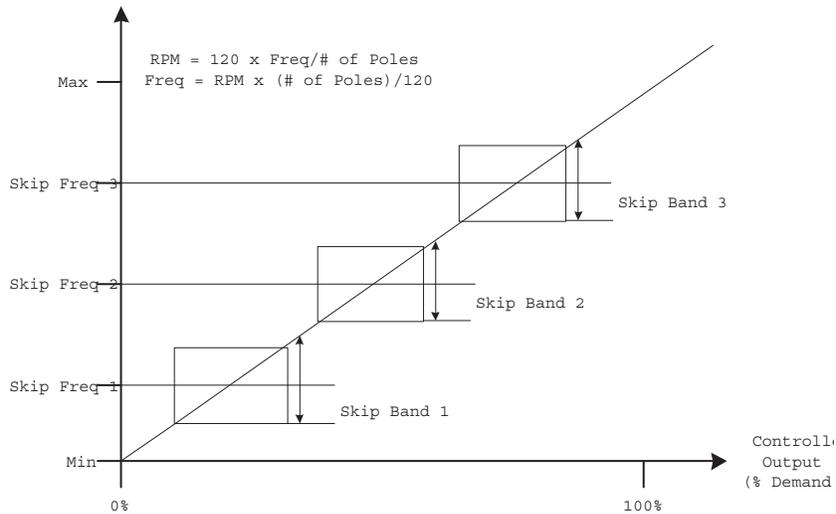
Figure 4-22: . Critical Speed (Resonance Avoidance) Parameters

Table 4-18: Spinning Load Menu (2420)

Parameter	ID	Units	Default	Min	Max	Description
Spinning load mode See Note below	2430		Off			Enable/Disable Spinning Load and set the direction of frequency scans: • Off • Forward • Reverse • Both (scans first in the forward direction, then in the reverse direction)
Scan end threshold	2440	%	20.0	1.0	50.0	Point where scan ends if motor flux is above this level, as a percentage of motor rated flux.
Current Level Setpoint	2450	%	15.0	1.0	50.0	Sets the drive current level (I_d), as a percentage of motor rated current, used during scanning.
Current ramp	2460	sec	0.01	0.00	5.00	Time to ramp drive current (I_d) to Current Level Setpoint.
Max current	2470	%	50.0	1.0	50.0	Sets the current trip level, as a percentage of motor rated current, for scanning. Use the default value of 50%.
Frequency scan rate	2480	sec	3.00	0.00	5.00	Sets the time taken to scan from rated speed to zero. The default value of 3.00 sec should be satisfactory for most cases.

Note: If spinning load mode is disabled from this parameter, it will enable automatically on an as-needed basis; however, this occurs *only* when fast bypass is enabled and *only* for the duration of the bypass. This is an internal action that does not require user intervention, nor does it affect the spinning load mode parameter.

Table 4-19: Conditional Timer Setup Menu (2490)

Parameter	ID	Units	Default	Min	Max	Description
Cond stop timer	2500	sec	0.8	0.0	999.9	Dwell time after stop is invoked. User function defined. (Not currently implemented.)
Cond run timer	2510	sec	0.8	0.0	999.9	Dwell time after start is invoked. User function defined. (Not currently implemented.)

Table 4-20: Cell Menu (2520)

Parameter	ID	Units	Default	Min	Max	Description
Installed cells/phase	2530		4	1	8	Installed cells per phase in the drive.
Min cells/phase count (n/3)	2540		4	1	8	Minimum cells per phase count. Due to neutral point shifting, 3 times this number, allowing one active cell per phase, is the minimum allowable cells (n) permitted to run in a system, allowing for the shift in the neutral point.
Cell voltage	2550	Vrms	630			Sets the value of the cell rated voltage: 460V 630V 690V 750V (MicroHarmony Systems) 1375V (High Voltage Cell Systems) 600V AP AFE (PWM Regen) 750V AP 750V AP 4Q (Six-Step Regen)
Thermistor warn level	2560	%	20.0	5.0	70.0	Sets the level at which a temperature alarm is generated.
Contactor settling time	2570	msec	250.0	0.0	1000.0	Time taken by bypass contactors to change state. Use 100ms for small contactors and 250ms for larger ones. **Note:** The default is not adequate for larger contactors.
Max back EMF decay time	2580	sec	7.0	0.0	10.0	Sets the maximum time that the control waits for the motor voltage to decay while attempting a fast bypass. Once cell fault(s) occurs, the drive may not be able to support actual motor voltage. If the motor voltage does not decay below the max drive voltage capability (with the faulted cell(s)) within the time set by this parameter, the drive issues a fault.
Bypass Type	2590		Mech			Designates the type of bypass in the drive: Mechanical None

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Parameter	ID	Units	Default	Min	Max	Description
Fast bypass	2600		Disable			This parameter enables or disables fast cell bypass. Disabling fast bypass with mechanical contactors will still provide manual bypass after a manual reset.
AP Settings	2585	Submenu				AFE cell settings.
Display Cell Status	2610	Function				Displays cell status: A = active B = bypassed F = faulted Format is all A phase, followed by all B phase, followed by all C phase.
Display Bypass Status	2620	Function				Displays bypass status: Same format as for cell status. A = available B = active U = unavailable
Reset Bypassed Cells	2640	Function				Allows bypassed cells to be reset when the drive is in an **idle** state. Use the reset function only after verifying that the problems with the faulted cell(s) have been resolved.
Neutral Connection	2630		T2			Sets the pole inversion type based on the cell neutral connection point. Select the terminal, T1 or T2, which forms the neutral connection. This selection depends on the terminal of cells A1, B1, and C1 that is used to form the drive start-point neutral.
Precharge enable	2635		off			Enables input transformer precharge for the protection of cells from in-rush current. • TYPE 1 "Resonant Precharge" 3CB • TYPE 2 "Resonant Precharge" 2CB • TYPE 3 Parallel Drive • TYPE 4 µH • TYPE 5 Open (750V AP and 750V AP 4Q)
Precharge delay time	2636	sec	1.0	0.0	10.0	Time delay between end of precharge and start of cell diagnostics

Parameter	ID	Units	Default	Min	Max	Description
Precharge service mode	2637		0	0	1	Precharge maintenance mode. Run from secondary transformer.
Precharge service start	2638		0	0	1	Start running in maintenance mode. Run from secondary transformer.

To precharge WCIII, parameter 2635, 'Precharge Enable,' must be set to 'Type 5 Open.' Parameter 2550, 'Cell Voltage,' must be set to either '750V AP' or '750V AP 4Q.' Refer to the *WCIII Product User Manual* (19001590) for more information on the 750 V AP cell.

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> ⚠ **Warning!**
>
> The drive will not work properly if relevant parameters are not set correctly.

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Table 4-21: AP Settings (2585)

Parameter	ID	Units	Default	Min	Max	Description
AP Cells/phase	2581		0	0	8	Enter number of AFE cells installed per phase.
AP cell current rating	2582	A	787	300	1500	Sets AFE input current rating for cell.
AP cell overcurrent	2621	%	165	100	180	Sets AFE overcurrent rating for cell.
AFE cell input reactance	2583	µH	242	50	500	Sets AFE per phase input line reactance.
AP cell PWM harmonic	2584		6			This parameter selects the AFE cell PWM frequency as a multiple of the fundamental frequency.
AP cell control mode	2586		1			This parameter selects the AFE cell control algorithm.
AFE cell DC P gain	2587		1.24	0.5	3.3	Sets the AFE cell DC control proportional constant.
AP cell DC I gain	2588		4.8435	1	10	Sets the AFE cell DC control integral constant.
AP cell Id P gain	2589		0.2187	0.0078	4	Sets the AFE cell real current regulator proportional constant.
AP cell Id I gain	2591		46.875	5.859	3000	Sets the AFE cell real current regulator integral constant.
AP cell Id D gain	2592	x100	0.0166	0	0.0333	Sets the AFE cell real current regulator derivative constant.
AP cell Iq P gain	2593		0.2187	0.0078	4	Sets the AFE cell reactive current regulator proportional constant.
AP cell Iq I gain	2594		46.875	5.859	3000	Sets the AFE cell reactive current regulator integral constant.
AP cell Iq D gain	2595	x100	0.0166	0	0.0333	Sets the AFE cell reactive current regulator derivative constant.
AP diff temp fault lvl	2596	deg	24	10	30	Sets the AFE cell maximum temperature differential before fault.
AP Mplx Data Select	2597					Selects the source of the AFE cell multiplexed data.
AP sync ang offset	2579	deg	0	-180	180	Sets the AFE cell carrier sync angle offset for all cells. Used to offset drive carriers among two or more drives.
Set Angles	2598					Sets the AFE cell angles as they relate to the primary voltage.
AP cell ang off 1	2571	deg	-181	-181	180	Sets the AFE cell angle offset from the transformer primary voltage for this rank; -181 indicates AFE cells are not installed on this rank.

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Parameter	ID	Units	Default	Min	Max	Description
AP cell ang off 2	2572	deg	-181	-181	180	Sets the AFE cell angle offset from the transformer primary voltage for this rank; -181 indicates AFE cells are not installed on this rank.
AP cell ang off 3	2573	deg	-181	-181	180	Sets the AFE cell angle offset from the transformer primary voltage for this rank; -181 indicates AFE cells are not installed on this rank.
AP cell ang off 4	2574	deg	-181	-181	180	Sets the AFE cell angle offset from the transformer primary voltage for this rank; -181 indicates AFE cells are not installed on this rank.
AP cell ang off 5	2575	deg	-181	-181	180	Sets the AFE cell angle offset from the transformer primary voltage for this rank; -181 indicates AFE cells are not installed on this rank.
AP cell ang off 6	2576	deg	-181	-181	180	Sets the AFE cell angle offset from the transformer primary voltage for this rank; -181 indicates AFE cells are not installed on this rank.
AP cell ang off 7	2577	deg	-181	-181	180	Sets the AFE cell angle offset from the transformer primary voltage for this rank; -181 indicates AFE cells are not installed on this rank.
AP cell ang off 8	2578	deg	-181	-181	180	Sets the AFE cell angle offset from the transformer primary voltage for this rank; -181 indicates AFE cells are not installed on this rank.
AP enable mask	2599		-1	-1	16777215	Masks AFE cell operation. Each bit enables an AFE cell; -1 enables all AFE cells.
Regen OV I gain	2623		0.0010	0.0001	1.000	Regen overvoltage rollback regulator integral gain *
Regen OV P gain	2624		0.0000	0.0000	10.0000	Regen overvoltage rollback regulator proportional gain *
Regen Shift Angle	2625	deg	0.00	-11.25	11.25	Regen angle adjustment *

* Default values are recommended

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Table 4-22: Sync Transfer Menu (2700)

Parameter	ID	Units	Default	Min	Max	Description
Phase I gain	2710		2.0	0.0	15.0	Phase integrator gain.
Phase P gain	2720		4.0	1.0	12.0	Phase proportional gain.
Phase offset	2730	deg	2.0	-90.0	90.0	Specifies the phase angle setpoint used during Up Transfer. This is set positive, expressed in degrees leading to prevent power flow back into drive.
Phase error threshold	2740	deg	1.5	0.0	5.0	Specifies the phase synchronization error window during Up Transfer. This parameter adjusts the amount of error allowed during phase-locking and is expressed in degrees.
Frequency Offset	2750	%	0.5	-10.0	10.0	Frequency offset used during Down Transfer.
Up Transfer Timeout	2760	sec	0.0	0.0	600.0	If the time taken for Up Transfer exceeds this value, then an Up Transfer Timeout Fault is generated. This setting should be greater than the acceleration time setting (2270, 2290, or 2310). Setting zero disables the timeout fault.
Down Transfer Timeout	2770	Sec	0.0	0.0	600.0	If the time taken for Down Transfer exceeds this value, then a Down Transfer Timeout Fault is generated. This is unaffected by the acceleration rate and zero disables the timeout fault.

Table 4-23: External I/O Menu (2800)

Parameter	ID	Units	Default	Min	Max	Description
Analog Inputs	2810		0	0	24	Sets the quantity of analog inputs in the attached external I/O.
Analog Outputs	2820		0	0	16	Sets the quantity of analog outputs in the attached external I/O.
Digital Inputs	2830		0	0	96	Sets the quantity of digital inputs in the attached external I/O.
Digital Outputs	2840		0	0	64	Sets the quantity of digital outputs in the attached external I/O.
Wago timeout	2850	sec	0	0	600	Sets the Wago watchdog timeout period. Setting to zero disables this function.

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4.4.3   Internal I/O

The Internal I/O Menu (**2805**) consists of the following submenus:

- (**2815**) Internal Analog Input #1 Setup Menu
- (**2825**) Internal Analog Input #2 Setup Menu
- (**2835**) Internal Analog Input #3 Setup Menu
- (**2845**) Internal Analog Output #1 Menu
- (**2855**) Internal Analog Output #2 Menu
- (**2860**) Internal Test Point #28 Setup Menu
- (**2865**) Internal Test Point #29 Setup Menu
- (**2870**) Internal Test Point #31 Setup Menu
- (**2875**) Internal Test Point #24 Setup Menu
- (**2880**) Internal Test Point #25 Setup Menu
- (**2885**) Internal Test Point #26 Setup Menu

Contents of these menus are explained in the tables that follow.

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Table 4-24: Internal I/O Menu (2805)

Parameter	ID	Units	Default	Min	Max	Description
Internal Analog Input #1 Setup Menu	2815	Submenu				Contains the Setup menu for Internal Analog Input #1. See Table 4-25
Internal Analog Input #2 Setup Menu	2825	Submenu				Contains the Setup menu for Internal Analog Input #2. See Table 4-26
Internal Analog Input #3 Setup Menu	2835	Submenu				Contains the Setup menu for Internal Analog Input #3. See Table 4-27
Internal Analog Output #1 Menu	2845	Submenu				Contains the Setup menu for Internal Analog Output #1. See Table 4-28
Internal Analog Output #2 Menu	2855	Submenu				Contains the Setup menu for Internal Analog Output #2. See Table 4-29
Internal Test Point #28 Setup Menu	2860	Submenu				Contains the Setup menu for Internal Test Point #28. See Table 4-30
Internal Test Point #29 Setup Menu	2865	Submenu				Contains the Setup menu for Internal Test Point #29. See Table 4-31
Internal Test Point #31 Setup Menu	2870	Submenu				Contains the Setup menu for Internal Test Point #31. See Table 4-32
Internal Test Point #24 Setup Menu	2875	Submenu				Contains the Setup menu for Internal Test Point #24. See Table 4-33
Internal Test Point #25 Setup Menu	2880	Submenu				Contains the Setup menu for Internal Test Point #25. See Table 4-34
Internal Test Point #26 Setup Menu	2885	Submenu				Contains the Setup menu for Internal Test Point #26. See Table 4-35

Table 4-25: Internal Analog Input #1 Menu (2815)

Parameter	ID	Units	Default	Min	Max	Description
Type	2816		1			This parameter sets the operational mode for internal AI1
Hardware Zero	2817		0	-200	200	Internal Analog Input #1 Zero
Hardware Span	2818		1	0.75	1.25	Internal Analog Input #1 Span

Table 4-26: Internal Analog Input #2 Menu (2825)

Parameter	ID	Units	Default	Min	Max	Description
Type	2826		1			This parameter sets the operational mode for internal AI2
Hardware Zero	2827		0	-200	200	Internal Analog Input #2 Zero
Hardware Span	2828		1	0.75	1.25	Internal Analog Input #2 Span

Table 4-27: Internal Analog Input #3 Menu (2835)

Parameter	ID	Units	Default	Min	Max	Description
Type	2836		1			This parameter sets the operational mode for internal AI3
Hardware Zero	2837		0	-200	200	Internal Analog Input #3 Zero
Hardware Span	2838		1	0.75	1.25	Internal Analog Input #3 Span

Table 4-28: Internal Analog Output #1 Menu (2845)

Parameter	ID	Units	Default	Min	Max	Description
Analog variable	2846		1			Internal Analog output #1 source
Full range	2847	%	100	0	300	Scales output range of selected variable
Output Mode	2848		0			Internal Analog Output #1 Mode
Output Min	2841	%	0	-300	300	Internal Analog Output #1 Minimum
Output Max	2842	%	100	-300	300	Internal Analog Output #1 Maximum
Hardware Zero	2843		0	-200	200	Internal Analog Input #1 Zero
Hardware Span	2844		1	0.75	1.25	Internal Analog Input #1 Span

Table 4-29: Internal Analog Output #2 Menu (2855)

Parameter	ID	Units	Default	Min	Max	Description
Analog variable	2856		1			Internal Analog output #2 source
Full range	2857	%	100	0	300	Scales output range of selected variable
Output Mode	2858		0			Internal Analog Output #2 Mode
Output Min	2851	%	0	-300	300	Internal Analog Output #2 Minimum
Output Max	2852	%	100	-300	300	Internal Analog Output #2 Maximum
Hardware Zero	2853		0	-200	200	Internal Analog Input #2 Zero
Hardware Span	2854		1	0.75	1.25	Internal Analog Input #2 Span

Table 4-30: Internal Test Point #28 Menu (2860)

Parameter	ID	Units	Default	Min	Max	Description
Analog variable	2861		0			Internal Test point #28 source
TP 28 Scaler	2862		0	0	1000	Scales output range of selected variable

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Table 4-31: Internal Test Point #29 Menu (2865)

Parameter	ID	Units	Default	Min	Max	Description
Analog variable	2866		0			Internal Test point #29 source
TP 29 Scaler	2867		0	0	1000	Scales output range of selected variable

Table 4-32: Internal Test Point #31 Menu (2870)

Parameter	ID	Units	Default	Min	Max	Description
Analog variable	2871		0			Internal Test point #31 source
TP 31 Scaler	2872		0	0	1000	Scales output range of selected variable

Table 4-33: Internal Test Point #24 Menu (2875)

Parameter	ID	Units	Default	Min	Max	Description
Analog variable	2876		0			Internal Test point #24 source
TP 24 Scaler	2877		0	0	1000	Scales output range of selected variable

Table 4-34: Internal Test Point #25 Menu (2880)

Parameter	ID	Units	Default	Min	Max	Description
Analog variable	2881		0			Internal Test point #25 source
TP 25 Scaler	2882		0	0	1000	Scales output range of selected variable

Table 4-35: Internal Test Point #26 Menu (2885)

Parameter	ID	Units	Default	Min	Max	Description
Analog variable	2886		0			Internal Test point #26 source
TP 26 Scaler	2887		0	0	1000	Scales output range of selected variable

Table 4-36: Output Connection Menu (2900)

Parameter	ID	Units	Default	Min	Max	Description
Filter CT Secondary Turns	2910		0	0	250	Secondary side turns (assuming primary turns = 5) of the CTs used to measure filter capacitor currents.
Filter Inductance	2920	%	0.0	0.0	20.0	Sets the output filter inductor (impedance) value as a ratio of the base output impedance of the drive (typically 5%).
Filter Capacitance	2930	%	0.0	0.0	20.0	Sets the output filter capacitor (admittance) value as a ratio of the base output admittance of the drive (typically 10%). Admittance is the inverse of impedance.
Cable Resistance	2940	%	0.0	0.0	50.0	Output cable resistance value as a ratio of the base output impedance of the drive.
Cable inductance	2941	%	0.0	0.0	50.0	Output cable inductance used for long runs of cable.
Filter damping gain	2950		0.50	-5.00	5.00	Controls the gain for damping oscillations due to output filter. Use a positive constant (typically 0.5) with short cable lengths (< 30,000 feet) and a negative constant (typically -0.5) for long cable lengths.

Table 4-37: High Starting Torque Menu (2960)

Parameter	ID	Units	Default	Min	Max	Description
Enable high torque	2961		0			This parameter enables or disables high starting torque mode.
Torque current	2962	%	50	0	125	Torque current used in high starting torque mode.
Current ramp time	2963	sec	0.5	0	5	Ramp time for high starting torque mode.
PLL Acq time	2964	sec	2	0	5	Settling time for PLL in high starting torque mode.

Table 4-38: Watchdog Menu (2970)

Parameter	ID	Units	Default	Min	Max	Description
Enable watchdog	2971		0			This parameter enables or disables high starting torque mode.

4.4.4   Stability Menu (3) Options

The Stability Menu (**3**) consists of the following menu options:

- (**3000**) Input Processing Menu
- (**3050**) Output Processing Menu
- (**3460**) Control Loop Test Menu
- (**3550**) Dead Time Compensation
- (**3560**) Feed Forward Constant
- (**3580**) Carrier Frequency

The Stability Menu also contains additional menus and parameters. These menus and parameters are explained in tables that follow.

Table 4-39: Stability Menu (3)

Parameter	ID	Units	Default	Min	Max	Description
Input Processing Menu	3000	Submenu				Contains all of the sub menus related to drive line side processing. See Table 4-40.
Output Processing Menu	3050	Submenu				Contains all of the sub menus related to drive motor side processing. See Table 4-42.
Control Loop Test Menu	3460	Submenu				Contains all of the sub menus related to speed and torque loop testing. See Table 4-49.
Dead time comp	3550	msec	16.0	0.0	50.0	Sets the dead time (or firing delay time) of the IGBTs for software compensation.
Feed forward constant	3560		0.0	0.0	1.0	Sets the gain for voltage feed forward. This is used to improve the torque current regulator response.
Carrier frequency	3580	Hz	400.0	100.0	1500.0	IGBT switching frequency. The control adjusts the entered value according to available resolution from the modulator registers (e.g., if you enter 400.0 the actual frequency may be 398.6).

Table 4-40: Input Processing Menu (3000)

Parameter	ID	Units	Default	Min	Max	Description
PLL prop gain	3010		70.0	0.0	200.0	Proportional gain of input phase locked loop (PLL).
PLL integral gain	3020		3840.0	0.0	12000.0	Integral gain of input PLL.
Input current scaler	3030		1.0	0.0	2.0	Sets the scaling for input current feedback. Normally should be set to 1.0.
CT Turns	3035		200	50	3000	Secondary side turns for input current CT (with primary turns equal to 5).
Input voltage scaler	3040		1.0	0.0	2.0	Sets the scaling for input line voltage feedback. Normally should be set to 1.0.
PT secondary turns	3011		1	1	3000	Secondary turns input voltage PT.
Var Control	3041	Submenu				This menu contains the cell input control parameters.
Input Attenuator Sum	3045	kOhm	3000	100	10000	Sets scaling for input nominal value. This is the sum of the two input resistors per phase.

Table 4-41: Var Control Menu (3041)

Parameter	ID	Units	Default	Min	Max	Description
VAR prop gain	3042		0.2	0	200	VAR PI regulator proportional gain term.
VAR integral gain	3043		0.1	0	1200	VAR PI regulator integral gain term.
AFE Vd scaler	3036		1	0	2	Scaler for input voltage to AFE Vd feed forward.
AFE Id scaler	3037		0	0	2	Scaler for input Id to AFE Id feed forward.
AFE Iq scaler	3038		1	0	2	Scaler for Var regulator output to AFE Iq command.
AFE current scaler	3039		0.745	0	2	Scaler to match AFE cell per unit current with drive per unit current.
AFE Iq limit filter	3044		0.95	0.5	1	Filter constant for AFE Iq limit.
AFE Sat. filter	3046		1	0	3	Weight applied to Var error depending upon how many AFE cells are in saturation.

Table 4-42: Output Processing Menu (3050)

Parameter	ID	Units	Default	Min	Max	Description
Low freq comp	3060	Submenu				Menu contains parameters that affect motor flux calculation. See Table 4-43.
Flux control	3100	Submenu				This menu contains the flux control parameters. See Table 4-44.
Speed loop	3200	Submenu				This menu contains the speed loop parameters. See Table 4-45.
Current loop	3250	Submenu				This menu contains the current loop parameters. See Table 4-46.
Stator resistance	3300	Submenu				This menu contains the stator resistance estimator parameters. See Table 4-47.
Braking	3350	Submenu				This menu contains the dual frequency braking parameters. See Table 4-48.
Output current scaler	3440		1.0	0.0	2.0	Scaling for output current feedbacks. Normally should be set to 1.0.
Output voltage scaler	3450		1.0	0.0	2.0	Scaling for output voltage feedbacks. Normally should be set to 1.0.
Output attenuator sum	3455	kOhms	3000	100	10000	Scaling for the output nominal value. This is the sum of the two input resistors per phase

> ☞ **Note:** Many of the parameters in the Output Processing section are automatically set up during auto-tuning. They are presented here so the user can do additional fine-tuning of the drive. Additional fine-tuning is not generally required, but may be needed in special circumstances.

Table 4-43: Low Frequency Compensation Menu (3060)

Parameter	ID	Units	Default	Min	Max	Description
Low Freq Wo	3070	Rad	12.566	0.0	100.0	Pole of hardware RC integrator. This is the setting for the -00 board. For the 02 board the value should be 37.859.
Low freq com gain	3080		1.0	0.5	5.0	Low Frequency compensation gain for scaling estimated flux.
S/W compensator pole	3090		2.0	0.5	12.6	Pole of software integrator used for flux estimation.

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Table 4-44: Flux Control Menu (3100)

Parameter	ID	Units	Default	Min	Max	Description
Flux reg prop gain	3110		1.72	0.0	10.0	Flux PI regulator proportional gain term.
Flux reg integral gain	3120		1.0	0.0	1200.0	Flux PI regulator integral gain term.
Flux Filter Time Const	3130	sec	0.0667	0.0	10.0	Time constant of the low pass filter used on the flux error.
Flux demand	3150	per unit	1.0	0.0	10.0	Sets the flux demand (or desired Volts-per-Hertz ratio) in per unit.
Flux ramp rate	3160	sec	0.5	0.0	5.0	Sets the ramp time to go from zero to rated flux. This time establishes the time to magnetize the motor.
Energy saver min flux	3170		100.0	10.0	125.0	This parameter sets the lowest value of flux (as a percentage of Rated Motor Flux) that the drive will apply to an unloaded motor. Energy Saver is enabled if a value that is less than the Flux Demand is entered. The control establishes the amount of flux (or motor voltage) that minimizes the losses in the motor.
Ids DC	3190	%	10.0	1.0	25.0	DC current level used when stator resistance estimator is enabled.
Flux droop	3195	%	0	0	200	Flux droop for parallel drives.

Table 4-45: Speed Loop Menu (3200)

Parameter	ID	Units	Default	Min	Max	Description
Speed reg prop gain	3210		0.02	0.0	1.0	Speed PI regulator proportional gain term. Automatically calculated after Auto-Tuning stage 2.
Speed reg integral gain	3220		0.046	0.0	1200.0	Speed PI regulator integral gain term. Automatically calculated after Auto-Tuning stage 2.
Speed reg Kf gain	3230		0.6	0.1	1.0	Allows a smooth variation of the speed regulator from a simple PI (Kf =1.0) to a double speed loop (Kf=0.5).
Speed filter time const	3240		0.0488	0.0	10.0	Time constant of the low pass filter used on the speed error. Automatically calculated after Auto-Tuning stage 2.
Speed Droop	3245	%	0.0	0.0	10.0	Droop in percent of rated speed at full load current.

Table 4-46: Current Loop Menu (3250)

Parameter	ID	Units	Default	Min	Max	Description
Current reg prop gain	3260		0.5	0.0	5.0	Current PI regulator proportional gain term.*
Current reg integ gain	3270		25.0	0.0	6000.0	Current PI regulator integral gain term.*
Prop gain during brake	3280		0.16	0.0	5.0	Current PI regulator proportional during dual frequency braking.*
Integ gain during brake	3290		9.6	0.0	6000.0	Current PI regulator integral gain term during dual frequency braking.*

* All values in this table are automatically updated after Auto-Tuning stage 1.

Table 4-47: Stator Resistance Estimator Menu (3300)

Parameter	ID	Units	Default	Min	Max	Description
Stator resistance est	3310		Off			This parameter enables or disables the stator resistance estimator function. Off On
Stator resis filter gain	3320		0.0	0.0	1.0	Stator resistance estimator filter gain.
Stator resis integ gain	3330		0.002	0.0	1.0	Stator resistance estimator integral gain.

Table 4-48: Braking Menu (3350)

Parameter	ID	Units	Default	Min	Max	Description
Enable braking	3360		Off			Enable or disable dual frequency braking (DFB). User must be aware of torque pulsations and motor heating produced with this method.
Pulsation frequency	3370	Hz	275.0	100.0	5000.0	Torque pulsation frequency when dual-frequency braking is enabled. Adjust for a different torque pulsation frequency. The control always recalculates the desired value due to limited resolution. Can be adjusted to avoid mechanical resonance frequencies.
Brake power loss	3390	%	0.25	0.0	50.0	Amount of high frequency losses at the onset of braking. Affects the limit of the V_q component of output braking voltage.
VD Loss	3400	p.u.	0.25	0.0	0.5	Max amplitude of the loss inducing voltage. Use this to adjust the braking torque. Sets the maximum loss limiting (V_d) voltage amplitude.
Braking constant	3410		1.05	0.0	10.0	Ratio of motor (induced) losses to power absorbed from load. **This parameter should always be set to a value greater than 1.0**. Setting this parameter higher increases V_q and V_d voltage amplitude of losses in the motor and increases braking. Caution must be exercised to prevent a motor thermal trip.

☞ **Note:** The need for braking capacity is addressed through a feature known as dual frequency braking. This feature essentially creates a braking function by means of injecting a counter-rotating flux vector at well beyond the slip of the machine. This generates additional losses in the motor. The injection frequency is adjustable via a menu setting to allow critical frequencies (i.e. mechanical resonances) to be avoided.

☞ **Note:** When AFE is enabled, Dual Frequency Braking is disabled.

Table 4-49: Control Loop Test Menu (3460)

Parameter	ID	Units	Default	Min	Max	Description
Test type	3470		Speed			This pick list selects the type of loop test desired (speed or torque). Speed Torque
Test positive	3480	%	30.0	-200.0	200.0	Positive going limit of the test waveform.
Test negative	3490	%	-30.0	-200.0	200.0	Negative going limit of the test waveform.
Test time	3500	sec	30.1	0.0	500.0	Sets the time for the drive to spend in either the positive or negative test setting.
Begin test	3510	Function				This Function starts the speed or torque loop test.
Stop test	3520	Function				This function stops the speed or torque loop test.

4.4.5 Auto Menu (4) Options

The Auto Menu (**4**) consists of the following menu options:

- Speed Profile Menu (**4000**)
- Analog Input Menu (**4090**)
- Analog Outputs Menu (**4660**)
- Speed Setpoint Menu (**4240**)
- PID Select Menu (**4350**)
- Comparator Setup Menu (**4800**)

These menus are explained in the tables that follow.

Table 4-50: Speed Profile Menu (4000)

Parameter	ID	Units	Default	Min	Max	Description
Entry point	4010	%	0.0	0.0	200.0	Sets the % of speed cmd at which the drive begins following the speed cmd.
Exit point	4020	%	150.0	0.0	200.0	Sets the % of speed cmd at which the drive stops following the speed cmd.
Entry speed	4030	%	0.0	0.0	200.0	Sets the speed to which the drive accelerates when given a start command when the speed profile function is enabled.
Exit speed	4040	%	150.0	0.0	200.0	Sets the speed that the drive reaches at the exit point.
Auto off	4050	%	0.0	0.0	100.0	Sets the level of cmd at which the drive turns off.
Delay off	4060	sec	0.5	0.5	100.0	Sets a time delay between the time the cmd reaches the Auto Off point and the time the drive shuts off.
Auto on	4070	%	0.0	0.0	100.0	Sets the level of cmd at which the drive turns on.
Delay on	4080	sec	0.5	0.5	100.0	Sets a time delay between the time the cmd reaches the Auto On point and the time the drive starts.

Figure 4-23 illustrates the advantages of using speed profiling control. This method of control provides an increased resolution in the "usable control range" for the motor. Ultimately, the speed of the motor can be adjusted in much finer increments when speed profiling is used.
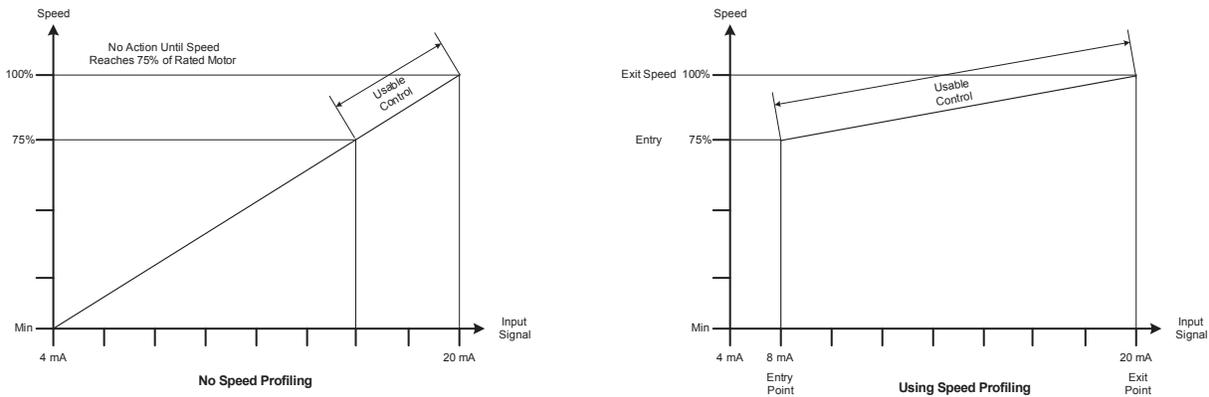
Figure 4-23: Advantages of Using Speed Profiling Control

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Table 4-51: Analog Input Menu (4090)

Parameter	ID	Type	Description
Analog input #1	4100	Submenu	Menu for Analog input #1. See Table 4-52.
Analog input #2	4170	Submenu	Menu for Analog input #2. See Table 4-53.
Analog input #3	4232	Submenu	Menu for Analog input #3. See Table 4-54.
Analog input #4	4332	Submenu	Menu for Analog input #4. See Table 4-55.
Analog input #5	4341	Submenu	Menu for Analog input #5 See Table 4-56.
Auxiliary input #1	4500	Submenu	Menu for Auxiliary input #1. See Table 4-57.
Auxiliary input #2	4580	Submenu	Menu for Auxiliary input #2. See Table 4-58.

> ☞ **Note:** When an external PID controller is used as the speed reference, Analog Input 1 is used for PID command, and Analog Input 2 is used for PID feedback. See Tables 4-52 and 4-53 for scaling information.

Table 4-52: Analog Input #1 Menu (4100)

Parameter	ID	Units	Default	Min	Max	Description
Source	4105		Off			This parameter sets the input source for analog input #1. Can be any one of 24 External Analog Inputs. Off Ext 1-24
Type	4110		4 – 20mA			This parameter sets the operational mode for analog input 1. 0 - 20mA 4 - 20mA 0 - 10V
Min input	4120	%	0.0	0.0	200.0	Minimum Analog input
Max input	4130	%	100.0	0.0	200.0	Maximum Analog input
Loss point threshold	4140	%	15.0	0.0	100.0	Threshold where loss of signal action is activated. Entered as percentage of upper range for any type (does not differentiate).
Loss of signal action	4150		Preset			Select loss of signal action. Preset Maintain Stop
Loss of signal setpoint	4160	%	20.0	0.0	200.0	Loss of signal preset speed.

Table 4-53: Analog Input #2 Menu (4170)

Parameter	ID	Units	Default	Min	Max	Description
Source	4175		Off			This parameter sets the input source for analog input #2. Off Ext 1-3
Type	4180		4 – 20mA			This parameter sets the operational mode for analog input 2. 0 – 20mA 4 – 20mA 0 – 10V
Min input	4190	%	0.0	0.0	200.0	Minimum Analog input
Max input	4200	%	100.0	0.0	200.0	Maximum Analog input
Loss point threshold	4210	%	15.0	0.0	100.0	Threshold where loss of signal action is activated. Entered as percent of upper range for any type (does not differentiate).
Loss of signal action	4220		Preset			Select loss of signal action. Preset Maintain Stop
Loss of signal setpoint	4230	%	20.0	0.0	200.0	Loss of signal preset speed.

☞ **Note:** When an external PID controller is used as the speed reference, Analog Input 1 is used for PID command, and Analog Input 2 is used for PID feedback. See Tables 4-52 and 4-53 for scaling information.

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Table 4-54: Analog Input #3 Menu (4232)

Parameter	ID	Units	Default	Min	Max	Description
Source	4233		Off			This parameter sets the input source for analog input #1. Off Ext 1-24
Type	4234		4 – 20mA			This parameter sets the operational mode for analog input 1. 0 – 20mA 4 – 20mA 0 – 10V
Min input	4235	%	0.0	0.0	200.0	Minimum Analog input
Max input	4236	%	100.0	0.0	200.0	Maximum Analog input
Loss point threshold	4237	%	15.0	0.0	100.0	Threshold where loss of signal action is activated. Entered as percentage of upper range for any type (does not differentiate).
Loss of signal action	4238		Preset			Select loss of signal action. Preset Maintain Stop
Loss of signal setpoint	4239	%	20.0	0.0	200.0	Loss of signal preset speed.

Table 4-55: Analog Input #4 Menu (4332)

Parameter	ID	Units	Default	Min	Max	Description
Source	4333		Off			This parameter sets the input source for analog input #1. Off Ext 1-24
Type	4334		4 – 20mA			This parameter sets the operational mode for analog input 1. 0 – 20mA 4 – 20mA 0 – 10V
Min input	4335	%	0.0	0.0	200.0	Minimum Analog input
Max input	4336	%	100.0	0.0	200.0	Maximum Analog input
Loss point threshold	4337	%	15.0	0.0	100.0	Threshold where loss of signal action is activated. Entered as percentage of upper range for any type (does not differentiate).
Loss of signal action	4338		Preset			Select loss of signal action. Preset Maintain Stop
Loss of signal setpoint	4339	%	20.0	0.0	200.0	Loss of signal preset speed.

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Table 4-56: Analog Input #5 Menu (4341)

Parameter	ID	Units	Default	Min	Max	Description
Source	4342		Off			This parameter sets the input source for analog input #1. Off Ext 1-24
Type	4343		4 – 20mA			This parameter sets the operational mode for analog input 1. 0 – 20mA 4 – 20mA 0 – 10V
Min input	4344	%	0.0	0.0	200.0	Minimum Analog input
Max input	4345	%	100.0	0.0	200.0	Maximum Analog input
Loss point threshold	4346	%	15.0	0.0	100.0	Threshold where loss of signal action is activated. Entered as percentage of upper range for any type (does not differentiate).
Loss of signal action	4347		Preset			Select loss of signal action. Preset Maintain Stop
Loss of signal setpoint	4348	%	20.0	0.0	200.0	Loss of signal preset speed.

Table 4-57: Auxiliary Input #1 Menu (4500)

Parameter	ID	Units	Default	Min	Max	Description
Source	4510		Off			Auxiliary input source. Off Ext 1-3
Type	4520		4 – 20mA			This parameter sets the operational mode for auxiliary input 1. 0 - 20mA 4 - 20mA 0 - 10V
Min input	4530	%	0.0	0.0	200.0	Minimum auxiliary input.
Max input	4540	%	100.0	0.0	200.0	Maximum auxiliary input.
Loss point threshold	4550	%	15.0	0.0	100.0	Threshold where loss of signal action is activated. Entered as percentage of upper range for any type (does not differentiate)

Parameter	ID	Units	Default	Min	Max	Description
Loss of signal action	4560		Preset			Select loss of signal action. Preset Maintain Stop
Loss of signal setpoint	4570	%	20.0	0.0	200.0	Loss of signal preset speed.

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Table 4-58: Auxiliary Input #2 Menu (4580)

Parameter	ID	Units	Default	Min	Max	Description
Source	4590		Off			Auxiliary input source Off Ext 1-3
Type	4600		4 – 20mA			This parameter sets the operational mode for analog input 1. 0 – 20ma 4 – 20ma 0 - 10V
Min input	4610	%	0.0	0.0	200.0	Minimum auxiliary input.
Max input	4620	%	100.0	0.0	200.0	Maximum auxiliary input.
Loss point threshold	4630	%	15.0	0.0	100.0	Threshold where loss of signal action is activated. Entered as percentage of upper range for any type (does not differentiate).
Loss of signal action	4640		Preset			Select loss of signal action. Preset Maintain Stop
Loss of signal setpoint	4650	%	20.0	0.0	200.0	Loss of signal preset speed.

Table 4-59: Analog Outputs Menu (4660)

Parameter	ID	Units	Default	Min	Max	Description
Analog Output #n*	4660+4(n-1)+1	Submenu				ID of submenu for Analog Output #n (n=1-16).
Analog variable	4660+4(n-1)+2		Total Current			This variable sets the input source for analog output #n. See Table 4-60.
Output module type	4660+4(n-1)+3		Unip			Sets the output type for the module. Unip (Unipolar) Bip (Bipolar)
Full range	4660+4(n-1)+4	%	0.0	0.0	300.0	Scales the output range of the variable selected.

* Each analog output parameter, 1 to 16, contains a submenu consisting of Analog variable, Output module type, and Full range. The formulas presented in the ID column will give you the direct ID number for the corresponding Analog output. For example, for Analog output 4, the Analog output ID will be 4660+4(4-1)+1, or 4673. The Analog variable ID for Analog output 4 will be 4660+4(4-1)+2, or 4674, etc.

Table 4-60: Pick list for Analog Variable parameters (all units are %)

Motor Voltage	Total Current	Average Power	Analog Input #1
Motor Speed	Speed Demand	Speed Reference	Analog Input #2
Raw Flux Demand	Flux Reference	Current (RMS)	Analog Input #3
Zero Sequence Av	Neg Sequence D	Neg Sequence Q	Analog Input #4
Input Frequency	Input Power Avg	Input Pwr Factor	Analog Input #5
Ah Harmonic	Bh Harmonic	Total Harmonics	Analog Input #6
Xfmr Therm Level	1 Cycle Protect	Single Phase Cur	Analog Input #7
Under Volt Limit	Out Neutral Volts	Synch Motor Field	Analog Input #8
Motor Torque	Encoder Speed	Input KVAR	Drive Losses
Excess React I	Speed Droop		

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Table 4-61: Speed Setpoint Menu (4240)

Parameter	ID	Units	Default	Min	Max	Description
Speed setpoint 1	4250	rpm	0	-18000	18000	Programmable speed setpoint that can be selected through an external contact and the system program.
Speed setpoint 2	4260	rpm	0	-18000	18000	Programmable speed setpoint that can be selected through an external contact and the system program.
Speed setpoint 3	4270	rpm	0	-18000	18000	Programmable speed setpoint that can be selected through an external contact and the system program.
Speed setpoint 4	4280	rpm	0	-18000	18000	Programmable speed setpoint that can be selected through an external contact and the system program.
Speed setpoint 5	4290	rpm	0	-18000	18000	Programmable speed setpoint that can be selected through an external contact and the system program.
Speed setpoint 6	4300	rpm	0	-18000	18000	Programmable speed setpoint that can be selected through an external contact and the system program.
Speed setpoint 7	4310	rpm	0	-18000	18000	Programmable speed setpoint that can be selected through an external contact and the system program.
Speed setpoint 8	4320	rpm	0	-18000	18000	Programmable speed setpoint that can be selected through an external contact and the system program.
Jog speed	4330	rpm	0	-18000	18000	This parameter sets the drive jog speed.
Safety setpoint	4340	rpm	0	-18000	18000	Safety Override preset speed.

Table 4-62: Incremental Speed Setup Menu (4970)

Parameter	ID	Units	Default	Min	Max	Description
Speed increment 1	4971	%	1.0	0.0	200.0	When selected through the SOP, it will increase the speed demand by the program amount.
Speed decrement 1	4972	%	1.0	0.0	200.0	When selected through the SOP, it will decrease the speed demand by the program amount.
Speed increment 2	4973	%	5.0	0.0	200.0	When selected through the SOP, it will increase the speed demand by the program amount.
Speed decrement 2	4974	%	5.0	0.0	200.0	When selected through the SOP, it will decrease the speed demand by the program amount.
Speed increment 3	4975	%	10.0	0.0	200.0	When selected through the SOP, it will increase the speed demand by the program amount.
Speed decrement 3	4976	%	10.0	0.0	200.0	When selected through the SOP, it will decrease the speed demand by the program amount.

Table 4-63: PID Select Menu (4350)

Parameter	ID	Units	Default	Min	Max	Description
Prop gain	4360		0.39	0.0	98.996	Sets the PID loop Proportional (P) gain.
Integral gain	4370		0.39	0.0	98.996	Sets the PID loop Integral (I) gain.
Diff gain	4380		0.0	0.0	98.996	Sets the PID loop Derivative (D) gain.
Min clamp	4390	%	0.0	-200.0	200.0	Sets the minimum value for the PID loop integrator.
Max clamp	4400	%	100.0	-200.0	200.0	Sets the maximum value for the PID loop integrator.
Setpoint	4410	%	0.0	-200.0	200.0	Sets a value to be used as the reference setpoint for the external PID loop. The value is set as a percent of full scale.

☞ **Note:** When an external PID controller is used as the speed reference, Analog Input 1 is used for PID command, and Analog Input 2 is used for PID feedback. See Tables 4-52 and 4-53 for scaling information.

⚠ **Attention!** The user is responsible for providing correct inputs for PID command and feedback.

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Table 4-64: Comparator Setup Menu (4800)

Submenu	Description
Comparator *n* Setup	Submenus that contain 32 sets of comparators for custom use in the system program. Each comparator set (Compare 1 through Compare 32) consists of three parameters that are located in the comparator setup menus. Comparators are system program flags (Comparator1_I through Comparator32_I) which can be used anywhere within the system program environment to control software switches. Refer to Table 4-65.

Table 4-65: Compare 1-32 Setup Menu Parameter Descriptions

Menu Item	Default Value	Description
Comp *n* A in variable select (list) (*n*=1-32)	Manual value	"Comp *n* A" and "Comp *n* B" inputs can be selected from the list in Table 4-66.
Comp *n* B in variable select (list) (*n*=1-32)	Manual value	The comparator flag *compar_**n**_f* (where ***n**=1-16*) in the system program is set true if "Comp *n* A in" > "Comp *n* B in".
Comp *n* manual value	0.0%	Min: -1,000% Max: 1,000%
Compare *n* type (list) (n=1-32)	'Mag' if *n*=1; 'Off' if *n*>1	"Compare *n*" can be set to the following: signed (e.g., 10 > -50) magnitude (e.g., -50 > 10) disabled (no compare is done)

Table 4-66: Variable Pick List for Comparator Setup Submenus

Manual Value		
Analog Input 1	Analog Input 13	Motor speed
Analog Input 2	Analog Input 14	Motor current
Analog Input 3	Analog Input 15	Enter Manual Value
Analog Input 4	Analog Input 16	Manual ID
Analog Input 5	Analog Input 17	Max Avail Out Vlt
Analog Input 6	Analog Input 18	Magnetizing Current Ref (Ids Ref)
Analog Input 7	Analog Input 19	Magnetizing Current (Ids)
Analog Input 8	Analog Input 20	Torque Current Ref (Iqs Ref)
Analog Input 9	Analog Input 21	Torque Current (Iqs)
Analog Input 10	Analog Input 22	Input frequency
Analog Input 11	Analog Input 23	Manual ID Number
Analog Input 12	Analog Input 24	

4.4.6   Main Menu (5) Options

The Main Menu (**5**) consists of the following menu options:

- Motor Menu (**1**)

- Drive Menu (**2**)

- Stability Menu (**3**)

- Auto Menu (**4**)

- Log Control Menu (**6**)

- Drive Protect Menu (**7**)

- Meter Menu (**8**)

- Communications Menu (**9**)

- Security Edit Functions Menu (**5000**)

- Parameter Default/File Functions

- Language and Security Functions

The contents of submenus 1-4 are explained earlier in this chapter. The contents of submenus 6-9 are explained later in this chapter. All of these submenus can be accessed directly using the keypad or from the Main Menu (**5**). Refer to the appropriate sections elsewhere in this chapter for descriptions of menu options within these submenus. Figure 4-24 depicts a typical menu selection from the Main Menu level.
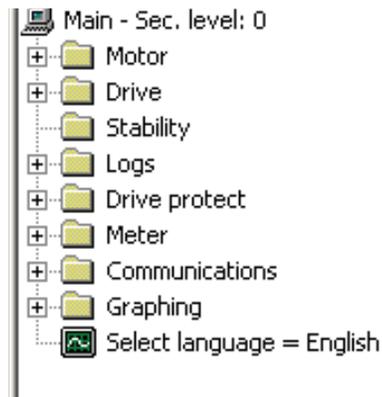

Figure 4-24: : Example of Main Menu

Main Menu (**5**) functions and submenus are explained in the tables that follow.

Table 4-67: Main Menu (5) Options

Parameter (ID)	ID	Type	Description
Motor Menu	1	Submenu	Provides access to the Motor Menu.
Drive Menu	2	Submenu	Provides access to the Drive Menu.
Stability Menu	3	Submenu	Provides access to the Stability Menu.
Auto Menu	4	Submenu	Provides access to the Auto Menu.
Log Control	6	Submenu	Provides access to the Log Control Menu.
Drive Protect Menu	7	Submenu	Provides access to the Drive Protect Menu.
Meter Menu	8	Submenu	Provides access to the Meter Menu.
Communications Menu	9	Submenu	Provides access to the Communications Menu.
Security Edit Functions Menu	5000	Submenu	This menu contains functions that are used to edit a menu item's security codes.
Set Defaults to Current	5045	Submenu	Used to set all default parameters to the current parameter settings.
Reset to Defaults	5050	Submenu	Used to reset all parameters to their factory defaults.
Select Language	5080	Pick List	Sets language for keypad. English (default) French German Spanish
Change Security Codes	5090	Function	Used to change the security codes for the various security levels used by the drive. Default codes are shown in Table 4-70.
Enter Security Code	5500	Function	Used to enter the security code to set the clearance level for access.

An electronic security code is provided to limit unauthorized access to various parameters within the drive equipment. The default factory settings for parameter security codes is as follows:

Table 4-68: Security Edit Functions Menu (5000)

Parameter	ID	Type	Description
Change security level	5010	Function	This function is used to change a menu item's security level. When active, an "x" will appear as the first character on the second line of the display. Please scroll past Main(5) into another menu. The current security level will appear as the last character on the second line of the display. Press [ENTER] to edit the security level for the ID that is shown. Choose among levels 0, 5, 7, or 8. See Table 4-69.
Drive running inhibit	5020	Function	This function is used to change a menu item's run inhibit. When active, an "x" will appear as the first character on the second line of the display. The current run inhibit state will appear as the last character on the second line of the display. See Table 4-69.

Table 4-69: Security Edit Menu Function Descriptions (5010, 5020)

ID	Name	Description
5010	Change Security Level Level = 0,5,7,8	"Change security level" prohibits access to menu or menu items until "enter security level" is set to that level or higher. Sets the level of security on that particular menu item.
5020	Drive Running Inhibit 1 = enable 0 = disable	Prohibits certain parameters from being changed when drive is in the Run State (D). Drive running lockout will not allow the parameter to be changed while the drive is running. "0" indicates that a parameter may be changed while the drive is running. "1" indicates that a parameter may <u>not</u> be changed while the drive is running.

CAUTION!-Do not change the Drive Running Inhibit (5020) setting of any parameter unless you are <u>completely</u> certain that the change is safe. Changes may result in drive trip or instability.

When you select either of these functions, the display returns to the top of the Main Menu (5), allowing you to navigate the menu system as you normally would. When the menu item to be changed is displayed, press the ENTER key to edit the security level, An asterisk character (*) appears on the left of the display to indicate that the menu or submenu is in the security edit mode, and not in normal mode.

Press the CANCEL key to exit the security edit mode.

Table 4-70: Default Security Access Levels and Access Codes

Access Level	Default Access Code	Level of Security
0	None	Minimum Access
5	5555	Startup Access for Service and/or Startup
7	7777	Advanced Access for Troubleshooting
8	Proprietary	Factory Use Only

Note that menu options above security level 5 are more technical in nature and are typically used by Siemens personnel during commissioning or servicing.

The Security Edit Menu (5000) can be accessed to change the factory default security settings. When the Perfect Harmony is configured for security level 7 access, the Security Edit Menu (5000) is visible from the Main Menu (5). Functions within this menu are used to set the security levels for menu items, to "hide" menu items, and to prevent changes to specific parameters. The Security Edit Functions Menu (5000) contains security functions described in Table 4-70.

4.4.7 Log Control Menu (6) Options

The Log Control Menu (**6**) consists of the following menu options:

- Event Log Menu (**6180**)
- Alarm/Fault Log Menu (**6210**)
- Historic Log Menu (**6250**)

The contents of these menus are explained in the tables that follow.

Table 4-71: Event Log Menu (6180)

The event log is stored in a file on the CompactFLASH. The maximum file size is 65Kbytes. The file is overwritten once the maximum size is reached.

Parameter	ID	Units	Default	Min	Max	Description
Upload event log	6190	Function				Upload the event log via the RS232 serial port.
Clear event log	6200	Function				Used to clear the event log.

Table 4-72: Alarm/Fault Log Menu (6210)

Parameter	ID	Units	Default	Min	Max	Description
Alarm/Fault log display	6220	Function				Used to display the fault log.
Alarm/Fault log upload	6230	Function				Upload the fault log via the RS232 serial port.
Alarm/Fault log clear	6240	Function				Used to clear the fault log.

Table 4-73: Historic Log Menu (6250)

The historic log is stored in non-volatile battery backed up RAM. Seventy-eight "snapshots" are recorded at the slow cycle update rate, 58 before a fault occurs and 20 after. If the "Store in event log" is "On", several historical logs can be stored. The maximum number is limited by the event log size (512Kbytes).

Parameter	ID	Default	Description
Store in event log	6255	On	When selected, the Historical log is stored in the event log
Historic log variable 1	6260	Spd Ref	Select the 1st variable for the historic log. See Table 4-74 for pick list variables.
Historic log variable 2	6270	Trq I Cmd	Select the 2nd variable for the historic log. See Table 4-74 for pick list variables.
Historic log variable 3	6280	Mtr Flux	Select the 3rd variable for the historic log. See Table 4-74 for pick list variables.
Historic log variable 4	6290	Pwr Out	Select the 4th variable for the historic log. See Table 4-74 for pick list variables.
Historic log variable 5	6300	I Total Out	Select the 5th variable for the historic log. See Table 4-74 for pick list variables.
Historic log variable 6	6310	Mag I Fdbk	Select the 6th variable for the historic log. See Table 4-74 for pick list variables.
Historic log variable 7	6320	Mtr Flux	Select the 7th variable for the historic log. See Table 4-74 for pick list variables.
Historic log upload	6330		Upload Historic log to serial port.

Table 4-74: Pick List Variables for Historic Log (all units are %)

Abbreviation	Description
Mtr Spd	Motor speed
Spd Ref	Speed reference
Spd Dmd	Raw Speed Demand
Trq I Cmd	Torque Current Command
Trq I Fdbk	Torque Current Feedback
Mag I Cmd	Magnetizing Current Command
Mag I Fdbk	Magnetizing Current Feedback
I Total Out	Total Motor Current
Mtr Volt	Motor Voltage
Mtr Flux	Motor Flux
V Avail	Line Voltage Available
V Avail RMS	Line Voltage RMS
Pwr Out	Output Power
V Neutral	Output Neutral Volts
I Total In	Total Input Current
Pwr In	Input Power
Freq In	Input Frequency
KVAR In	Input reactive power PU
Xcess I Rct	Excessive input reactive current (above limit) PU
Freq Out	Output Frequency PU
Drv Loss	Internal drive power losses in PU input power
Spd Droop	Speed Droop PU

4.4.8   Protect Menu (7) Options

The Drive Protect Menu (**7**) consists of the following menu options:

• Input Protect Menu (**7000**)

• Single Phasing Menu (**7010**)

These menus are explained in tables that follow.

Table 4-75: Drive Protect Menu (7) Parameters

Parameter	ID	Units	Default	Min	Max	Description
Input Protection	7000	Submenu				Input protection parameters. See Table 4-76.
Drive IOC Setpoint	7110	%	150.0	50.0	200.0	Drive instantaneous overcurrent setpoint (as a percentage of drive output rating).
Cell Overload Level	7112	%	100.0	100.0	150.0	Cell current overload (as a percentage of drive output rating) allowed for 1 minute out of every 10 minutes.
Auto Reset Enable	7120		No			Enables the reset of the Drive after a fault.
Auto Reset Time	7130	sec	1	0	120	Adjusts the time between the fault and its automatic reset.
Auto Reset Attempts	7140		4	1	10	The number of attempts a drive will be reset before a permanent shutdown.
Auto Reset Memory Time	7150	sec	10	1	1000	The amount of time between faults that will clear the attempts counter.
Fault Reset	7160	Function				Issues a Drive fault reset when selected.

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Table 4-76: Input Protect Menu (7000)

Parameter	ID	Units	Default	Min	Max	Description
Single phasing	7010		Submenu			Single phasing protection parameters. See Table 4-77.
Undervoltage prop gain	7060		0.0	0.0	10.0	Under voltage PI regulator proportional gain term.
Undervoltage integ gain	7070		0.001	0.0	1.0	Undervoltage PI regulator integral gain term.
1 Cyc Protect integ gain	7080		0.0025	0.0	1.0	Gain of integral regulator for detecting excessive input reactive current. Output of this regulator is used to fault the drive in case high reactive currents flow in the input (other than the instant when MV is applied to the drive). Adjust the gain to change the response to high reactive currents.
1 Cycle Protect Limit	7081	%	50.0	0.0	100.0	Integrator output level at which drive issues a 1 Cycle Protect Fault.
Excess Loss Idle	7084	%	5	1	5	Sets excessive drive loss trip point when idle.
Excess Loss Running	7086	%	7	3	12	Sets excessive drive loss trip point when running.
Xformer tap setting	7050	%	1			Choose from the {-5,0,+5%} settings to match transformer tap setting.
Xformer thermal gain	7090		0.0133	0.0	1.0	Gain of integral regulator to limit input current to 105% of its rated value.
Xformer protection const	7100		0.5	0.0	10.0	Gain to adjust model of input transformer. Use the default value of 0.5.
Phase Imbalance Limit	7105	%	40.0	0.0	100.0	Input current level (as a percent of Rated Input Current) above which Input Phase Imbalance Alarm is issued.
Ground Fault Limit	7106	%	40.0	0.0	100.0	Level above which drive issues an Input Ground Fault Alarm.
Ground Fault Time Const	7107	sec	0.2	0.001	2.0	Time constant of filter used for averaging input neutral voltage.

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Table 4-77: Single Phasing Menu (7010)

Parameter	ID	Units	Default	Min	Max	Description
SPD prop gain	7020		0.0	0.0	10.0	Single phase detector PI regulator proportional gain term.
SPD integral gain	7030		0.001	0.0	1.0	Single phase detector PI regulator integral gain term.
SPD threshold	7040	%	50.0	0.0	100.0	Regulator output level below which an alarm is generated

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4.4.9   Meter Menu (8) Options

The Meter Menu (**8**) consists of the following menu options:

- Display Parameters Menu (**8000**)

- Hour Meter Setup Menu (**8010**)

- General Drive Parameters Menu (Set Time, Software Version, Language, Output Units)

- Input Harmonics Menu (**8140**)

These menus are explained in tables that follow.

Table 4-78: Meter Menu (8)

Parameter	ID	Units	Default	Min	Max	Description
Display Parameters	8000		Submenu			This menu contains display parameters. See Table 4-79.
Hour Meter Setup	8010		Submenu			This menu contains hour meter setup. See Table 4-81.
Input Harmonics	8140		Submenu			This menu contains input harmonics. See Table 4-82.
Fault Display Override	8200		Off			Enables or disables the display of Fault/Alarm messages on the keypad.
Set the clock time	8080		Function			Used to change the time and date of the real-time clock chip.
Display version number	8090		Function			Displays the installed version of firmware.
Customer order	8100		0	0	9999999	Customer order number (7 decimals).
Customer drive	8110		1	0	20	Customer drive number.

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Table 4-79: Display Parameters Menu (8000)

Parameter	ID	Default	Description
Status variable 1	8001	DEMD	Select variable 1 to be displayed on the LCD display. Pick List – See Table 4-80.
Status variable 2	8002	%SPD	Select variable 2 to be displayed on the LCD display. Pick List - See Table 4-80.
Status variable 3	8003	VLTS	Select variable 3 to be displayed on the LCD display. Pick List - See Table 4-80.
Status variable 4	8004	ITOT	Select variable 4 to be displayed on the LCD display. Pick List - See Table 4-80.
Status variable 5	8005	IMRF	Select variable 5 to be displayed on the LCD display. Pick List - See Table 4-80.
Status variable 6	8006	IMRF	Select variable 6 to be displayed on the LCD display. Pick List - See Table 4-80.
Status variable 7	8007	IMRF	Select variable 7 to be displayed on the LCD display. Pick List - See Table 4-80.

This menu contains the pick lists to select the variables to be displayed on the front panel default display.

Note: Table 4-80 contains name, abbreviation, display, and variable columns of standard pick list variables (used in the Historic Log Menu, the Display Variable Menu, etc.). The name column contains the name of the display variable. This is what is displayed as the user scrolls through the list of available display variables. The abbreviation column contains an abbreviation that is displayed after a variable is selected from the list. The display column contains an even more abbreviated form of the variable name. This final abbreviation (between 2 and 5 characters in length) is what the Perfect Harmony displays on the front panel of the drive. The variable column shows the associated system program variable for reference.
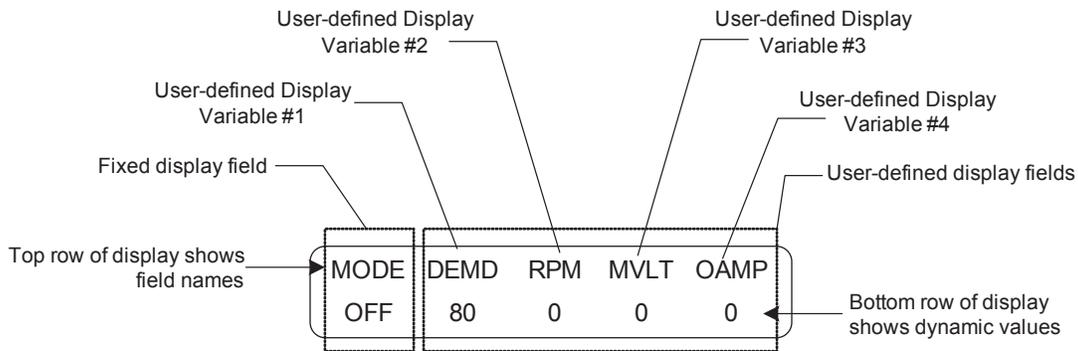

Figure 4-25: Dynamic Programmable Meter Display

Table 4-80: Pick List Variables for the Front Display

Abbreviation	Description & Units	Abbreviation	Description & Units
IMRF	Magnetizing current ref (A)	VAIN	Phase A input voltage (V)
ITRF	Torque current ref (A)	VBIN	Phase B input voltage (V)
FLDS	Flux DS (%)	VCIN	Phase C input voltage (V)
FLQS	Flux QS (%)	VZSQ	Zero sequence voltage (V)
VDRF	Vds reference (%)	VNSD	Negative sequence D voltage (V)
VQRF	Vqs reference (%)	VNSQ	Negative sequence Q voltage (V)
SLIP	Slip frequency (%)	VDIN	Input D voltage (V)
%SPD	Motor speed (%)	VQIN	Input Q voltage (V)
FREQ	Motor speed (Hz)	VAVI	Input voltage (V)
RPM	Motor speed (RPM)	FRIN	Input frequency (Hz)
VLTS	Motor voltage (V)	KWIN	Input power average (kW)
IMAG	Magnetizing current filtered (A)	PFIN	Input power factor (%)
ITRQ	Torque current filtered (A)	HRCA	Ah harmonic coefficient (%)
ITOT	Motor current (A)	HRCB	Bh harmonic coefficient (%)
%TRQ	Torque out (%)	HARM	Total A, B harmonics (%)
KWO	Output power (kW)	XTHL	Transformer thermal level (%)
RESS	Stator resistance	1CRI	One cycle reactive current level (%)
DEMD	Speed demand (%)	SPHI	Single phasing current level (%)
SREF	Speed reference (%)	UNVL	Under Voltage level (%)
FDMD	Raw flux demand (%)	EFF	Efficiency (%)
FXRF	Flux reference (%)	THD	Total Harmonic Distortion (%)
IDIN	Id input current (A)	VNGV	Output Neutral Voltage (V)
IQIN	Iq input current (A)	%VNG	Output Neutral Voltage (%)
IAIN	Phase A input current (A)	SMFC	Synch Motor Field Current (A)
BIN	Phase B input current (A)	%ESP	Encoder Speed (%)
ICIN	Phase C input current (A)	ERPM	Encoder Speed (RPM)
IAVI	Total input current (A)	KVAR	Input KVAR in PU power
IAF	Phase A filter current (A)	LOSS	Drive losses in PU input power
IBF	Phase B filter current (A)	XRCA	Input Excessive Reactive current (Amps)
ICF	Phase C filter current (A)	UXFR	Up transfer state machine value
MVAO	Measured phase A volts (V)	DXFR	Down transfer state machine value
MVBO	Measured phase B volts (V)	%DRP	Percent Droop (in speed)
MVCO	Measured phase c volts (V)		
MVNG	Measured output neutral voltage (V)		
% MAV	Max avail output volts (%)		

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Table 4-81: Hour Meter Setup (8010)

Parameter	ID	Units	Default	Min	Max	Description
Display hour meter	8020		Function			Used to display the amount of time that the drive has been operational since it was commissioned.
Preset hour meter	8030		Function			Used to preset the hour meter to the accumulated time that the drive has been operational since it was commissioned (in the event that a micro board has been replaced on an existing drive.)
Reset hour meter	8040		Function			Used to reset the hour meter when the drive is commissioned.
Display Output kWH meter	8050		Function			Displays the total output kW hours that have been accumulated since the drive was commissioned.
Preset output kWH meter	8060		Function			Presets the output kW hour counter to a previous value (when the microboard is replaced).
Reset output kWH meter	8070		Function			Resets the output kW hour counter to zero.
Display input kWH meter	8072		Function			Displays the total input kW hours that have been accumulated since the drive was commissioned.
Preset input kWH meter	8074		Function			Presets the input kW hour counter to a previous value (when the microboard is replaced).
Reset input kWH meter	8076		Function			Resets the input kW hour counter to zero.

Table 4-82: Input Harmonics Menu (8140)

Parameter	ID	Units	Default	Min	Max	Description
Selection for HA	8150		IA			Selection for Harmonic Analysis • IA • IB • IC • VA • VB • VC
Harmonics order	8160		1.0	0.0	30.0	Harmonic Order
Harmonics integral gain	8170		0.001	0.0	1.0	Harmonics regulator integral gain term

4.4.10 Communications Menu (9) Options

The Communications Menu (**9**) consists of the following menu options:

- Serial Port Setup Menu (**9010**)

- Network Control (**9943**)

- Network 1 Configure (**9900**)

- Network 2 Configure (**9914**)

- SOP and Serial Functions (**9110**)

- TCP/IP Setup (**9300**)

These menu items are explained in tables that follow.

Table 4-83: Communications Menu (9) Parameters

Parameter	ID	Units	Default	Min	Max	Description
Serial port setup	9010		Submenu			This menu contains all serial port setup parameters. See Table 4-84.
Network Control	9943		Submenu			Please refer to *NXG Communications Manual* (902399).
Network 1 Configure	9900		Submenu			
Network 2 Configure	9914		Submenu			
Display Network Monitor	9950		Function			
Serial echo back test	9180		Function			
Sop & serial Functions	9110		Submenu			This menu contains functions that utilize the local serial port. See Table 4-85.
TCP/IP Setup	9300		Submenu			This menu contains functions which set the parameters for TCP/IP. See Table 4-86.

Table 4-84: Serial Port Setup Menu (9010)

Parameter	ID	Units	Default	Min	Max	Description
Serial port use	9020		Local			Designates the usage of the on board serial port. • Remote • Modem • Local
Modem password	9025					Four character password can consist of 1-9, A-F (Hex).
Flow Control	9030		Xon/ Xoff			Designates the type of flow control used by the serial port. • None • Xon/Xoff
Baud rate	9040		19200			Designates the baud rate of the on board serial port: • 9600 • 19200 • 38400 • 57600 • 115200

Note: Baud rates of 19.2k or greater require the newer Siemens Communications Board -- Siemens part number 1000 0096.

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Table 4-85: Serial Functions Menu (9110)

Parameter	ID	Units	Default	Min	Max	Description
System program download	9120	Function				Used to transfer the system program to a remote system.
System program upload	9130	Function				Used to transfer the system program from a remote system.
Display sys prog name	9140	Function				Displays the current system program name.
Display directory version	9147	Function				Displays current directory file version.
Select system program	9145		None			Displays the list of system program files.
Multiple config files	9185		Off			Enables multiple configuration files.
Parameter data upload	9150	Function				Used to transfer the current configuration file to a remote system.
Parameter data download	9160	Function				Used to transfer the current configuration file from a remote system.
Parameter dump	9170	Function				Used to get a print-out of the current configuration data.
Menu based timer setup	9111	Submenu				Menu contains the menu-based SOP timers 1-16.
Menu timers 1-8	9112-9119	Sec	0	0	86400	
Menu timers 9-16	9121-9128	Sec	0	0	86400	

Parameter upload functions are used to transmit data from the drive to a printer or computer. Parameter download functions are used to transmit data to the drive. A terminal emulator such as Microsoft's® "HyperTerminal" program or equivalent is required to upload, download, and echo files. Windows "Terminal" protocol settings for the RS232 port are no parity, one stop bit, and a baud rate that is appropriate for the on-board serial port.

All parameters are printed on the parameter dump.

Table 4-86: TCP/IP Setup Menu (9300)

Parameter	ID	Units	Default	Min	Max	Description
IP address	9310		172.16.106.16	0.0.0.0	255.255.255.255	Used to enter the system IP address in dotted decimal.
Subnet mask	9320		255.255.0.0	0.0.0.0	255.255.255.255	Used to enter the system subnet mask in dotted decimal.
Gateway address	9330		172.16.1.1	0.0.0.0	255.255.255.255	Used to enter the system gateway address in dotted decimal.

Menu Setup for Multiple Configuration Files (Slaves)

The NXG drive is designed to operate with multiple motors that may or may not be of the same size. This is accomplished by using multiple parameter configuration files. There is one master configuration file that is always named current cfg. The slave files are stored in a sub directory of CfgFiles named SubCfgs and can have any legal name conforming to the "eight dot three" file naming convention. (xxxx xxxx.yyy)

☞ **NOTE**: All slave configuration files have the '.sfg' extension. This is not changeable through the menus; therefore, only eight characters can be chosen.

The configuration files can be created at runtime in the drive's memory and then stored to a flash disk. The slave files are created via the keypad menus by setting the slave parameters as desired and writing them to a flash disk (see Table 4-87).

There are up to eight SOP flags that can be set to point to a configuration file. The menus are used to map each SOP flag to a corresponding configuration file. Once mapped, the SOP flags are used to activate the SOP for a particular motor.

Menu Item Descriptions

Multiple config files	This pick list enables the switching of the slave configuration files. If set to OFF, no other multiple configuration file menus will be displayed. Once enabled, if any one of SOP flags is set to true, the corresponding configuration file will become active.
Show active config file	Function to display the current active configuration file. If correct configuration file is not displayed, the SOP file should be checked for accuracy. Check the Setup SOP configuration flags menu to be sure the correct file is mapped to the SOP flag.
Set active config file	This pick list sets the displayed file to be the active configuration file. This function overrides what is set in the SOP program. Any change in the SOP program is checked against the file set in this function. Once a change in the SOP is detected, that file will then be the active file. The keypad menu setting is now ignored. This insures no unintentional toggling of the configuration files. To switch back to the keypad file, set it by this menu. If no change in the SOP program occurs, the keypad set configuration file will remain in memory.
Setup SOP config flags	Submenu for SOP flag configuration.
Create new config file	This function allows you to save slave parameters to a file name you specify. The name is entered using the drive keypad. To get to the alphanumeric characters, you must use the left or right arrow keys to position the cursor. Then using the up or down arrow keys, scroll to the desired letter or number.
Set SOPConfigFileX_O (X = 1 to 8)	This function allows you to map the name of the flag in the SOP file, SOPConfigFileX_O, where X = 1 to 8, to a name of a slave configuration file. Then, when the SOP program is running, and this flag is set to 'true,' the configuration file will be switched into memory. This is a method of switching among multiple motors using one drive. The file names are selected from a pick list. New files can be created using the method described previously.

☞ **NOTE**: You do not need to add the file extension. The file extension is **always** 'sfg'. Press the 'enter' key to save the parameter(s) as they exist in memory to a new configuration file name. This file will be stored to the flash disk in the 'SubCfgs' subdirectory. This function does **NOT** make this configuration file the active configuration file. It uses the current data in memory to create a new slave configuration file. Any parameter that is saved to a slave configuration file is easily identifiable by the small '**s**' adjacent to the parameter ID number if it has not changed from the default setting, or a '**$**' if it has been changed from its default setting, i.e. (s9586) or ($9586).

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Table 4-87: Slave Parameter

Parameter	ID	Units	Default	Min	Max	Description
Multiple config files	9185		OFF			Enable multiple config file operation.
Show active config file	9195					Display current active config file.
Set active config file	9196		Defaults.sfg			Set the displayed file to be the active config file.
Setup SOP config flags	9186		Sub menu			Sub-menu for SOP flag configuration.
Create new config file	9197					Create new config file using numeric keypad.
Set SOPConfigFile1_O	9187		Defaults.sfg			Set name of config file #1 that corresponds to the SOP flag #1.
Set SOPConfigFile2_O	9188		Defaults.sfg			Set name of config file #2 that corresponds to the SOP flag #2.
Set SOPConfigFile3_O	9189		Defaults.sfg			Set name of config file #3 that corresponds to the SOP flag #3.
Set SOPConfigFile4_O	9190		Defaults.sfg			Set name of config file #4 that corresponds to the SOP flag #4.
Set SOPConfigFile5_O	9191		Defaults.sfg			Set name of config file #5 that corresponds to the SOP flag #5.
Set SOPConfigFile6_O	9192		Defaults.sfg			Set name of config file #6 that corresponds to the SOP flag #6.
Set SOPConfigFile7_O	9193		Defaults.sfg			Set name of config file #7 that corresponds to the SOP flag #7.
Set SOPConfigFile8_O	9194		Defaults.sfg			Set name of config file #8 that corresponds to the SOP flag #8.

Table 4-88: Parameter Menu - Slave

Parameter	ID	Parameter	ID
Motor Menu			
Motor kW rating	1010	50 Percent Break Point	1156
Motor frequency	1020	100 Percent Break Point	1157
Full load speed	1030	Maximum Load Inertia	1159
Motor voltage	1040	Motor trip volts	1160
Full load current	1050	Overspeed	1170
No load current	1060	Underload enable	1180
Leakage inductance	1070	I underload	1182
Stator resistance	1080	Underload timeout	1186
Inertia	1090	Motor torque limit 1	1190
Overload select	1130	Regen torque limit 1	1200
Overload pending	1139	Motor torque limit 2	1210
Overload	1140	Regen torque limit 2	1220
Overload timeout	1150	Motor torque limit 3	1230
0 Percent Break Point	1152	Regen torque limit 3	1240
10 Percent Break Point	1153	Phase Imbalance Limit	1244
17 Percent Break Point	1154	Ground Fault Limit	1245
25 Percent Break Point	1155	Ground Fault Time Const	1246
Drive Menu			
Control loop type	2050	Skip center freq 3	2370
Ratio control	2070	Skip bandwidth 1	2380
Speed fwd max limit 1	2080	Skip bandwidth 2	2390
Speed fwd min limit 1	2090	Skip bandwidth 3	2400
Speed fwd max limit 2	2100	Freq avoid accel time	2410
Speed fwd min limit 2	2110	Spinning load mode	2430
Speed fwd max limit 3	2120	Scan end threshold	2440
Speed fwd min limit 3	2130	Current Level Setpoint	2450

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Parameter	ID	Parameter	ID
Speed rev max limit 1	2410	Current ramp	2460
Speed rev min limit 1	2150	Max current	2470
Speed rev max limit 2	2160	Frequency scan rate	2480
Speed rev min limit 2	2170	Cond. stop timer	2500
Speed rev max limit 3	2180	Cond. run timer	2510
Speed rev min limit 3	2190	Min cells/phase count (n/3)	2540
Accel time 1	2270	Fast bypass	2600
Decel time 1	2280	Phase I gain	2710
Accel time 2	2290	Phase P gain	2720
Decel time 2	2300	Phase offset	2730
Accel time 3	2310	Phase error threshold	2740
Decel time 3	2320	Frequency Offset	2750
Jerk rate	2330	Up Transfer Timeout	2760
Skip center freq 1	2350	Down Transfer Timeout	2770
Skip center freq 2	2360	Cable Resistance	2940
Stability Menu			
Flux reg prop gain	3110	Integ gain during brake	3290
Flux reg integral gain	3120	Enable braking	3360
Flux Filter Time Const	3130	Pulsation frequency	3370
Flux demand	3150	Brake power loss	3390
Flux ramp rate	3160	VD Loss Max	3400
Energy saver min flux	3170	Braking constant	3410
Speed reg prop gain	3210	Test Type	3470
Speed reg integral gain	3220	Test positive	3480
Speed reg Kf gain	3230	Test negative	3490
Speed filter time const	3240	Test time	3500
Current reg prop gain	3260	Slip constant	3545
Current reg integ gain	3270	Feed forward constant	3560

Parameter	ID	Parameter	ID
Prop gain during brake	3280		
Auto Menu			
Entry point	4010	Delay on	4080
Exit point	4020	Prop gain	4360
Entry speed	4030	Integral gain	4370
Exit speed	4040	Diff gain	4380
Auto off	4050	Min clamp	4390
Delay off	4060	Max clamp	4400
Auto on	4070	Setpoint	4410
Logs Menu			
Historic log variable 1	6260	Historic log variable 5	6300
Historic log variable 2	6270	Historic log variable 6	6310
Historic log variable 3	6280	Historic log variable 7	6320
Historic log variable 4	6290		
Drive Protection Menu			
Auto reset Enable	7120	Auto Reset Attempts	7140
Auto Reset Time	7130	Auto Reset Memory Time	7150
Display Configuration Data Menu			
Status variable 1	8001	Status Variable 5	8005
Status variable 2	8002	Status Variable 6	8006
Status variable 3	8003	Status Variable 7	8007
Status variable 4	8004		
Meters Menu			
Customer Order	8100	Harmonics order	8160
Customer Drive	8110	Harmonics integral gain	8170
Selection for HA	8150	Fault Display Override	8200

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5   Applications and Advanced Features

5.1 Introduction

This chapter covers the functions of the Harmony series drive, including both basic drive features and advanced features. The format is to include the feature and associated menu parameters and SOP flags. The features more or less follow the logical format of the Menu structure.

5.2 Signal Frame of Reference for Motor Control

The control signals used for controlling the motor must be assigned a polarity for use over four quadrants of control to maintain consistency of the algorithms. This section clarifies what they are and what their polarities mean in the various quadrants.

5.2.1   Frame of Reference

The four-quadrant frame of reference is defined as the four quadrants of operation of a motor. They are divided left to right by the direction of rotation, and from top to bottom by the polarity of the torque in the machine. Energy flow from the drive into the machine is called motoring, and energy flow from the machine and into the drive is called regeneration or braking. The diagram is shown in Figure 5-1.

Figure 5-1 shows the relationship between the polarities of the signals. For example, starting at rest (in the ordinances of the two axes), if a positive torque is applied to the motor, the acceleration is positive and the resultant speed increases in the forward direction. This is governed by the following equations:

$$\alpha = \frac{T}{J} \qquad\qquad \omega = \int \alpha\, dt$$

where:

α =   acceleration T =   torque

J =   inertia (an unsigned magnitude) ω =   rotational speed.
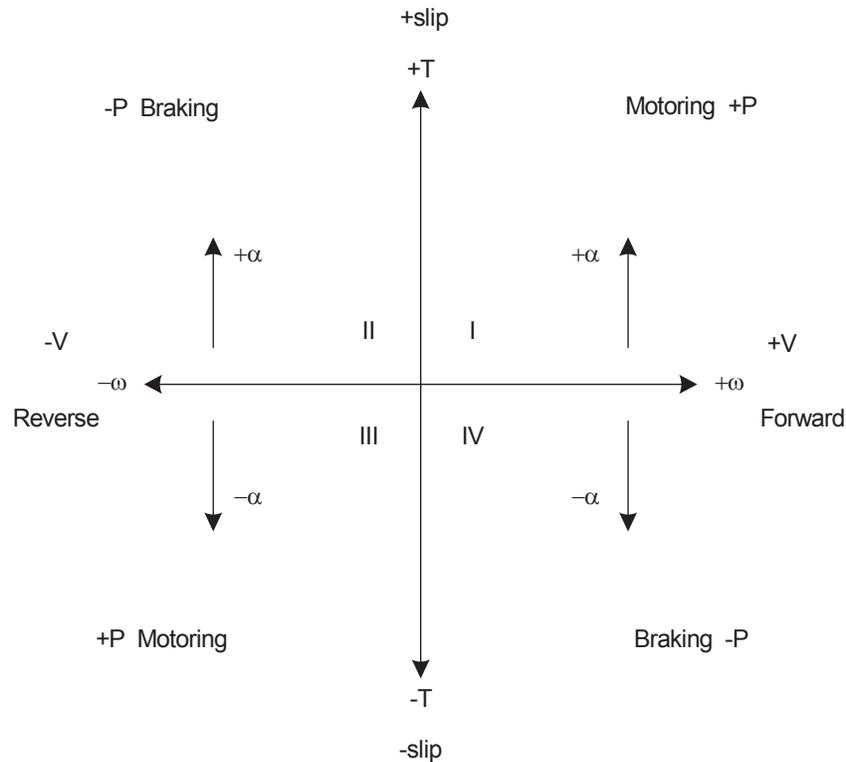
Figure 5-1: Four Quadrant Operation of a Motor

This then carries over into quadrant 4 showing that a negative torque produces negative acceleration (deceleration), stopping the motor. If however, the same torque is applied continuously, the speed of the motor will decrease to zero and begin to accelerate in the opposite direction, producing a negative rotational speed (ω) in what is now quadrant 3. Now if a positive torque is applied, the motor enters quadrant 2 and begins to decelerate. Since the rotational speed is negative and begins to diminish and approaches a positive value, the acceleration must be positive to conform to the above equations. Again, if the torque is held constant, the motor will slow to zero and then accelerate in the forward direction passing back into quadrant 1.

The injection frequency must always be opposing the direction of rotation and is only used in the case of braking or negative energy flow. Therefore, it is zero in the motoring quadrants (1 and 3) and is the inverse polarity of the electrical frequency in the braking quadrants (2 and 4) (see Table 5-1).

5.2.2   Signal Polarities

Table 5-1: Signal Polarities

Signals	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
Rotation speed (ω_r)	+	-	-	+
Electrical frequency (ω_s)	+	-	-	+
Slip (ω_{slip})	+	+	-	-
Torque	+	+	-	-
Current (I_q)	+	+	-	-
Voltage (v_{qs})	+	+	-	-
Acceleration	+	+	-	-
Injection Frequency (ω_{inj})	0	+	0	-
Power (flow)	+	-	+	-
Mag Current (I_d)	+	+	+	+
Voltage (v_{ds})	+	+	+	+

> ☞ **Note:** For the electrical frequency (ω_s) in the braking quadrants (2 and 4) where the slip opposes the rotational speed, when the speed magnitude approaches the slip magnitude, the electrical polarity is uncertain (when the slip magnitude is greater than the rotor speed, the sign will match that of the slip rather than the sign of the rotor speed). This is due to the relationship.

5.3 Mechanical Cell Bypass

When the Perfect Harmony was first introduced, its most salient attributes were improved power quality at the utility interface, and at the motor interface. A third attribute is now becoming recognized, which offers extremely high reliability by utilizing the inherent redundancy of these drives. Mechanical Cell Bypass is the feature that allows this third attribute to be realized.

The Mechanical Cell Bypass option is implemented by adding a contactor to the output of each cell as shown in Figure 5-2. Now when the control detects that a cell has failed, a command can be sent to close the appropriate contactor. This simultaneously disconnects the cell output from the circuit and connects the two adjacent cells together, effectively taking the failed cell out of the circuit. The drive can then be restarted and operation can continue at reduced capacity.

It does not matter which of the components has failed within the cell, as long as the failure can be detected. In fact, even a failure in the fiber optic link that communicates to the cell can be detected and bypassed. Therefore, this approach protects against the failure of any component in the power circuits or in the communications circuits, rather than protecting the drive against power semiconductor failure only.

The amount of reduction in capacity that can be tolerated will depend on the application, but in most cases a reduction in capacity is preferable to a complete shutdown. Neutral Point Shift is a feature that was developed to minimize the reduction in capacity after a bypass. Neutral Point Shift is discussed in Section 5.5. Another related feature is Fast Bypass. This feature is designed to quickly bypass a cell and get the drive running again in less than ½ second. Fast Bypass is discussed in Section 5.4.

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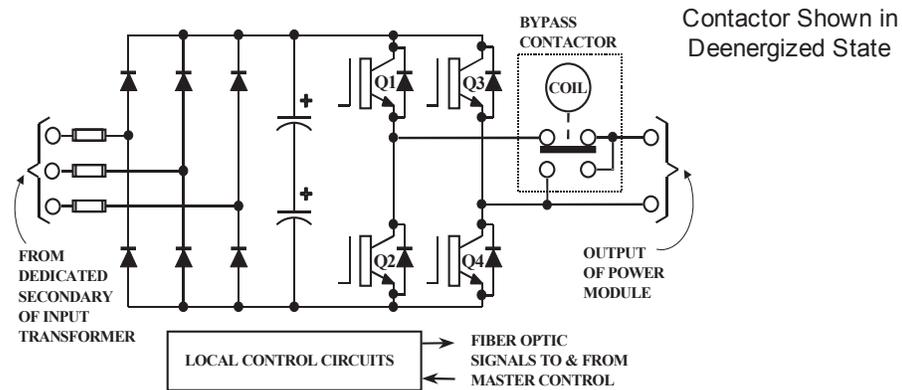
Figure 5-2: Typical Cell with Bypass Contactor

5.4 Fast Bypass

Up time is an important factor in many processes. A Medium Voltage drive is often a critical part of the process and even small interruptions in output torque of a Medium Voltage drive can cause the process to stop. This can result in lost material and production time.

Fortunately, in general, a process can ride through an interruption of ½ second or less. The NXG control has a feature that is designed to limit the interruption of torque to the process to less than ½ second if a cell failure is detected. This feature is called Fast Bypass. The conditions as to when the drive can meet this ½ second maximum interruption are described below.

All cell failures are detected in hardware. This hardware is designed to quickly shut down the drive so that additional damage will not occur. Once this happens, the control is notified. The control can then quickly determine which cell failed, and the bypass process can be started.

When the drive trips and stops delivering torque to the motor, the motor acts like a generator and produces a voltage on the drive output terminals. This voltage decays over time, but can be near the drive rated output voltage for a few seconds. If a cell is bypassed, the remaining cells may not be able to support this voltage and damage can occur.

To prevent this damage, a check is done in the control to verify if the motor output voltage can be supported before a cell is bypassed and the drive is restarted. If this check passes when it is first done, the cell can be bypassed and torque can be delivered to the drive in under ½ second from the time the fault occurred. If the motor voltage is too high, an additional delay may be needed to allow the voltage to decay.

To guarantee that the drive will bypass a cell fault in under ½ second, the drive needs to be running at an output voltage that can be supported by one less than the existing number of cells per phase. One way is for the drive to be sized so that it has more than the minimum number of cells required to provide the voltage needed. Another way is to limit the maximum speed. These issues will have been studied and resolved before the drive is installed.

> ☞ **Note:** In a drive with an additional cell per phase, bypass in under ½ second will happen only on the first cell failure per phase. If a second cell in a phase fails, the control needs to wait for the motor voltage to decay, hence the bypass time may exceed ½ second.

> ☞ **Note:** In Fast Bypass, the drive will start to deliver torque to the motor in ½ second after a fault occurs. It may take longer for the drive to get back up to the set-point speed.

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5.5 Neutral Point Shift During Bypass

Since the cells in each phase of a Perfect Harmony Drive are in series, bypassing a failed cell has no effect on the current capability of the drive, but the voltage capability will be reduced. Usually the required motor voltage is roughly proportional to speed, so that the maximum speed at which the drive can fulfill the application requirements will also be reduced. Therefore, it is important to maximize the motor voltage available after one or more cells have failed.

Figures 5-3 through 5-7 illustrate the voltage available from a Perfect Harmony drive, where the cells, represented by circles, are shown as simple voltage sources. Figure 5-3 shows a 15-cell drive in which no cells are bypassed. With 100% of the cells in use, 100% of the original voltage is available. The voltage commands to the three phase groups of cells will have phase A displaced from phase B by 120°, and from phase C by 120°.
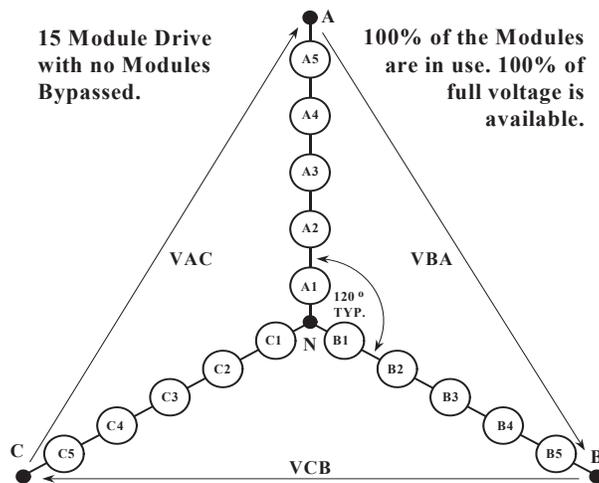
Figure 5-3: A Simplified diagram of a 15 Cell Drive

When cells are bypassed in one of the drive phases, the output voltage will tend to become unbalanced, as illustrated in Figure 5-4. One possible remedy is to bypass an equal number of cells in all three phases, even though some may not have failed. Figure 5-5 illustrates this approach. Obviously, this method prevents unbalance but sacrifices possible voltage capability. In Figure 5-5, 87% of the cells are functional, but only 60% are in use, and only 60% voltage is available.
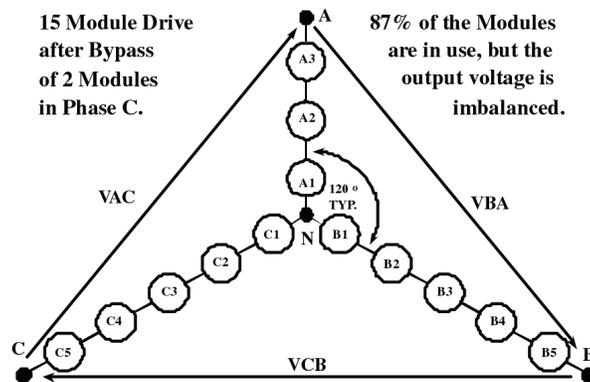
Figure 5-4: Drive output with 2 Cells Bypassed

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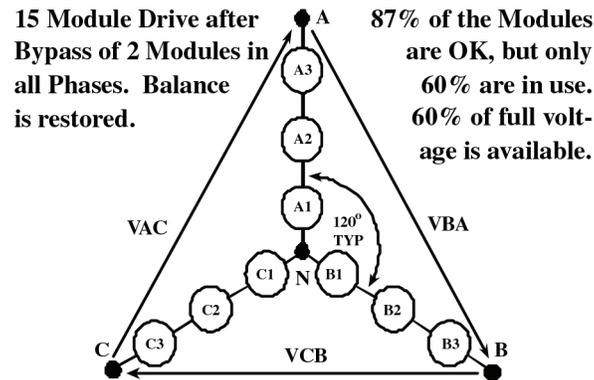
Figure 5-5: Drive output re-balanced by Bypassing Functional Cells

A better approach is illustrated in Figure 5-6. This method takes advantage of the fact that the star-point of the cells is floating, and is not connected to the neutral of the motor. Therefore the star-point can be shifted away from the motor neutral, and the phase angles of the cell voltages can be adjusted, so that a balanced set of motor voltages is obtained even though the cell group voltages are not balanced.

Siemens calls this approach *Neutral-Shift*, and has a US Patent (5,986,909) that covers it. This approach is equivalent to introducing a zero-sequence component into the voltage command vectors for the cells. In Figure 5-6 the full remaining 87% of functional cells are in use, and 80% of the original voltage is available. The phase angles of the cell voltages have been adjusted so that phase A is displaced from phase B and from phase C by 132.5°, instead of the normal 120°.
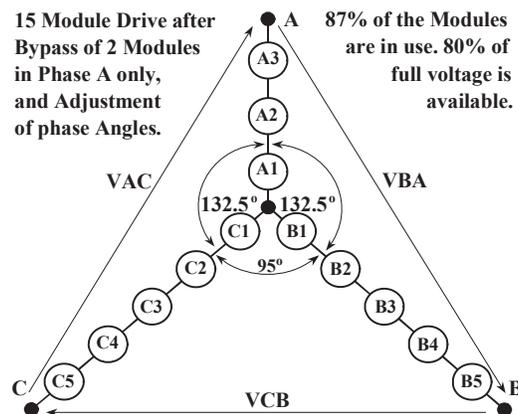
Figure 5-6: Drive output re-balanced by Adjusting Phase Angles (Neutral-Shift)

The same neutral-shift approach can be applied to more extreme situations, as is illustrated by Figures 5-7 and 5-8. Figure 5-7 shows a drive which originally had five cells per phase, or a total of 15 cells. All five cells remain in phase A, but one cell has failed in phase B and two cells have failed in phase C. Without neutral-shift, all phases would need to be reduced to match the cell count of phase C to maintain balanced motor voltages. One functional cell would be bypassed in phase B, and two functional cells would be bypassed in phase A. Only 60% of the original cells would remain in use, and only 60% of the original voltage would be available.

However, with the neutral-shift approach shown in Figure 5-7, only the failed cells are bypassed. The phase angles of the cell voltages have been adjusted so that phase A is displaced from phase B by 96.9° and from phase C by 113.1°, instead of the normal 120°. The star point of the cells no longer coincides with the neutral of the motor voltages, but the motor voltage is still balanced. The neutral-shift keeps 80% of the original cells in use, and 70% of the original voltage is available.
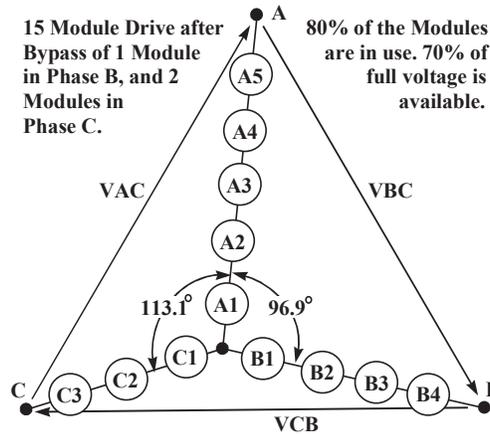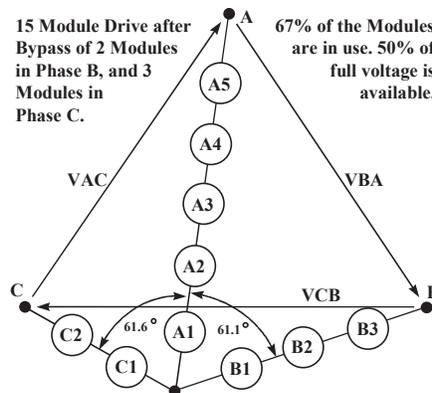

Figure 5-7: Drive output after loss of 3 Cells

As another example, Figure 5-8 shows the same 15-cell drive. All five cells remain in phase A, but two cells have failed in phase B and three cells have failed in phase C. Without neutral-shift, one functional cell would be bypassed in phase B, and three functional cells would be bypassed in phase A. Only 40% of the original cells would remain in use, and only 40% of the original voltage would be available. However, in Figure 5-8, only the failed cells are bypassed. The phase angles of the cell voltages have been adjusted so that phase A is displaced from phase B by 61.1° and from phase C by 61.6°. The star point of the cells is far removed from the neutral of the motor voltages, but the motor voltage is still balanced. The neutral-shift keeps 67% of the original cells in use, and 50% of the original voltage is available.

Figure 5-8: Drive output after loss of 5 Cells

Figure 5-9 compares the available voltage after one failure with and without using neutral-shift. In many cases, the extra voltage available with neutral-shift will determine whether or not a cell failure can be tolerated. The voltage capability of a drive after cell bypass can be calculated by using the following procedure.

If **X** is the largest number of cells in bypass in **two of the phases**, then the maximum voltage at the drive output will be:

$$\text{Vout\_bypass} = \text{Vout} * (2*N - X) / (2*N)$$

where: Vout is maximum output voltage that the drive can deliver (Vout = 1.78*N*Vcell)
N is the number of ranks (or the total number of cells = 3*N)
Vcell is the cell voltage rating.

Example: Consider a drive with 18 cells, each rated for 690V. The maximum output voltage that this drive can deliver is (with N = 6 and Vcell = 690):

$$\text{Vout} = 1.78 * 6 * 690 = 7.37 \text{ kV}$$

If after cell bypass, the drive has 6 cells operational in phase A, 5 cells in phase B, and 4 cells in phase C, then the maximum voltage that the drive can produce with neutral shift from the above formula is (with **X** = 1 + 2 = 3, because 2 cells in phase C and 1 cell in phase B are bypassed):

$$\text{Vout\_bypass} = 7370 * (2 * 6 - 3) / (2 * 6) = 5.53 \text{ kV}$$

The ratio (Vout_bypass / Vout) is available as the Max. Available Drive Voltage (%MAV) for display on the Keypad and for use in the Comparator and Analog Output Menus.
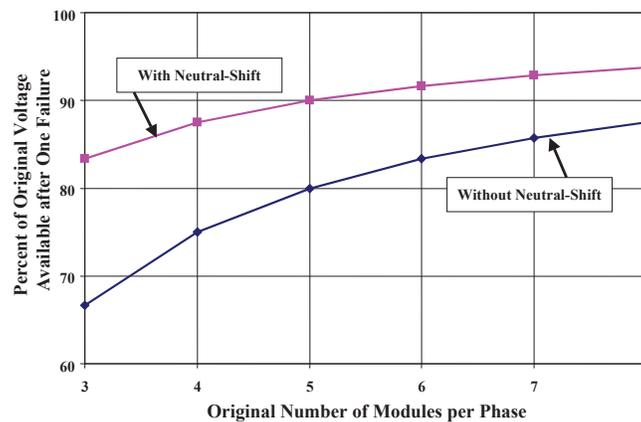
Figure 5-9: Available Voltage After First Failure

The drive control uses the information of faulted cells to automatically calculate the phase angles of cell voltages to maintain balanced motor voltages. During neutral-shift, each phase of the drive operates with a different power factor. Under lightly loaded conditions it is possible that one or more phases is absorbing real power while the other phase(s) are delivering power to the motor. To prevent the cell DC-voltage (corresponding to cells that are absorbing real power) from increasing (and subsequently causing a drive trip condition), the control automatically enables the "Energy Saver" function. Under light loads, the energy saver function reduces motor flux sufficiently so that the motor operates with 70% power factor. At this operating point, the magnetizing and torque components of motor current are equal and all cells deliver real power to the motor. As motor load is increased, the motor flux level is automatically increased to maintain 70% power factor until rated flux (or maximum possible flux) is achieved. This function ensures that the cells are delivering real power under all operating conditions.

☞   **Note:** In Cell Bypass, the drive will invoke Energy Saver under light loads to prevent certain cells from charging-up.

5.6 Power Monitoring

Many Perfect Harmony Drives that Siemens builds have requirements for optional Power Quality Meters (PQM). Adding PQMs can be an expensive option. NXG control builds this functionality into the drive.

NXG control does processing on the input waveforms to aid in control of the drive. Because of this, the drive can determine and display information about the drive input. Likewise, since the control is continuously sampling the drive output, the drive output information can also be displayed. Tables 5-2 and 5-3 list the parameters that can currently be displayed. See Meter Menu (8) for details on displaying this information.

5

Table 5-2: Input

Input Display Parameters
Phase A Input Current
Phase B Input Current
Phase C Input Current
Phase A Input Voltage
Phase B Input Voltage
Phase C Input Voltage
Input Frequency
Average Input Power (kilowatts)
Input Power Factor
Average Input Current THD
Efficiency
Input KWHrs
Input Reactive Power (kVAr)

Table 5-3: Output

Output Display Parameters
Motor Current
Motor Voltage
Magnetizing Current
Torque Current
Motor Speed
Output Torque
Motor Flux
Motor Slip
Output Power
Output KWHrs

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5.7 Dual Frequency Braking

5.7.1 Introduction to Dual Frequency Braking

There are many applications for VFDs that need occasional negative torque for braking. Unfortunately, at present the most popular static converters used for VFDs are not capable of returning energy to the utility. Such applications therefore require additional circuits to regenerate the braking energy into the AC mains, or to dissipate the braking energy in a resistor. Both of these solutions add cost to the VFD, and are especially undesirable for large modular medium-voltage VFDs.

Additional power devices can be avoided by using the existing circuits to inject DC current into the motor windings. This method dissipates the braking energy in the motor and adds little cost to the VFD. However, DC injection braking is not very effective unless the available current is several times rated, especially for large motors. Another drawback is that estimation of motor speed is very difficult during DC injection braking.

Dual Frequency Braking is another method in which braking energy can be dissipated in the motor. Dual Frequency Braking provides much higher torque per ampere than DC injection braking, and permits continuous estimation of motor speed. Like DC injection braking, this approach is implemented in software and requires no additional hardware that can reduce the reliability of the drive.

Siemens has a patent on Dual Frequency Braking (US 6,417,644).

5.7.2 Operation

Dual Frequency Braking (DFB) causes extra losses to be induced in the motor by applying a second set of three-phase voltage vectors to the motor in addition to the normal set of voltage vectors used for speed control. These extra losses are used to absorb the kinetic energy released during braking.

There are two side effects of Dual Frequency Braking (DFB) against which protection is applied as follows:

1. Torque pulsations: The motor can be subjected to as much as 1 per-unit torque pulsation at the pulsation frequency with DFB. However, the customer can select the torque pulsation frequency via the menu entry for Pulsation Frequency to avoid any mechanical resonance frequencies.

2. Motor heating: The losses generated during DFB cause motor heating and limit the number of deceleration ramps (from full speed to zero) that can be performed repetitively. Motor heating due to the additional losses is designed to be no worse than a line start. The software motor thermal model in NXG monitors motor heating due to these losses, and can provide an alarm and/or a trip to indicate excessive heating. (Refer to Section 5.9, Motor Thermal Overload Protection, for information on the thermal model.) The number of repetitive deceleration ramps (from full speed to zero) is limited to 2-per-hour (based on MG-1, Part 20, which assumes that the motor has cooled down to its rated temperature before the second ramp down). This recommendation applies when the load inertia and load torque are those for which the motor is designed. With lower values of load inertia and/or smaller speed reductions, DFB can be used more frequently.

The second set of voltage vectors creates a counter-rotating flux vector that produces high slip in the machine and generates these additional losses in the motor. The pulsation frequency is adjustable via a menu setting to allow critical frequencies (i.e. mechanical resonances) to be avoided. The injection frequency is always in opposite rotation to the applied motor electrical frequency (speed and direction of the machine).

☞ **Note:** Zero Sequence Voltage is the DC offset voltage.

Figure 5-10 is a block diagram showing how the two voltage vectors (normal VA1 and loss-inducing VA2) are added together to produce the braking function. Figure 5-11 is a scope picture of the two voltage vectors added together. The higher frequency voltage waveform VA2 is riding on the lower frequency waveform VA1.

> ☞ **Note:** The pulsation frequency is programmable via the NXG Control (Parameter ID 3370), which is selectable by the end user. It provides the reference to produce the desired additional braking for the system and is adjustable to avoid resonance in the system.
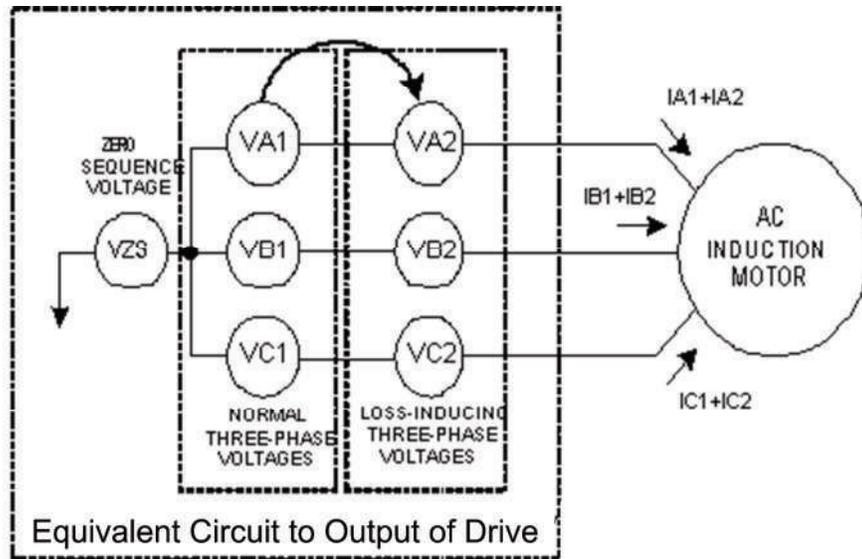

Figure 5-10: Dual Frequency Voltages Being Added Together With The Normal Three-phase Voltages

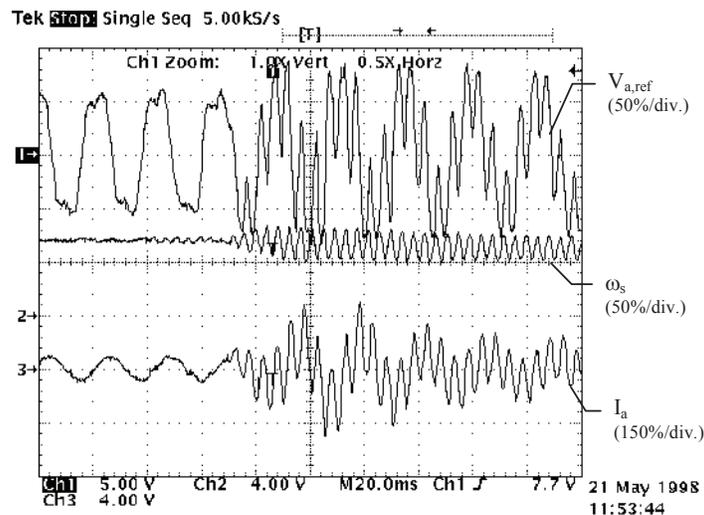> ☞ **Note:** Zero Sequence Voltage is the DC offset voltage.

Figure 5-11: Scope Picture Showing Dual Frequency Braking Waveform

In this method, the first vector set controls the torque and flux in the motor, and is nearly synchronous. The second vector set induces losses in the motor to absorb the braking power returned by the first vector set. The amplitudes of the two vector sets are coordinated to best utilize the current and voltage limitations of the converter. The frequency of the loss-inducing vector set is chosen with the goal of maximizing losses per ampere. This automatically minimizes the torque pulsations by minimizing the loss-inducing current.

The dominant losses in a motor are conduction losses, proportional to I^2R. Maximum losses per ampere require a large value of R. The nominal resistance of the motor windings is fixed by the design. Fortunately, the <u>effective</u> resistance depends on the frequency. The rotor windings are deliberately designed to exhibit a strong "deep-bar" effect, so that their resistance (above a low threshold) increases roughly proportional to frequency.

In principle, the frequency of the loss-inducing vector set should be as high as possible, for maximum effective resistance. Since this high loss-inducing frequency produces negative slip, it will have negative sequence. The maximum applied frequency is limited by the control bandwidth of the converter, and also by the available voltage. However, because the loss-inducing vector set is negative sequence, the rotor frequency will be higher than the stator frequency due to the rotational speed.

5.7.3   Setting Parameters for Dual-Frequency Braking

Table 5-4 provides a description of parameters in the Braking Menu (ID 3350). The Pulsation Frequency should be chosen so that it avoids the (mechanical) resonant frequencies of the system (motor, shaft and load). A study of the mechanical system is required to determine these resonant frequencies. The Brake Power Loss parameter sets the initial value of motor losses; the default value is satisfactory for most cases. The maximum voltage that is applied at the second (loss inducing) frequency is set by VD loss. This parameter cannot be set to a value higher than 0.5p.u. Adjustment of this parameter will have a direct effect on the achievable braking torque. Braking Constant sets the ratio of the power losses created in the motor to the power absorbed by the drive during braking. Using the default value gives sufficient margin and prevents the cell DC-bus voltages from increasing to trip levels.

Table 5-4: Description Of Parameters For Dual-frequency Braking (DFB)

Parameter Name	Units	ID #	Description
Enable		3360	Enable or disable DFB. User must be aware of torque pulsations and motor heating produced with this method.
Pulsation Frequency	Hz	3370	Torque pulsation frequency when DFB is enabled. Adjust for a different torque pulsation frequency. The control always recalculates the desired value due to limited resolution. Can be adjusted to avoid mechanical resonance frequencies.
Brake Power Loss	%	3390	Amount of high frequency losses at the onset of braking. Affects the limit of the V_q component of output braking voltage.
VD loss	p.u.	3400	Max amplitude of the loss inducing voltage. Use this to adjust the braking torque. Sets the maximum loss limiting (V_d) voltage amplitude.
Braking Constant	p.u.	3410	Ratio of motor (induced) losses to power absorbed from load. **This parameter should always be set to a value greater than 1.0**. Setting this parameter higher increases V_q and V_d voltage amplitude of losses in the motor, and increases braking. Caution must be exercised to prevent a motor thermal trip.

5.7.4   Limitations

The drive output current plus the braking current must not exceed the current capability of the cells in the drive. Hence the braking torque is limited in the drive and is greatest at slow speed and smallest at high speed. Figure 5-12 shows the typical braking torque that can be expected with Dual Frequency Braking.
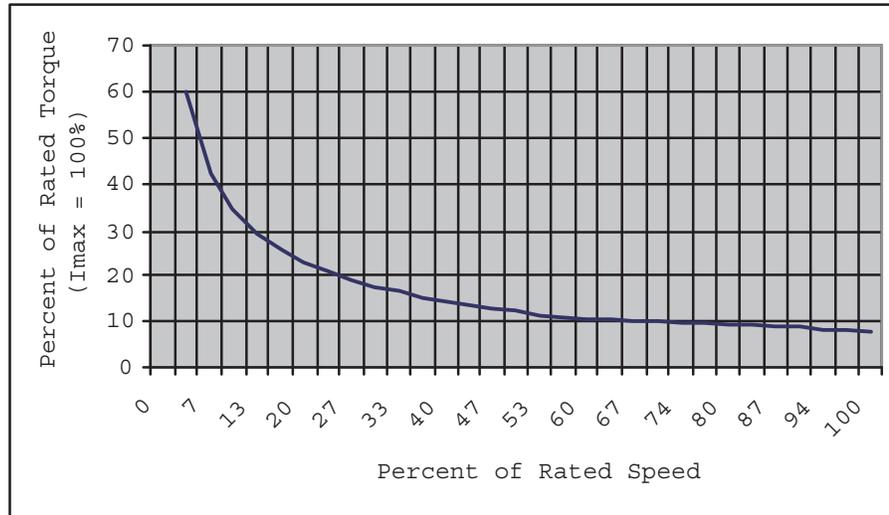

Figure 5-12: Best Case Braking Torque With Dual Frequency Braking For A Typical Motor

With high efficiency motors and inverter duty motors, the braking torque that can be achieved with DFB is lower than the values shown in Figure 5-12. Contact Siemens Engineering with the following motor-related data to determine the braking torque capability with a higher efficiency motor (see Table 5-5):

Table 5-5: Motor Related Data

Rated HP	Rated Voltage
Rated Frequency	Full-load Speed
Half-load Efficiency	Full-load Efficiency
Half-load Power Factor	Full-load Power Factor
Locked-rotor Torque	Locked-rotor Current
Pull-out Torque	Critical Frequencies of the Mechanical System

Information on critical frequencies will allow a selection for the torque pulsation frequency.

5.8 Energy Saver

Energy saver control allows the reduction of motor losses (and improves overall efficiency) when the demanded motor load is low. To activate the energy saver control, adjust the Energy Saver Min Flux Demand (parameter ID 3170) in the Flux Control Menu (3100) to a value that is less than the Flux Demand (ID 3150, which is typically set to 1.0). Depending on the motor load, the control will reduce motor flux to a level between the Energy Saver Min Flux Demand and Flux Demand. As motor load increases, the control will increase motor flux until the value set by Flux Demand is achieved. Note that the response of the drive to sudden load changes is reduced with lower flux demand.

Energy saver is automatically invoked when an unbalanced set of cells is present after fast bypass. Under light loads, it is possible for one or more phases to be absorbing power from the motor. To prevent the cell DC bus from charging up to a trip level, the control reduces motor flux to improve power factor, which allows all three phases to provide power to the motor and prevents the cells from charging up.

5.9 Motor Thermal Overload Protection

Table 5-6: Parameters For Motor Thermal Overload Protection

Parameter	ID	Description	Default
Overload select	1130	Selects the overload trip algorithm. • Constant (fixed current-based TOL) • Straight inverse time (motor temperature based TOL) • Inv time w/ speed derating (motor temperature based TOL)	Constant
Overload pending	1139	Sets the thermal overload level at which a warning is issued (constant mode).	100.0
Overload	1140	Sets the motor thermal overload trip level at which the timeout counter is started (constant mode).	120.0
Overload timeout	1150	Sets the time for the overload trip (constant mode).	60.0
Speed Derate Curve	1151	This menu sets allowable motor load as a function of speed.	Sub-menus
Maximum Load Inertia	1159	Sets the maximum load inertia that the motor can line start without exceeding maximum temperature.	0.0

NXG Perfect Harmony control provides Motor Thermal Overload (TOL) protection to prevent the motor from being subjected to excessive temperatures. TOL protection of the motor can be set up using the menus shown in Table 5-6. The "overload select" parameter allows one of three options to be selected for motor protection. The first model, which is called "constant," is based on the current flowing into the motor. A Motor Thermal Overload Alarm 1 is issued as a warning to the user (of an impending overload fault) when the motor current exceeds the "overload pending" parameter. When the drive current exceeds the "overload" setting, Motor Thermal Overload Alarm 2 is issued and a thermal trip timer is started. If this condition is present for a period greater than the time set in the "overload timeout" parameter, the drive will trip and annunciate the event as Motor Thermal Overload Fault. **It should be noted that both the Alarms 1 and 2 have to be enabled through the SOP for the drive to display those conditions.**

The second and third thermal models, which are called "straight inverse time" and "inverse time with thresholds," use a software motor thermal model to determine motor temperature. See Figure 5-13. For these options, the "overload pending" and "overload" settings represent the motor temperature limits (in percent of rated motor temperature) at which the overload warning and trip are generated. A brief description of the thermal model follows.
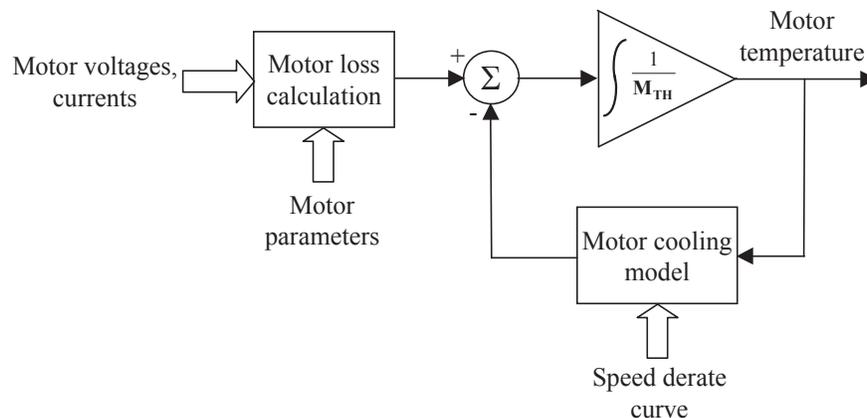

Figure 5-13: Block Diagram Of Motor Thermal Model

The motor model estimates motor temperature based on the net heat generated in the motor and its thermal mass. A block diagram of the implementation is shown in Figure 5-13. The heat generated in the motor is estimated from the stator voltages, currents, and motor parameters, while an estimate of the heat transferred from the motor (due to motor cooling) is made from the allowable motor current (more on this in the following paragraph). The motor loss calculation also includes the losses generated with Dual-Frequency Braking. The thermal mass (shown as M_{TH}) of the motor (or its heat capacity) is determined from the maximum load inertia listed in Table 20-1 of NEMA Standard MG-1 1993 Part 20.42. The user has the option of entering a known value of max load inertia as well (which can be obtained from the manufacturer).

If "straight inverse time" protection is chosen, then it is assumed that the motor has an allowable current level of 100% (for example, when the motor is equipped with a constant-speed cooling fan). With "inverse time with speed-derating," the allowable current level is determined from the speed-derating curve entered through the keypad. This curve requires the user to enter allowable motor load for various speed breakpoints. The default-derating curve provides breakpoints for a quadratic cooling curve (and is shown in Figure 5-14). The motor manufacturer normally provides data for this curve. The control software uses the allowable current level to determine the cooling capability of the motor.

If the user's preference is to enter a fixed value of an allowable current level other than 100% (as with the "straight inverse time" option), the speed-derating curve can be modified to have the same desired level for all the breakpoints.
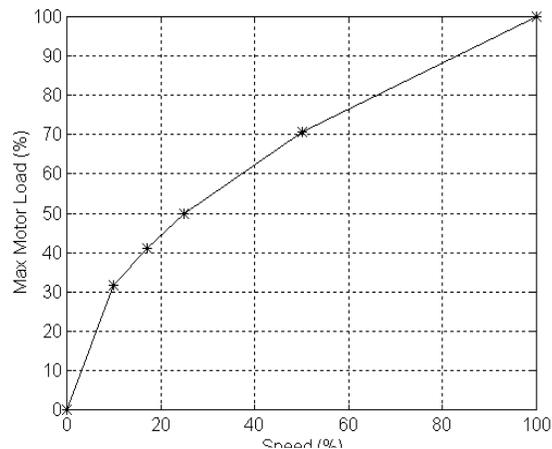
Figure 5-14: Default Speed-derating Curve Showing Maximum Motor Load As A Function Of Speed

The plot in Figure 5-15 shows results from an experimental evaluation of the software thermal model with the "straight inverse time" option (100% "overload" setting) for various levels of drive current. A 4kV, 300 Hp motor was used for this test. The experimental data shows the time taken for the estimated motor temperature to go from rated temperature to 120% of rated. This curve is quite conservative as compared to a Class 10 TOL that trips at 280 sec with 150% current and at 630 sec with 125% current.
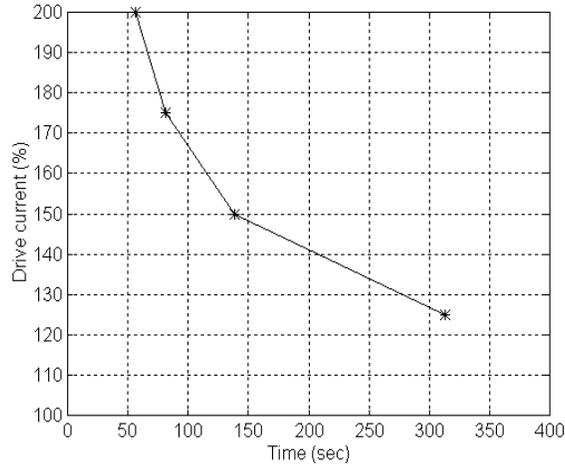
Figure 5-15: Drive Current (In Percent Of Motor Rated Current) Versus Time Taken For Motor Temperature

* The data was measured with the "straight inverse time" option.

5.10 Process Availability - The Perfect Harmony Advantage

Process availability is the primary prerequisite for applying a Medium Voltage VFD system in a process critical application. By combining the capabilities of Perfect Harmony's unique distributed power architecture with the power of the NXG control and the patented advanced power cell bypass feature, it is possible to deliver unparalleled opportunities for improved process availability. It is also essential that the process operator receive complete and accurate information on VFD status to allow for process adjustments, which can preclude process trips and disruptions in process capability.

5.10.1 What is ProToPS?

ProToPS is an acronym that stands for "Process Tolerant Protection Strategy." ProToPS is a standard implementation of the VFD System Operating Program. The ProToPS goal is simply to put the process operator in control of the process. ProToPS is a system program implemented from a customer process perspective.

ProToPS provides the operator with indication of a change in state in the VFD. These annunciations identify changes that can impact the ability of the VFD to meet process demands, or provide advance indication of a pending VFD trip. ProToPS allows the process operator to make process corrections to maintain the VFD in use in service, or adjust the process to address a pending VFD trip.

With ProToPS, the process operator not only knows the general status of the VFDs, but also understands the VFD condition that has caused the general alarm to exist.

5.10.2 How Does ProToPS Work?

In the ProToPS System Operating Program, all of the automatic roll-back flags are turned off, and both cell bypass and auto-restart are implemented as standard. The need to roll-back is still necessary, but the process operator is now responsible to implement a roll-back as part of a process correction, as opposed to having the VFD roll-back either dictating, or in worse case, upsetting the process.

ProToPS takes the standard fault indications available in the VFD, and categorizes them into four basic major categories as follows:

1. **Alarm**

    An alarm is an indication that a VFD parameter limit has been reached, or that a VFD system condition is present. An alarm provides the operator with awareness of the condition, but demands no immediate action. Examples of alarms include: over-voltage, under-voltage, and ground fault.

2. **Process Alarm**

    A process alarm is an indication that a VFD parameter limit has been exceeded and that the process either should be limited, or that the VFD capacity to meet the process demand is limited. Examples of process alarms include thermal limits above the rated limit, and the condition of a cell having been bypassed.

3. **Trip Alarm**

    A trip alarm provides a clear indication that a VFD high parameter limit has been reached. A trip alarm is an indication that a VFD trip is pending. The operator receives a message that unless the alarm can be cleared by a process change, the VFD will trip.

4. **Trip**

    Certain VFD faults cannot be provided with advance warning. This limited number of faults will result in a VFD trip. A trip message is also annunciated when a trip alarm time limit has been exceeded. The number of mandated trips is considerably reduced with the implementation of cell bypass.

    With ProToPS the (VFD Run) signal is maintained as "true" and the (VFD Trip) signal is maintained as "false" for all alarm states.

5.10.3 ProToPS Implementation

With ProToPS, the main protection indication categories are provided as separate digital output signals. The concept is to provide the operator or the process program with a clear message to indicate a status change in the VFD. These digital outputs are delivered from the Wago I/O system. The location of the outputs is maintained as a standard set of TB2 terminations.

The specific information on the VFD parameter change is indicated (along with the general category information) as a serial address across a serial communications interface. Any serial communications protocol supported by the VFD product can be supported in the ProToPS implementation.

If other specific digital output information is required for a specific customer project, that information must be mapped to a new digital output point on an additional digital output module. **The basic category outputs must be present as digital outputs, at the standard designated TB2 terminal point locations, to validate the ProToPS implementation.**

5.10.4 The ProToPS Advantage

With cell bypass, there are virtually no cell faults that are non-bypassable. With NXG control, the need for the designation "Transient Alarm" has disappeared as all bypassable faults become process transparent.

With ProToPS and the NXG control, combined with the unique benefits of the Perfect Harmony cell based distributed power technology, process availability can be considerably enhanced and the process operator can truly control the process.

5.11 PID Controller

The NXG Control has a built-in PID controller available for use as a process control input of the NXG Command Generator. The PID is depicted in Figure 5-16, and also in the Command Generator Diagram drawing number A5E01219450A located in Appendix C. The PID output is selected as the Speed Demand for the system by setting the System Program flag "RawDemandPid_0" to true. The PID command feedback source is fixed from Analog Input #2. This Analog input can be any of the available Analog inputs within the system, but must be designated as Analog input #2 in the setup menu (refer to "Analog Input #2 Menu (4170)" in Chapter 4). The PID command has two possible sources: Analog input #1 or the PID set point menu item (ID 4410). The source for the PID command is controlled by the state of the system program flag "PidMenu_0". Setting this flag to true selects the PID set point menu as the source. Setting this flag to false selects Analog Input #1. Analog input #1 source is configured from the "Analog input #1 menu (4100)" in Chapter 4. Refer to "PID Select Menu (4350)" in Chapter 4 for details regarding the PID parameters.
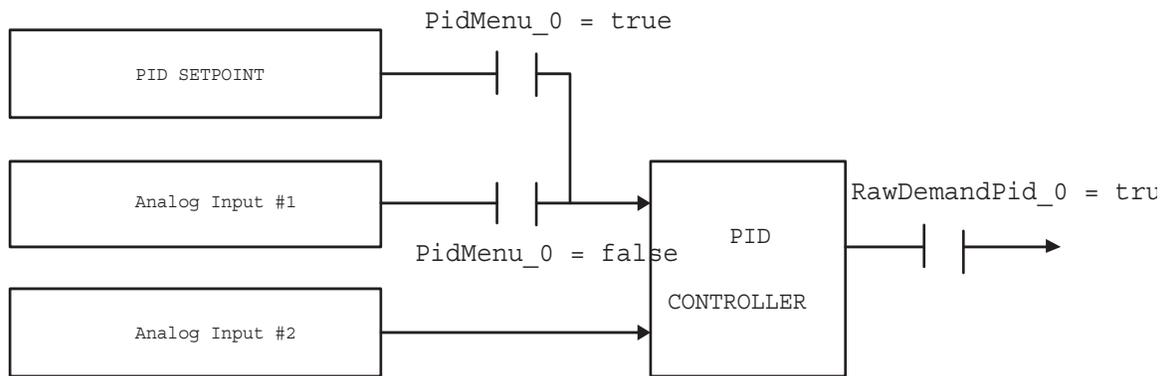
Figure 5-16: PID Controller

5.12 Speed Droop

Speed droop is used in systems that are mechanically coupled so that current (load) sharing can be accomplished. This works for controlling current sharing with multiple drives in parallel with a single motor, or in sharing load between multiple motors with separate drives (e.g. large conveyors, rock crushers, etc.) mechanically coupled to the same load. The load or current is shared by decreasing the speed demand slightly as load increases. Equilibrium is reached when the load is evenly shared between drives and/or motors.
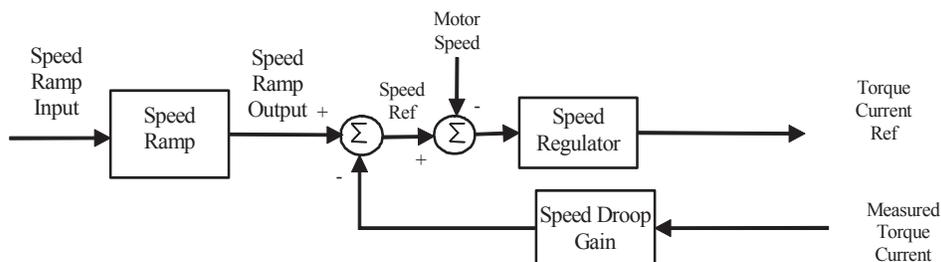

Figure 5-17: Speed Droop

This function is linear and the amount of droop is directly proportional to the load (torque) current. The Droop is applied across the entire speed range.

Modifications have been made to this feature from earlier versions to apply the speed modification after the speed ramp, rather than before the ramp as in earlier versions of drive software. This provides for faster load sharing response to load changes.

Settings for this parameter are completely application dependant. The default is zero, or disabled.

5.12.1 Parameters

Location: Stability → Output Processing → Speed Loop

Parameter	ID	Units	Default	Min	Max	Description
Droop in % of FL Speed	3245	%	0	0	10	Desired speed droop in percent of rated speed at full load current. Entering zero disables this feature.

5.13 Verification of Excessive Drive Losses Protection

NXG control utilizes input power and output power calculations to determine whether an internal fault has occurred. Drive Power Loss is estimated as the difference between input power and output power. This quantity is continuously checked with a pre-defined threshold that is inverse time-based, i.e., if the threshold is exceeded by a large margin, then the trip occurs in a short time after the event, and vice-versa.

Because the Drive Losses calculation (See Section 7.8 of Chapter 7) depends on input and output power calculations, it is important to make sure that the Drive Input and Output Rated Values (voltage and current – IDs 2010, 2020, 2030, and 2040), Drive Input Scalers (IDs 3030, 3040), Input CT turns ratio (ID 3045), Output Scalers (IDs 3440 and 3450), and Low Freq Wo (ID 3070) are correctly set.

A typical Perfect Harmony Drive has a full load efficiency of 96.0 to 96.5%. It is at full load that the drive has maximum losses, and hence this is the operating point that may get closest to the threshold setting. If, during startup, the drive trips on an Excessive Drive Losses Fault, then the following steps may be followed to determine if it was a nuisance trip:

1. Verify that the parameters listed above are correctly entered. Use VFD drawings along with visual inspection (if possible) to make the verifications. A common error is made in entering the Output Current Rating. This menu entry should always be set equal to the Cell Current Rating. A tech note on setting these parameters, "Drive Rated Parameters in NXG Control Topics," is available on the Siemens website.

2. Make sure that the Low Freq Wo parameter (ID 3070) matches the version of System Interface Board, since this parameter affects the phase-shift introduced in the measured voltage signals (and hence affects the output power calculation). This parameter should be set to 12.566 rad/s for the 461F53.00 version, or to 37.859 rad/s for the 461F53.02 version.

3. Run the drive to a speed-point at which measurable values of input and output, voltage and current are present. Use the table in the Startup Procedure chapter of the Perfect Harmony Manual to verify if the feedback signals on the System Interface Board (i.e., on the test-points VMA, …, IMA, …, VIA, …, IIB, IIC) correspond to the values displayed by the drive. A Tech Note describing Drive Voltage Feedback scaling and verification is available on the Siemens website.

4. Manually verify that the Drive Losses (= Input Power – Output Power, both of which can be read off of the keypad, ToolSuite, or the Debug Screen) are less than the threshold setting (for this type of drive and NXG software version).

5. Increase speed (and load) to make sure that the Drive Losses are within the range of 2.5% to 4.5% of Rated Input Power (which is defined in equation 1).

> **Note:** Transformers rated above 5000 Hp and those designed prior to summer of 2002 may have higher than normal losses. Drives with such units may have more than 3.5% losses at full load. Use of version 2.50 or later of NXG software will help if drive losses at full load are 5.0% or lower. If the losses are higher than 5.0%, then discuss the issue with Application Engineering or Product Development.

5.14 Transformer Protection Constant for One Cycle Protection

The menu parameter Xformer Protection Constant (ID 7100) can be set according to the expected input power factor at full load. On a typical Perfect Harmony Transformer, the full load power is no worse than 0.96. Hence, the default value of 0.50 for the Xformer Protection Constant is adequate. Table 5-7 shows that the default value is good for power factors as low as 0.90, but may be marginal. See Chapter 7 for details of the one cycle protection implementation.

Table 5-7: Transformer Protection Constant for Various Full Load Power Factors

Full load PF	K_{tr}
0.88	0.54
0.89	0.51
0.90	0.47
0.91	0.43
0.92	0.40
0.93	0.36
0.94	0.32
0.95	0.29
0.96	0.24

5.15 Effect of Slip Compensation on Motor Speed with NXG Control

With Slip Compensation, the electrical frequency is always greater than the desired shaft speed (mechanical frequency) for all non-zero loads. Therefore at 100% speed demand, the NXG OLVC will maintain the shaft speed at the rated synchronous speed of the motor – not full load speed.

Example:

A 6-pole motor rated for 60 Hz has a synchronous speed of 1200 RPM. The Full Load speed (entered from the nameplate to ID 1030) is 1192 rpm.

Sending a speed demand of 100% will produce a mechanical (shaft) speed of 1200 RPM with slip compensation. This will result in a higher output (electrical) frequency to the motor to provide the necessary torque to achieve the desired speed. The slip frequency is directly proportional to the required torque, up to the rated torque current. The display will show (depending on what is selected):

*   Motor speed, in RPM, of 1200 RPM

*   Motor speed, in percent, of 100%

*   Motor Frequency, in Hz, of 60.4 Hz at rated torque (101% if motor frequency is displayed in percent)

Theory:

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Sending the drive a speed demand of 100% means that Synchronous or Rated Speed is desired. This is calculated by equation 1 below.

Synchronous Speed, Ns, is defined by the formula:

1. $N_S = 120 * f_{RATED}$ / # of poles

Slip is defined as a percentage (at rated torque) of the difference between synchronous and full-load speed (N_{FL}) divided by the synchronous speed:

2. $\text{Slip (\%)} = 100 * (N_S - N_{FL}) / N_S$

With slip compensation, the slip frequency is subtracted from the output frequency (f_{OUT}) to ensure that the mechanical speed matches the desired speed. In simple terms, this is done by taking the per unit (PU) Torque (T_{PU}) times the slip, and subtracting it from the speed feedback (in frequency), effectively adding it to the speed reference:

3. $S_{MOT} = f_{OUT} - (\text{Slip} * T_{PU})$

4. $S_{ERR} = S_{DMD} - S_{MOT}$

In equation 4, S_{ERR} represents the error signal processed by the speed regulator. The implication for this is that for a speed command of 100%, based on the synchronous speed, the applied electrical frequency will be higher than rated frequency due to the increase created by the slip compensation (equation 3 and 4). This will result in the motor running at true requested mechanical speed with the electrical frequency adjusted to provide the torque necessary to produce that speed.

Limiting Frequency by Disabling Slip Compensation:

If the motor is to be limited to a specific frequency, then the slip compensation can be disabled. In the same example, the Full Load speed parameter (1030) must be set to 1200 RPM. This effectively disables the slip compensation by reducing equation 2 to produce a slip of zero. Then equation 3 and 4 reduce to:

1. $\text{Slip} = (1200 - 1200) / 1200 = 0$

2. $S_{MOT} = f_{OUT} - 0 = f_{OUT}$

The end result will be that the drive will regulate to the output frequency rather than the motor shaft speed (mechanical speed). No compensation for slip is done.

Conclusion:

With Slip compensation:

*   Output shaft speed will equal the percentage of synchronous speed requested
*   The frequency will vary depending on load, but the speed will be fixed
*   Motor Speed in RPM should be monitored

Without Slip Compensation (parameter 1030 set to the synchronous speed):

*   The Output Frequency will equal the speed demand percentage of rated frequency
*   The mechanical (shaft) speed will vary with load but the frequency will be fixed
*   Motor Frequency in Hz should be monitored

Note: The internal units for speed and frequency are in radians/sec. When plotting any related internal variables with the Siemens LD A ToolSuite, the selected values are normalized to rated speed, so a scaling factor of 1.0 can be used.

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5.16 Synchronous Transfer Operation for Induction Motors

5.16.1 Introduction

The term "up transfer" is used to transfer a motor running from a variable frequency drive (VFD) to the line, and then decouple the motor from the drive. "Down transfer" is used to match the drive with a motor running off the line, decouple the motor from the line, and transfer the motor to the VFD.

5.16.2 Transfer Setup and Faults

Before attempting synchronous transfer, the command generator options selected during pre-synchronous transfer should be examined. It is important to disable command generator functions that may cause the transfer to fail. Verify that the speed profile, polarity change function, and speed limits do not modify the input frequency when a synch transfer is requested. The input frequency is treated much the same way as any other raw speed demand into the drive. Refer to the Command Generator diagram (A5E01219450A).

During synchronous transfer, there are three alarm/fault conditions that can occur:

- Up Transfer timeout (alarm): Meaning that the transfer has taken longer than allocated in the "Up transfer timeout" menu (ID = 2760).

- Down Transfer timeout (alarm): Meaning that the transfer has taken longer than allocated in the "Down transfer timeout" menu (ID = 2770).

- Phase Sequence (alarm or fault): Indicating that the Drive input phase sequence or direction is different than the Drive output.

The timeout alarms may indicate that other conditions may be causing the transfer to fail. An example would be that there might not be enough active cells left in the drive to support the line voltage during down transfer. In this case, the drive sets the SOP flag *InsufficientOutputVolts_I* high.

5.16.3 Up Transfer

Up transfers are accomplished by taking the motor up to speed on the VFD to match the frequency of the line. This is accomplished by using the drive input line frequency as a velocity reference. This is accomplished by the drive software when the up transfer request is received. Once the frequency is matched, the phase also needs to be matched with a predetermined leading phase to ensure the power flow is out of the VFD while the line contactor is closed. This step is done by using the line frequency and phase information from the input PLL and the output phase information from the output PLL to determine a vernier adjustment to the frequency that is added to the velocity command. When the synchronization is complete, the drive contactor is opened and the drive coast-stopped to end the transition. The sequence of control logic is as follows:

☞ | **Note:** All discrete steps imply a time delay for the drive to recognize each step independently. All handshaking must allow a minimum of 250 ms between signals sent.

1. Start the VFD as a normal running drive with proper speed command. The drive must be in the "RUN" state to initiate transfer.

2. Initiate the transfer with the transfer request system flag (*UpTransferRequest_O*) when a transfer is desired. Also a menu timer can be enabled for transfer time-out (a transfer failed alarm). If no transfer failure exists, the drive enters "UP_TRANSFER" state and transfer state "TRANSFER_INIT" (A). **If the drive output voltage capability, due to cell bypass or high input line voltage, is less than the line voltage (see Section 5.5 on Neutral Point Shift during Cell Bypass), the control will prevent the Drive from entering the "UP_TRANSFER" state, and set the *InsufficientOutputVolts_I* flag high.**

3. From this point the transfer is controlled through the transfer state machine from within the "UP_TRANSFER" Drive State. With the entry into this state, the velocity regulator demand generator is forced to accept the reference from the line frequency measurement.

The Up Transfer State machine consists of the following five states (refer to Figure 5-18 and Table 5-8):

Table 5-8: Up Transfer States

State	Value*
A – TRANSFER_INIT	0
B – WAITING_FOR_FREQUENCY_LOCK	1
C – WAITING_FOR_PHASE_LOCK	2
D – WAITING_FOR_CONTACTOR_CLOSURE	4
E – TRANSFER_COMPLETE	6

*Value is the value of the state machine variable for plotting purposes.

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4. In Transfer State "TRANSFER_INIT"(A), the new velocity reference represents input line frequency as described above with no vernier for phase offset correction. The drive will stay in this state until the frequency error is reduced to less than 0.5 Hz. At this point, the Transfer State is advanced to "WAITING_FOR_FREQUENCY_ LOCK"(B).
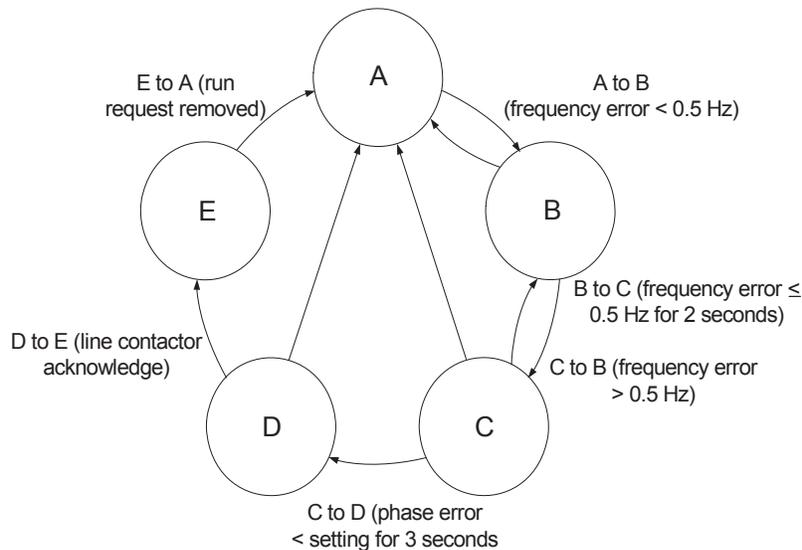
Figure 5-18: Synchronous Transfer State Diagram for "Up Transfer"

5. In transfer state "WAITING_FOR_FREQUENCY_LOCK"(B), the drive maintains frequency lock for 2 seconds before advancing to the next Transfer State "WAITING_FOR_PHASE_ LOCK"(C).

6. In transfer state "WAITING_FOR_PHASE_LOCK"(C), the drive uses the phase lock loop phase error in a P+I loop to calculate a phase correction velocity reference vernier adjustment, which is added to the line frequency reference as the input demand to the velocity regulator. This correction is continued until the phase error is less than a user-entered value for a period of 3 seconds. An optional offset to the error, programmable through a menu entry in degrees of phase shift, may be added as well. When the minimized phase error has been maintained for the proper time, the state machine sets a system program flag "*UpTransferPermit_I*" to enable the line contactor and advance to the next transfer state, waiting for contactor closure (D). This flag must be used to enable the line contactor. If frequency lock is lost during this state, the state machine drops back to state B until frequency lock is again restored.

7. In transfer state "WAITING_FOR_CONTACTOR_CLOSURE"(D), the drive maintains the phase lock loop and waits for the acknowledgment of the line contactor pickup. When the contactor closed is sensed via the system program flag "*LineContactorAcknowledge_O*", the drive sets the "*UpTransferComplete_I*" and advances to the final Transfer State "TRANSFER_COMPLETE".

8. In transfer state "TRANSFER_COMPLETE"(E), the drive is waiting until the Drive Run request is removed. The flag must be used to drop out the VFD contactor while maintaining the line contactor.

9. Once the drive enters the drive state "UP_TRANSFER", the only way out is through the normal completion of the transfer, or if a transfer time-out failure, a drive fault, or an E-stop occurs. A transfer timeout failure (alarm) occurs if the system is unsuccessful at completing a transfer before the end of the timeout period. If a timeout occurs before reaching the "TRANSFER_COMPLETE" (E) State, the drive returns to drive state "RUN" state and presets the Transfer State back to "TRANSFER_INIT"(A). The drive issues a Transfer Failure Warning and waits for a reset before attempting a new Up Transfer. If the drive makes it to the "TRANSFER_COMPLETE" (E) State, the drive will not issue a timeout.

A Drive Fault causes the drive to go into "Coast Stop" and then the drive "IDLE" state. A Fault Reset is required to re-enable the drive to run (ready-to-run equals true). A drive restart is required as in Step # 1 to begin a new Up Transfer Sequence. The drive responds to a CR3 or drive-inhibit in the same way as a Fault. If this occurs in any state other than the Transfer Complete State (E), the drive drops back to the Drive Run State.

5.16.4 Down Transfer

"Down transfer" is used to transfer a motor from the line to the Drive. With NXG control, the drive monitors the output voltage before locking-in to the motor frequency via the spinning load algorithm. For the drive to perform such a sync, the VFD contactor is required to be closed at the beginning of the Down Transfer sequence. The drive is capable of locking-in within a few milliseconds. The drive then raises the output torque current before indicating that it is ready to accept the motor (and open the line contactor). The sequence for down transfer is as follows:
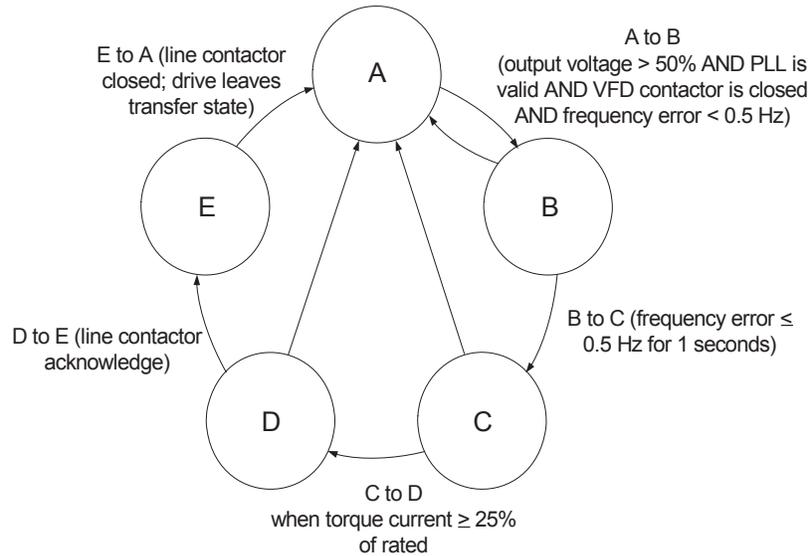
Figure 5-19: Synchronous Transfer State Diagram for "Down Transfer"

1. NXG Control requires Spinning Load to be enabled, and that the Drive is in the "IDLE" state prior to down transfer. To start, assume that the motor is running from the line, the line contactor is closed, and a contactor acknowledge is provided to the drive.

2. The down transfer request system program flag (*DownTransferRequest_O*) is set.

3. A "run request" is issued to the drive. If the drive is capable of supporting the voltage on the motor, the drive issues a permit (*DownTransferPermit_I*), which is used to **close** the VFD Output Contactor, then goes into the Down Transfer State machine. The Drive will begin to sense the voltage from the drive output. **If the drive output voltage capability, due to cell bypass is less than the line voltage (see Section 5.5 on Neutral Point Shift during Cell Bypass), the control will prevent the Drive from entering the "DOWN_TRANSFER" state, and set the *InsufficientOutputVolts_I* flag high.**

The Down Transfer State machine consists of the following five states (refer to Figure 5-19 and Table 5-9):

Table 5-9: Down Transfer States

State	Value*
A – TRANSFER_INIT	0
B – WAITING_FOR_FREQUENCY_LOCK	1
C – WAITING_FOR_TORQUE_TO_BUILD	3
D – WAITING_FOR_CONTACTOR_OPENING	5
E – TRANSFER_COMPLETE	6

*Value is the value of the state machine variable for plotting purposes.

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4. After entering "DOWN_TRANSFER" state, the drive is initially in the transfer state A-(TRANSFER_INIT), and will transition to transfer state B-(WAITING_FOR_ FREQUENCY_LOCK) after the output PLL stabilizes with the motor flux. The drive transistors are enabled in the transition from state A to state B. Transition from B to C requires that the drive output frequency and the line frequency be within ½ hertz for 1 second while the drive is connected to the line.

5. Now that the drive has matched the line frequency, it will begin to raise the amount of torque producing current to the motor in preparation for the transfer of motor control from the line to the drive. Transition from C to D occurs when the torque producing current is greater than or equal to 25% of the maximum permissible current (Iqs max). The drive issues a signal (sets it True) to unlatch the line contactor (*LineContactorUnlatch_I*).

6. Once the PLC opens the line contactor, it should clear the line contactor acknowledge flag (*LineContactorAcknowledge_O set to False*). The state machine then transitions to the E-(TRANSFER_COMPLETE) state. It is vital that this signal is sent only after ensuring that the contactor is open.

7. The drive issues a down transfer complete signal (*DownTransferComplete_I*), after which the down transfer request (*DownTransferRequest_O*) can be removed.

8. The drive then ramps to the speed setpoint set by the customer, and the Down Transfer State machine is reinitialized to state "A."

9. If a Transfer Time-out occurs when the drive is within the "DOWN_TRANSFER" state, then the drive goes back to the state A-(TRANSFER_INIT). The drive issues a Transfer Failure Warning and waits for a reset before attempting a new Down Transfer.

To Stop the Drive while it is connected to the line, issue a Stop Request by reviewing the Run Request. This will disable the Drive output immediately. Then remove the VFD Contactor Acknowledge, open the VFD Contactor, and remove the Down Transfer Request.

A Drive Fault causes the drive to go into "Coast Stop" and then to the "IDLE" state. A Fault Reset is required to allow the drive to run again. To reset the Fault, open the VFD Contactor, remove the VFD Contactor Acknowledge, and remove the Down Transfer Request. Follow the sequence listed from Step # 1 for a new Down Transfer sequence. The drive responds to a CR3 or drive-inhibit in the same way as a Fault, except that a fault reset is not required. However, the drive-inhibit must be cleared to run again.

5.16.5 Synchronous Transfer with Multiple Motors and a PLC

Perfect Harmony drives can be used to control multiple motors using synchronous transfer methodology. Such applications are used to sequentially control a series of motors, one motor at a time. Consider the following example. A reservoir is being filled with liquid at an unknown, variable rate. Up to three pumps are used to remove the liquid to keep the reservoir level at a certain setpoint (this is the external process). As the external system error (i.e., the positive or negative deviation from the setpoint) continues for an external process (e.g., the feedback value rises above a setpoint value), the first motor (a pump, for example) is controlled by the drive to attempt to correct the error and bring the reservoir level back to its setpoint level. If the error from the external process continues (i.e., the reservoir level remains above its setpoint value), the first pump may be unable to reach or maintain the level setpoint - even at greater than 100% speed. If this occurs, the first pump is smoothly transferred to line voltage (at 100% speed), and the drive begins to control a second pump motor. If the error of the external process remains, the second pump can then be operated in addition to the first pump (at 100%) using straight line voltage, while a third motor is brought on line and controlled by the drive. This transfer of drive control from one motor to the next can occur with a single Perfect Harmony drive and any number of motors.

Figure 5-20 shows a reservoir being emptied by pumps 1, 2, and 3 (which use induction motors M1, M2 and M3, respectively). As the tank fills past the setpoint level (monitored by an external feedback signal), the drive controls motor M1 (via motor control center MCC1) to maintain the level. As the tank level continues to increase, the motor on pump 1 will eventually reach 100% speed. If the tank level continues to increase, the Perfect Harmony initiates an "up transfer". This process involves electronically switching control of motor M1 to line control (rather than VFD control). This process is done smoothly using a serial communications network (MODBUS protocol, for example)

and a pair of electronically controlled contactors (**L1** for line control and **V1** for VFD control). With motor M1 running at 100% (line voltage), motor M2 (on pump 2) is switched from an idle state into VFD control using PLC commands and contactor **V2**. This process continues with additional motors until the external process feedback indicates that the tank level is at its setpoint. This entire process works in the reverse order (called a "down transfer") when a negative error occurs (i.e., the feedback signal shows that the measured value is below the setpoint value). An "up transfer" process is illustrated graphically in Figure 5-21. A "down transfer" process is illustrated graphically in Figure 5-22. These graphs show motor output percentages as functions of time with either continued demand (positive error) for "up" transfers or no demand (negative error) for "down" transfers.

Note that the graphs in Figures 5-21 and 5-22 show very "clean" proportional ramps. These ramps are for illustration purposes only and do not include any integral or derivative control action. A continued demand throughout time period t_4 is assumed in Figure 5-21, and no demand is assumed throughout time period t_9 in Figure 5-22. An overview of the control states of the motors used in the example of Figure 5-21 is given in Table 5-10. A similar overview for Figure 5-22 is given in Table 5-12.

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> **Note:** The state machines for up and down transfers reside in the Perfect Harmony's state control program. These interface with the control system integrator's PLC network via the VFD system operating program to handle handshaking between each motor control center (MCC) and the VFD. All controls for the VFD and line contactors are controlled from the system integrator's PLC.
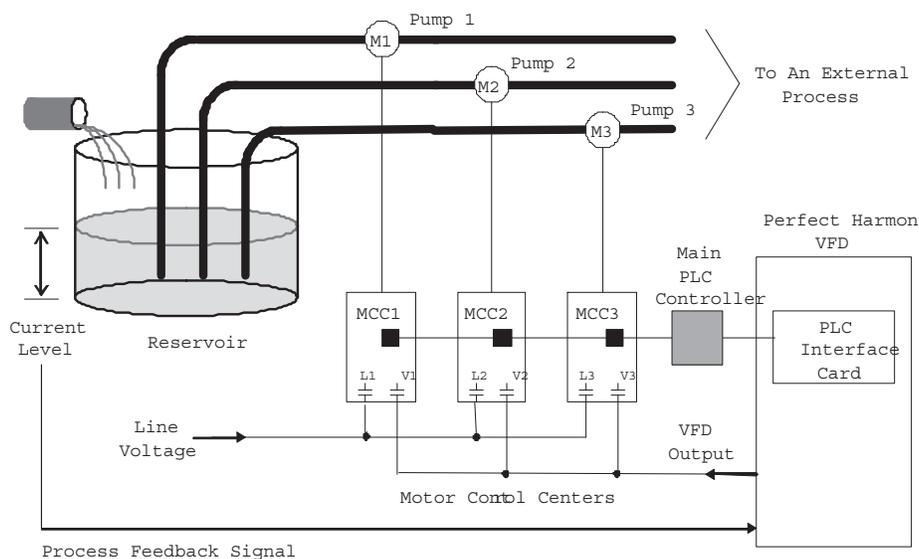
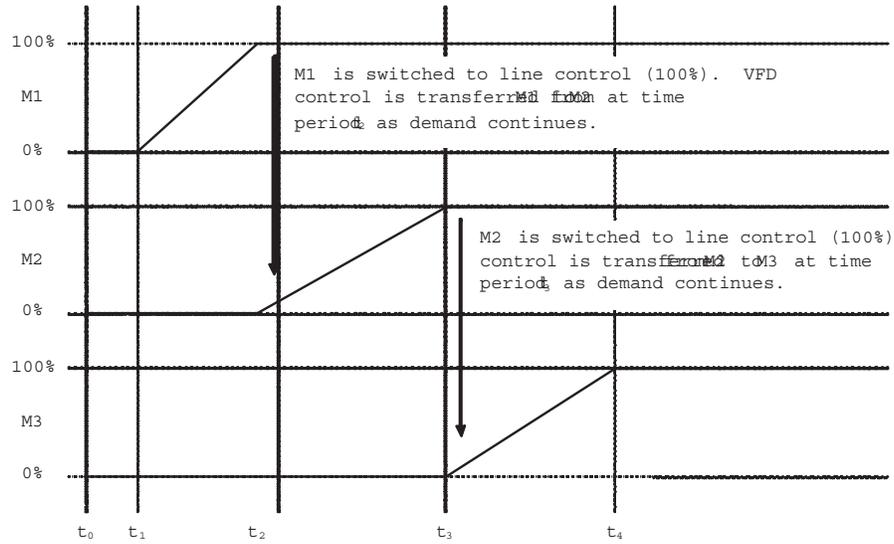**Figure 5-20: Overview of a Sample Transfer Application**

```
100% ┄┄┄┄┄┄┄┄
          ┌───────
M1       /│        M1 is switched to line control (100%).  VFD
        / │        control is transferred from M1 to M2 at time
  0% ───   │        period t₂ as demand continues.
          │
          │
100% ─────│────────
          │    ┌──────
M2        │   /│        M2 is switched to line control (100%)
          │  / │        control is transferred from M2 to M3 at time
  0% ─────┘─── │        period t₃ as demand continues.
              │
              │
100% ─────────│──────
              │   ┌────
M3            ▼  /
  0% ────────────┘
     t₀  t₁    t₂      t₃      t₄
```

Figure 5-21: Graphical Representation of a Sample "Up Transfer" with Continued Demand

Table 5-10: Control States of Motors in a Sample "Up Transfer"

Time	M1	M2	M3
t_0	VFD Off (0%)	Off (0%)	Off (0%)
t_1	VFD (0-100%)	Off (0%)	Off (0%)
t_2	Line (100%)	VFD (0-100%)	Off (0%)
t_3	Line (100%)	Line (100%)	VFD (0-100%)
t_4	Line (100%)	Line (100%)	VFD (100%)

```
100% ┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄
          ┌──────────────┐
M1        │              │\
          │              │ \
  0% ─────┘            ▲ └──────
                       │
100% ─────┐            │
          │\           │
M2        │ \          │    M2 is switched to idle control (0%
          │  \         │    control is transferred from M1 at time
  0% ─────┘   \────────┘    period t₈ as demand stays low.  At this
              ▲             time M1 control goes from Line to VFD
100% ──┐      │
       │\     │             M3 is switched to idle control (0%).  VFD control is
M3     │ \    │             transferred from M3 to M2 at time period t₇ as demand stays
       │  \   │             low.  At this time M2 control goes from Line to VFD.
  0% ──┘   \──┘
     t₅  t₆    t₇      t₈      t₉
```
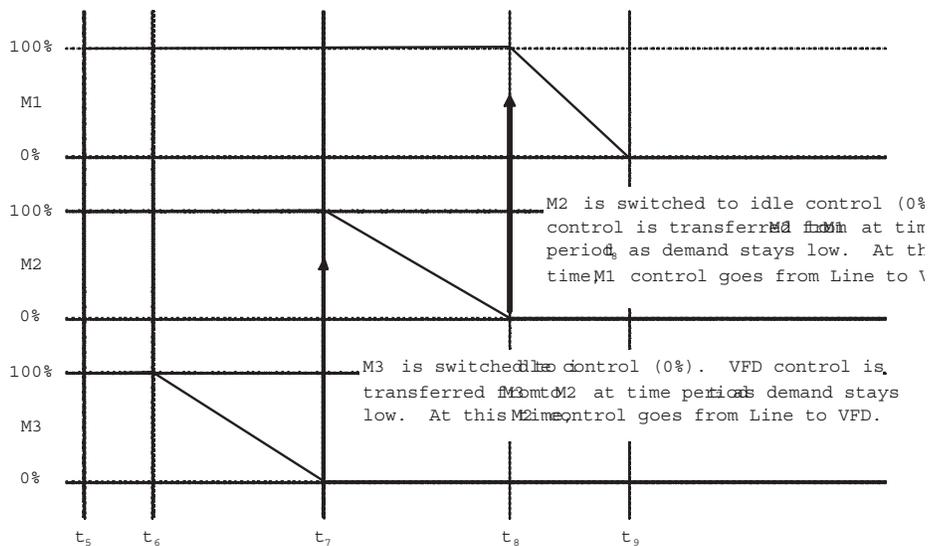
Figure 5-22: Graphical Representation of a Sample "Down Transfer" with No Demand

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Table 5-11: Control States of Motors in a Sample "Down Transfer"

Time	M1	M2	M3
t_5	Line (100%)	Line (100%)	VFD (100%)
t_6	Line (100%)	Line (100%)	VFD (100-0%)
t_7	Line (100%)	VFD (100-0%)	Off (0%)
t_8	VFD (100-0%)	Off (0%)	Off (0%)
t_9	VFD Off (0%)	Off (0%)	Off (0%)

5.16.6 The PLC Interface

All VFD control is accomplished over a RS485 serial communications network using a supported communications protocol (e.g., Modicon Corporation's MODBUS communications protocol). For example, a Modicon-compatible PLC interface is located at each motor control center. These PLCs are networked to a main MODBUS controller (e.g., a PC) and the communications board on the Perfect Harmony drive. Refer to Figure 5-23.

> **Note**: PLC interface refers to Modicon's MODBUS Serial interface only. This is for purposes of example only. Any supported communication network will do and the interface can also be done with no PLC, or by direct logic control.
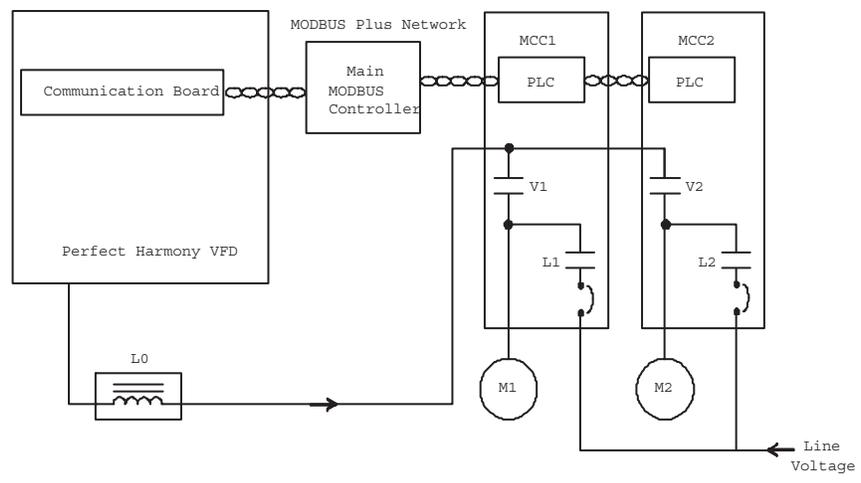
Figure 5-23: Communications Outline Drawing using a Modbus Network Configuration

5.16.7 "Up" Transfer (from VFD to Line Control)

> **Note:** All discrete steps imply a time delay for the drive to recognize each step independently. All handshaking must allow a minimum of 250 ms between signals sent.

This section provides the necessary steps to be followed for Up Transfer. The state transitions that occur during these sequences are graphically shown in Figure 5-24.

> **Note:** If the drive is not already running, the PLC should begin by closing the VFD Output Contactor.

1. The PLC issues an "up transfer request" [*UpTransferRequest_O*].

2. If the drive is not already running, the PLC issues a "run request" [*RunRequest_O*].

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3. The PLC provides the VFD with the output contactor acknowledge [*VFDContactorAcknowledge_O*].

4. The VFD ramps to line frequency and phase-locks to the line for 3 seconds. (The VFD substitutes the input line frequency as the raw speed demand.)

5. The VFD issues an "*Up Transfer Permit*" command [*UpTransferPermit_I*] to the PLC.

6. The line contactor (e.g., **L1**) is closed by the PLC.

7. The PLC signals the VFD that the line contactor (e.g., **L1**) is closed.

8. The VFD receives the "line contactor closed acknowledge" signal [*LineContactorAcknowledge_O*] and signals the PLC "up transfer complete" [*UpTransferComplete_I*].

9. The PLC stops the VFD through the serial interface by removing the "run request" [*RunRequest_O*].

10. The PLC removes the "up transfer request" [*UpTransferRequest_O*].

11. The VFD contactor (e.g., **V1**) is opened by the PLC.

12. The PLC removes the "VFD contactor closed" [*VFDContactorAcknowledge_O*] signal to the VFD.

13. PLC removes [*LineContactorAcknowledge*] for VFD while maintaining the line contactor closed.

14. New motor parameters are loaded through the serial interface for use in the next operation (or the VFD stays idle). This step is possible in Version 2.3 or higher of NXG software.

> **Note:** All hand shaking signals between the VFD and the PLC must be done sequentially as described. No two signals can be sent at the same time, as timing is critical for proper operation.
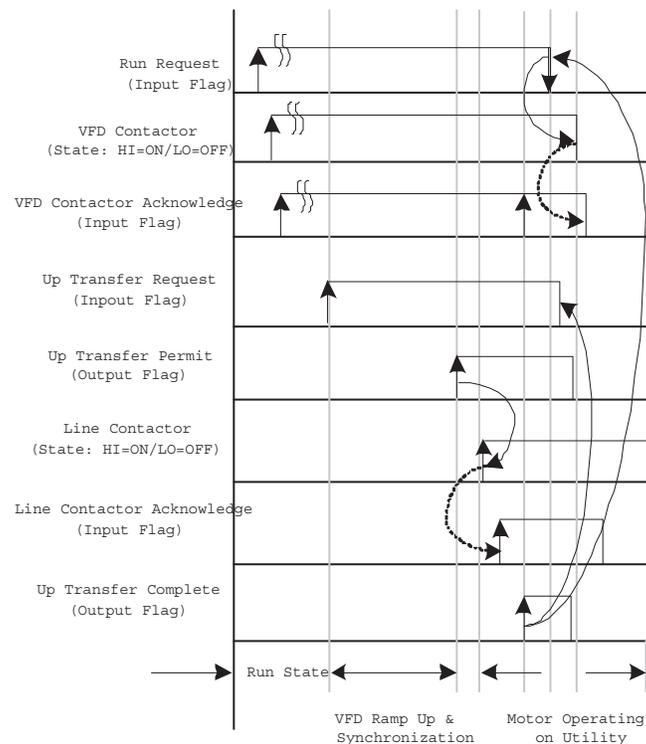
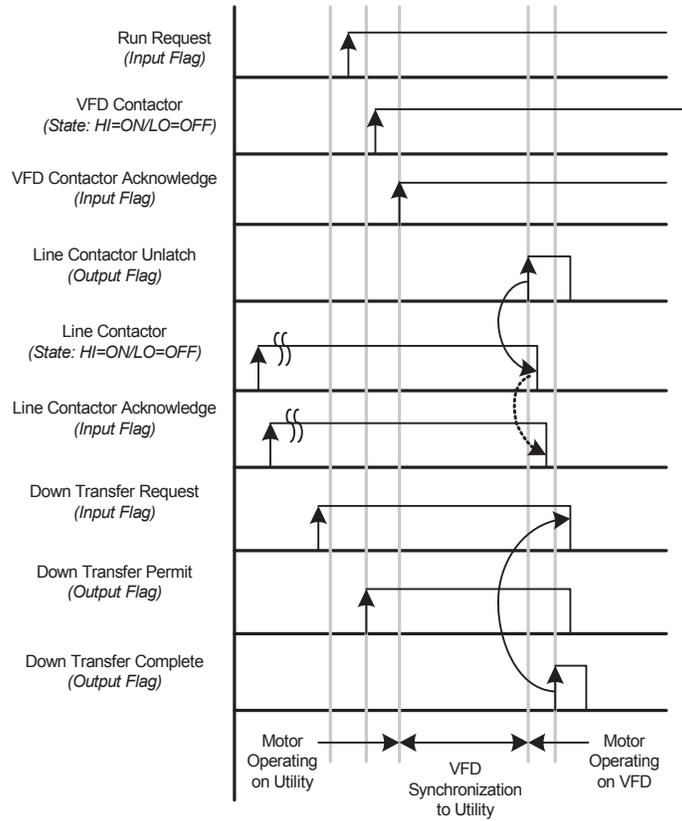**Figure 5-24: State Changes During Up Transfer Sequence**

The ⬆⬇ arrows indicate transitions that are used by the customer interface (for e.g., a PLC) to control the process.

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5.16.8 "Down" Transfer (from Line to VFD Control)

☞ **Note:** All discrete steps imply a time delay for the drive to recognize each step independently. All handshaking must allow a minimum of 250 ms between signals sent.

1. The Down Transfer process (refer to Figure 5-25) consists of the following steps. The line contactor is assumed to be closed at the beginning of this procedure.

2. The PLC switches to the correct motor parameters in the VFD through the system program, if required. (This step is possible in Version 2.3 or higher of NXG software.)

3. The PLC provides the VFD with the acknowledge from the line contactor [*LineContactorAcknowledge_O*].

4. The PLC issues a "down transfer request" [*DownTransferRequest_O*].

5. The PLC issues a "run request" [*RunRequest_O*] to the drive.

6. The VFD issues a "transfer permit" command [*DownTransferPermit_I*] to the PLC if the drive can provide sufficient voltage to match the line. The VFD then enters the Down Transfer drive state.

7. The PLC closes the VFD contactor. When the VFD contactor is closed, the PLC sends a signal to the VFD indicating the VFD contactor (e.g., **V1**) is closed [*VFDContactorAcknowledge_O*]. VFD then waits five seconds for stabilization of the PLL.

8. The VFD locks-in to the line frequency and builds torque current to 25%; it then issues the "line contactor unlatch" signal [*LineContactorUnlatch_I*] to the PLC.

9. The PLC verifies that the VFD has not faulted.

10. The line contactor (e.g., **L1**) is opened by the PLC. When the line contactor is opened, the signal [*LineContactorAcknowledge_O*] is cleared.

11. The VFD signals the PLC "down transfer complete" [*DownTransferComplete_I*].

12. The PLC removes the "down transfer request" [*DownTransferRequest_O*], but maintains the "run request."

13. The VFD clears the [*DownTransfer Permit_I*] and the Line [*ContactorUnlatch_I*] flags, exits the Down Transfer Drive state, and enters the Drive Run state.

14. The VFD follows the process setpoint from the PLC.

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Figure 5-25: State Changes during Down Transfer Sequence

The ⬆⬇ arrows indicate transitions that are used by the customer interface (for e.g., a PLC) to control the process.

☞   **Note:** Run Request must be maintained after the transfer is complete.

5.16.9 Required Signals

Table 5-12 lists descriptions of signals that are required for synchronous transfer operation.

Table 5-12: Required Signals and Descriptions

Signal	Description
UpTransferRequest_O	Input signal from PLC used to request transfer from VFD to Line.
DownTransferRequest_O	Input signal from PLC used to request transfer from Line to VFD.
VFDContactorAcknowledge_O	Input from PLC to indicate the VFD output contactor status.
LineContactorAcknowledge_O	Input from PLC to indicate the Line contactor status.
UpTransferPermit_I	Permit from drive to close the Line contactor during an Up Transfer.
UpTransferComplete_I	Signal from drive indicating successful synchronization of the drive to the line. After receiving this, the PLC can remove the run request and up transfer request.
LineContactorUnlatch_I	Signal from drive to open the Line contactor during Down Transfer. This is not a latched signal. It disappears on Transfer complete.
DownTransferPermit_I	Indicates the VFD is capable of supporting line voltage, and is used by the PLC to command the closing of the VFD contactor. The drive will then enter the Down Transfer State machine (TRANSFER_INIT state). This is not a latched signal. It disappears on Transfer complete.
DownTransferComplete_I	Signal from drive indicating a successful Down Transfer. After receiving this, the PLC can remove the down transfer request.

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5.16.10 Additional Parameter Description

The Sync Transfer Menu (2700) is used exclusively for synchronous transfer applications. The menu items and descriptions for this menu are listed in Table 5-13. This information is also available in Chapter 4 of this manual.

Table 5-13: Sync Transfer Menu (2700)

Parameter	ID	Units	Default	Min	Max	Description
Phase I gain	2710		2.0	0.0	15.0	Phase integrator gain
Phase P gain	2720		4.0	1.0	12.0	Phase proportional gain
Phase offset	2730	Degrees	2.0	-90.0	90.0	Specifies the phase angle setpoint used during Up Transfer. This is set positive, expressed in degrees leading to prevent power flow back into drive.
Phase error threshold	2740	Degrees	1.5	0.0	5.0	Specifies the phase synchronization error window during Up transfer. This parameter adjusts the amount of error allowed during phase-locking and is expressed in degrees.
Frequency Offset	2750	%	0.5	-10.0	10.0	Frequency offset used during Down transfer to establish torque current by driving the speed regulator into limit.

☞ **Note:** In software versions up to and including 2.4, parameter 2740 was actually in radians, not degrees. In these versions, the desired degrees should be multiplied by π/180 and then entered.

5.17 Spinning Load Operation

The Spinning Load feature allows the drive to determine the speed of a motor that is already rotating. The drive is thus able to apply output voltages at the same frequency as the rotating motor, and minimize any chance of a speed transient. The Spinning Load feature in NXG Control is divided into two stages. During the first stage, Spinning Load operates automatically when enabled and requires no user adjustments. The drive control monitors motor flux and is able to provide an instantaneous restart. This stage is valid as long as there is detectable flux in the motor. Typically, the drive is capable of restarting instantaneously if the time duration between drive disable and re-start is within 3 to 4 motor time constants.

The second stage consists of a scan feature during which a fixed level of current (set by the Current Level Set Point parameter) of varying frequency is applied to the motor. The control monitors the measured motor flux, and when the motor flux exceeds a flux threshold (set by the Scan End Threshold parameter), the control assumes that the applied frequency is equal to the rotating speed of the motor. This stage requires parameters to be tuned for the Scan to function properly.

Spinning Load should be enabled if any of the following operating modes or features is selected:

- Fast Bypass
- Auto-Restart
- Synchronous Motor Control (SMC and CSMC)
- Close Loop Vector Control (CLVC)

☞
> **Note:** Spinning Load does not provide instantaneous restart with V/Hz control.
>
> With synchronous motors, spinning load is always instantaneous, i.e., the drive will never go into a scan mode.

Table 5-14 describes the Spinning Load menu.

Table 5-14: Spinning Load Menu (2420)

Parameter	ID	Units	Default	Min	Max	Description
Spinning load mode	2430		Off			Enable/Disable Spinning Load and set the direction of frequency scans: • Off • Forward • Reverse • Both (scans first in the forward direction, then in the reverse direction)
Scan end threshold	2440	%	20.0	1.0	50.0	Point where scan ends if motor flux is above this level, as a percentage of motor rated flux. Set at 50% and 100% speed to match the motor for proper operation.
Current Level Setpoint	2450	%	15.0	1.0	50.0	Sets the drive current level (I_d), as a percentage of motor rated current, used during scanning. Set at 50% and 100% speed to match the motor for proper operation.
Current ramp	2460	sec	0.01	0.00	5.00	Time to ramp drive current (I_d) to Current Level Setpoint.
Max current	2470	%	50.0	1.0	50.0	Sets the current trip level, as a percentage of motor rated current, for scanning. Use the default value of 50%.
Frequency scan rate	2480	sec	3.00	0.00	5.00	Sets the time taken to scan from rated speed to zero. The default value of 3.00 sec should be satisfactory for most cases.

5.18 Sequence for Down Transfer with SM Control

5.18.1 Description

Synchronous Down Transfer is used to transparently transfer a motor running directly connected to a power line to control via the VFD. The VFD output is synchronized with the line connected to the motor (not necessarily the input to the drive), by utilizing the connection through the VFD output contactor with the power devices disabled. Once synchronized, the outputs of the power devices are enabled in sync with the line so that there is little or no power flow from the drive, and none back into the drive. (The drive, if 2 quadrant, cannot absorb power.) Transfer of Synchronous Machines (SM) involves not only the transfer of the stator voltage source, but of the separate field exciter control as well. This adds a level of complexity to the logic and control. Because of this, an external PLC or equivalent is required to control the transfer and to provide the external field exciter reference when the motor is on the line.

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All permissives required to begin the transfer must be verified by the external logic or PLC before the transfer sequence can begin. An external source of field exciter control must be available to control the field of the SM when the motor is connected directly to the line. The PLC must also provide the means to switch the control signals, generally 4-20ma current loops, by converting the signals to digital, then back to 4-20ma after the switching logic.

☝ | **Note:** Current loop signals cannot be switched directly.

Signals, in the form of SOP input and output flags, are used for handshaking. Each must be sent individually, allowing a minimum of 250ms between each, and they must be sent in the proper sequence for the transfer to work properly. Failure to follow this sequence could result in a drive trip or down transfer fail.

5.18.2 Preconditions Prior to Down Transfer

NXG Control uses the Spinning Load algorithm to sync the drive to the line connected motor. The Menu parameter for Spinning load enable must be set true. The Drive must be in the "IDLE" state prior to down transfer. To start, the motor is assumed to be running from the line with the line contactor closed, and with the contactor acknowledge provided to the drive.

Analog Input #4 (Auto Menu - Analog inputs - ID #4332), is used to preset the internal Field control regulator during transition between sources. This signal is fed back from the PLC as the active field command level. Select the correct analog source through the picklist on this parameter. The Field command from the drive must exit via a programmable Analog Output. Select the menu item for the desired analog output and select "Synch Motor Field" as the signal. This signal goes to the PLC as the drive source for the field command. Also, the SOP flag "EnableAnalog4_O" must be set true and the LOS (loss of signal) action needs to be selected. The sequence for down transfer is as follows (see Figure 5-26):
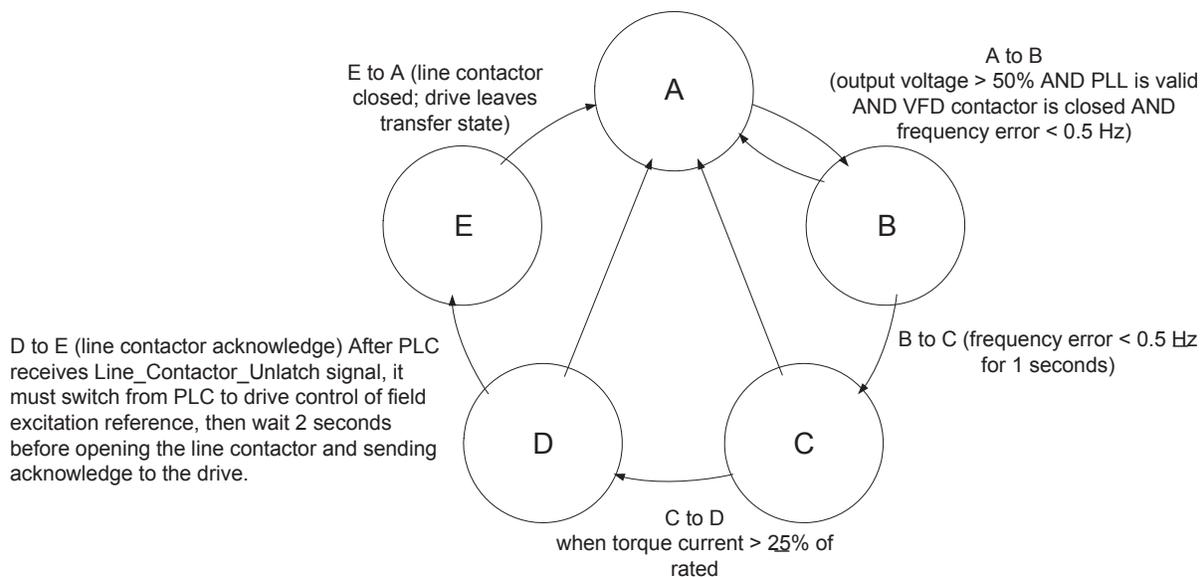
Figure 5-26: Synchronous Transfer State Diagram for "Down Transfer"

5.18.3 Transfer Sequence

1. The down transfer request system program flag (DownTransferRequest_O) is set by the controlling PLC. This signal is required prior to the run request for proper operation and entry into the Down Transfer control logic. This command cannot be issued simultaneously with the run request.

2. A "run request" (RunRequest_O flag) is issued to the drive from the PLC. If the drive is capable of supporting the voltage on the motor, the drive issues a permit (DownTransferPermit_I), which must be used

to close the VFD Output Contactor, directly or through the PLC. The drive then enters into the Down Transfer State machine, which is a subset of the Drive state machine. The Drive will begin to sense the voltage from the drive output.

If the drive output voltage capability, due to cell bypass, is less than the line voltage, the control will prevent the Drive from entering the "DOWN_TRANSFER" state, and set the InsufficientOutputVolts_I flag high. Also the Phase Sequence must be correct, and the line contactor acknowledge must be true. All these conditions will prevent the entry into the down transfer drive state and the DownTransferPermit_I flag will remain false.

The Down Transfer State machine consists of the following five states (refer to Table 5-15):

Table 5-15: Down Transfer Machine States

State	Value*
A - TRANSFER_INIT	0
B - WAITING_FOR_FREQUENCY_LOCK	1
C - WAITING_FOR_TORQUE_TO_BUILD	3
D - WAITING_FOR_CONTACTOR_OPENING	5
E - TRANSFER_COMPLETE	6

.

☞ **Note:** *Value is the value of the state machine variable for plotting purpose via the ToolSuite graphing calculated in PU of Transfer complete

3. After entering "DOWN_TRANSFER" state, the drive is initially in the transfer state A - (TRANSFER_INIT). The drive then looks for the following conditions before it can advance to the next state (B):

   o At least 50% voltage feedback (to ensure the VFD contactor is closed)

   o The PLL status must be valid

   o The frequency difference between the input line and detected output feedback must be less than ½ hertz

   o The VFD contactor acknowledge must be true

   o A built-in 5 second delay has expired

All of these conditions are required to transition to transfer state B - (WAITING_FOR_ FREQUENCY_LOCK) after the output PLL stabilizes with the motor flux. The drive transistors are enabled in the transition from state A to state B.

4. Transition from B to C (waiting for torque to build) requires that the drive output frequency and the line frequency be within ½ hertz for 1 second while the drive is connected to the line. No external handshaking is required in this transition.

5. Now that the drive has matched the line frequency, it will begin to raise the amount of torque producing current to the motor in preparation for the transfer of motor control from the line to the drive. During this state the drive flux regulator is preset to the value fed back through command generator analog reference 4. The SM field enable is also set true to begin controlling the field exciter. Since the feedback is always coming from the PLC independent of the source, the flux regulator will be preset to whatever source it

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receives. This keeps the field flux regulator in sync throughout the transition from an external to an internal source.

6. Transition from C to D occurs when the torque producing current is greater than or equal to 25% of the maximum permissible current (Iqs max). The drive issues a signal (sets SOP flag LineContactorUnlatch_I to True) to switch the control of the field, and two seconds later, to unlatch the line contactor. The PLC must use this flag to switch the control source of the field from the line-based source (usually within the PLC itself) and the drive internal signal, and must also provide the two second delay before dropping the line contactor.

☞ **Note:** No timing mechanism exists in the drive to control this delay and must be supplied by the external PLC. This two-second delay is critical to allow the field control to stabilize before the line contactor is dropped.

7. In the drive state D (WAITING_FOR_CONTACTOR_OPENING), the PLC opens the line contactor and then clears the line contactor acknowledge flag (LineContactorAcknowledge_O set to False), then the state machine transitions to drive state E - (TRANSFER_COMPLETE). It is vital that this signal is sent only after ensuring that the contactor is open.

8. The drive then issues a down transfer complete signal (DownTransferComplete_I), after which the down transfer request (DownTransferRequest_O) can be removed. Removing signals prematurely could cause a drive trip or transfer fault.

9. The drive then ramps to the speed set-point set by the customer, and the Down Transfer State machine is reinitialized to state "A."

10. If a Transfer time-out occurs when the drive is within the "DOWN_TRANSFER" state, then the drive goes back to the state A - (TRANSFER_INIT). The drive issues a Transfer Failure Warning and waits for a reset before attempting a new Down Transfer.

To Stop the Drive while it is connected to the line, issue a Stop Request by reviewing the Run Request. This will disable the Drive output immediately. Then remove the VFD Contactor Acknowledge, open the VFD Contactor, and remove the Down Transfer Request.

All states must be completed, up to the Transfer Complete, in the time allocated by the Drive/Down Transfer Menu parameter "Down Transfer timeout" (ID 2770), or a transfer failure will occur. Setting the timer to zero disables this timeout.

Any condition causing a Transfer failure will result in the drive going back to the Coast and then Idle state. This includes removing the transfer request before complete.

A Drive Fault causes the drive to go into "Coast Stop" and then to the "IDLE" state. A Fault Reset is required to allow the drive to run again. To reset the Fault, open the VFD Contactor, remove the VFD Contactor Acknowledge, and remove the Down Transfer Request. Follow the sequence listed from Step # 1 for a new Down Transfer sequence. The drive responds to a CR3 or drive-inhibit in the same way as a Fault, except that a fault reset is not required, but the drive-inhibit must be cleared to run again.

5.18.4 Timing Diagrams - Signal Sequence

The following are the timing diagrams for the signal interface for Down Transfer using NXG SM control (see Figures 5-27 and 5-28). Note that timing is approximate, except as noted in the diagrams, with a minimal time of 250 ms between each signal. Some signals depend on external events, and will vary from system to system. Also, the detail does not show the removal of any signals at the end of the transfer sequence.

These diagrams show the requirements of all the handshaking signals in the sequence in relationship to one another. Marked times on signals are critical.

The external field reference control is contained in the PLC logic and is not a part of the drive. It is shown in the detail diagram for clarity, Figure 5-28. It determines the source for the field exciter reference.
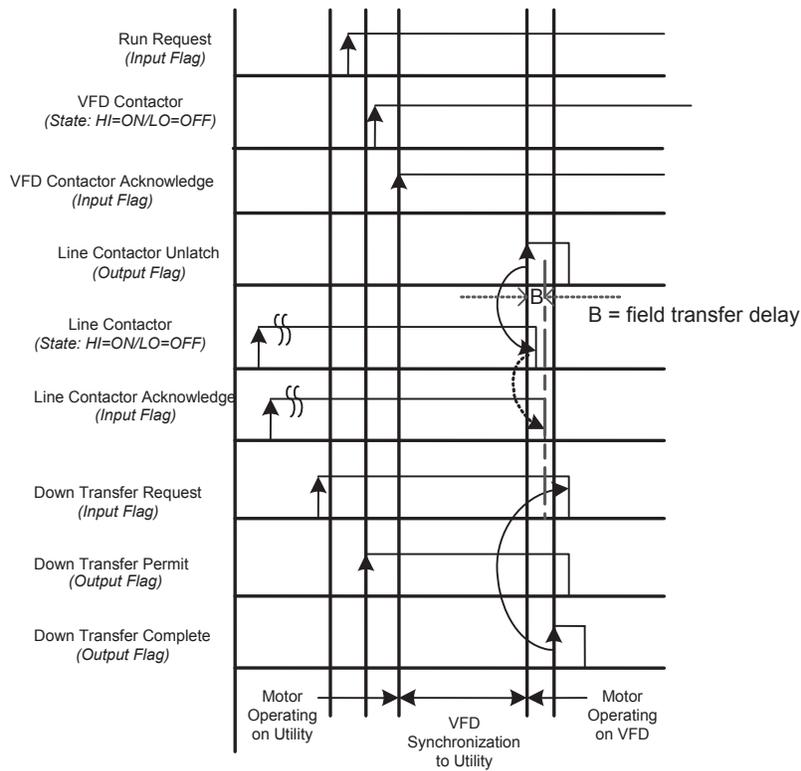
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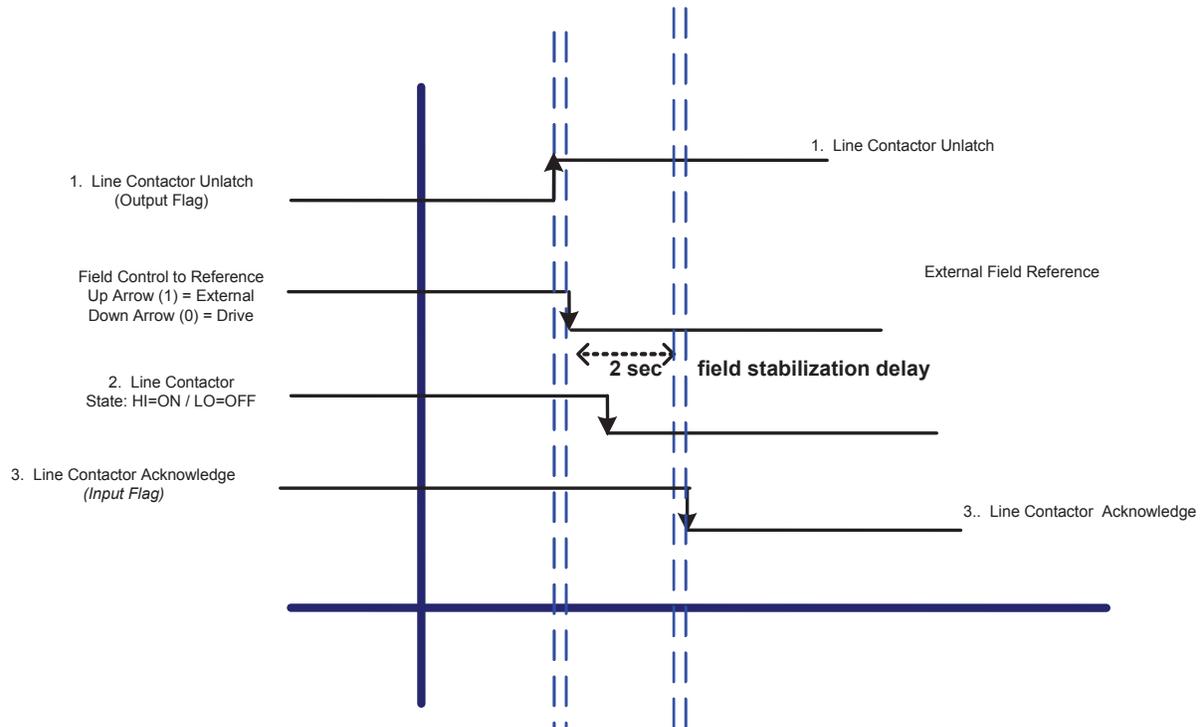**Figure 5-27: State Changes During Down Transfer Sequence in SM Control**

Figure 5-28: SM Down Transfer Delay (Detail 'B' Enlarged)

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5.19 Precharge

This document provides descriptions for NXG Control of the various Precharge methods used in the Perfect Harmony, HV Harmony, Parallel, and MicroHarmony Drives.

5.19.1 Precharge for Harmony Drives

With the development of new power topologies, and the introduction of film capacitors into the designs, it has become necessary to control the inrush current and the voltage overshoot seen by the drives, and in particular, the cell capacitors. Reduced capacitance in the cells has exacerbated the overshoot problem due to increased ringing, and so the cell charge voltage must be more closely controlled.

Several types of precharge techniques have been developed, based on the new cell designs and their special requirements. For the new Harmony Drive cells, there are a total of five types or methods of precharge. Three of these require software control over the main input contactor to operate properly and to protect the cells. The fourth, used for the new MicroHarmony product, uses a method and circuitry built directly into the cells – a method not feasible in the larger cell sizes. All five types of Precharge have some special requirements, and will be discussed independently.

It is important to note that should the control power be shut off, the Medium Voltage (MV) must be disconnected as well, and the precharge sequence re-started. This is for protection of the drive, as all the transformer and cell protection is accomplished by the NXG control.

For the first three of five types of precharge, the following applies:

- The complete precharge time cycle is 30 seconds maximum or a precharge fault will occur. This time takes into account the maximum low-level fault that can be sustained before serious damage is done to the drive should an input fault occur. Going beyond this time will result in a precharge fault.

- If the precharge start enable is removed before completion of the entire precharge cycle, the cycle will abort with a precharge fault.

5.19.2 Type 1 Precharge

The first precharge type is shown in Fig. 5-29. Two additional contactors, M2 and M3, are used in addition to the main input contactor M1. This method uses a capacitor circuit chosen to be in resonance with the inductance of the secondary windings of the input transformer. This allows a lower voltage source to charge a higher voltage rated cell, while limiting the inrush to both the transformer and the cell capacitors. This presents another problem though – without carefully monitoring the voltage, the cells could easily overvoltage. To prevent this, a resistor circuit is connected when the highest of the three input phase voltages (measured on the primary of the input transformer) reaches rated voltage. This resistor causes the Precharge circuit to be overdamped and the voltage increase ceases. At this point, the capacitor circuit is disconnected and the main contactor to the medium voltage source is closed. Once closed, the resistor network is opened, Precharge is complete, and the precharge request can be removed. This constitutes a *make-before-break* contactor sequence.

The precharge source can either be attached to one of the existing secondary windings, as is shown in the diagram, or can be a separate dedicated winding on the secondary. The second choice is preferable for the high voltage cells, since applying near rated voltage from an external source is less desirable than supplying 480 to 690 VAC to a special dedicated secondary winding on the transformer.

The voltage applied does not have to match exactly the full-rated voltage of the secondary winding, as the resonant circuit can achieve 150% rated or better if the resonance is allowed to continue unabated. The applied voltage to the cells is a gentle ramp, taking from ten to twelve seconds for one of the input phase voltages to reach 100% of rated value as measured on the primary attenuator on the transformer. The three phase voltages are not balanced during resonant precharge, so the maximum of the three phase voltages is monitored to determine when to stop the resonance. On this precharge type, the resonance is stopped by connecting a resistance circuit in parallel with the charging capacitors. This causes the resonant circuit to be overdamped and the voltage rise stops. The phase voltages can now stabilize and should be equal in magnitude. At this point, the capacitor circuit is disconnected. When the opening of the circuit is confirmed, the main contactor can now be closed. Once this is confirmed, the resistance circuit can be removed, and after that confirmation, the precharge request can be removed.

It is important that the Precharge input source be as close as possible in phasing to the phasing of the secondary winding of the input transformer, with the main input connection to the primary source connected. This is necessary so that the applied transformer voltage vectors from each source are aligned as closely as possible (***maximum 30 degrees out of phase***). It is also important that the applied voltage to the precharge winding be as close to the rated value of that winding (when MV is applied). This is due to the fact that this type of precharge has a *make-before-break* contactor sequence. The resultant flux vector will be the result of primarily the applied medium voltage source, since it is a stiffer source. The amount of transformer inrush current is dependent on the phase shift, the voltage difference, and the stiffness of the precharge source. The transformer flux is present throughout the entire precharge sequence, first established by the precharge circuit, maintained by the damping circuit, and realigned by the main contactor source. The input voltage, once established, remains constant and is not disrupted.
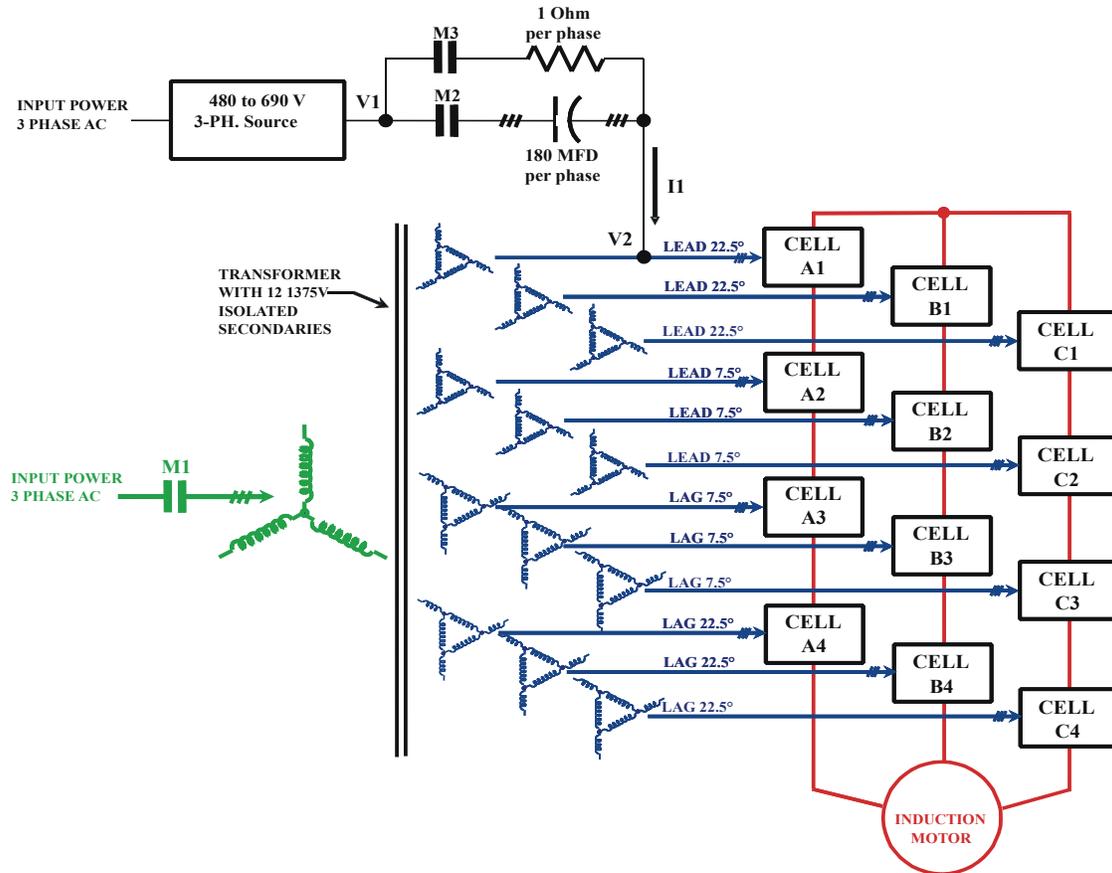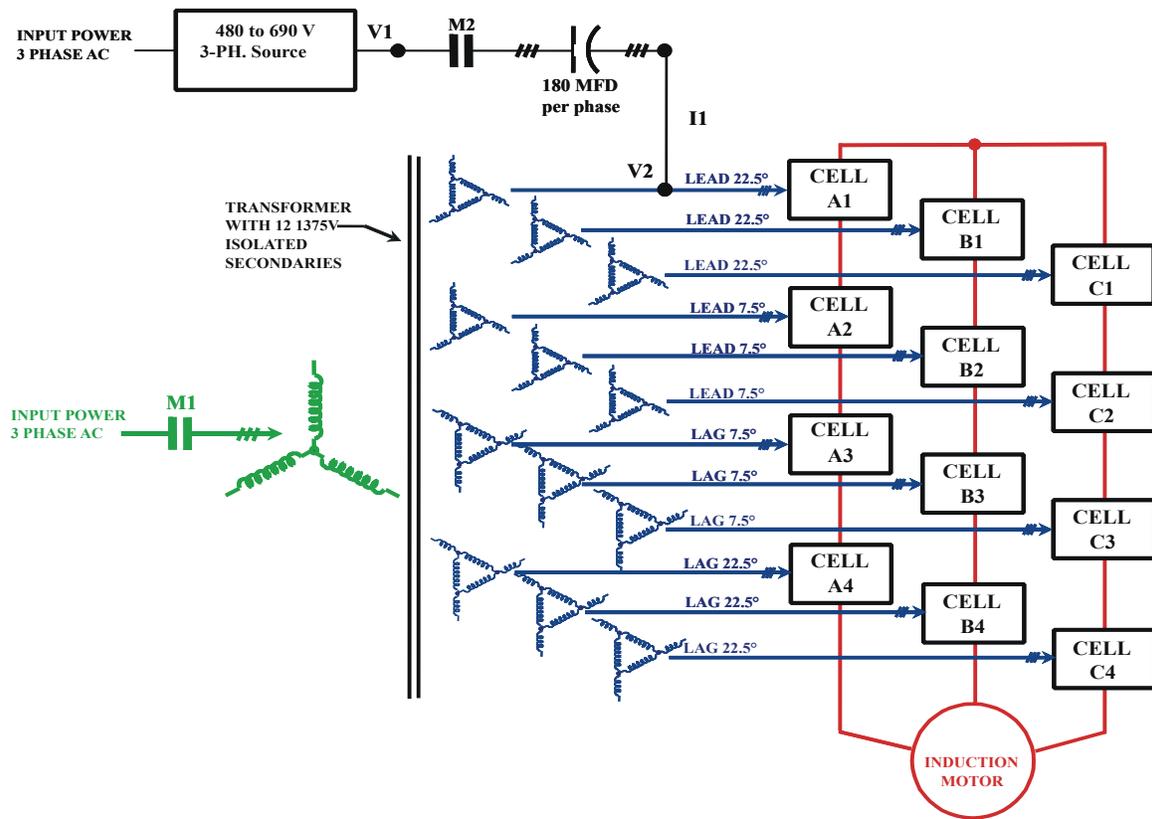

Figure 5-29: Type 1 Precharge Component Connections Diagram

The following sequence describes Type 1 Precharge. Figure 5-29 shows contactor states and secondary voltage during Precharge.

1. Precharge begins with a Precharge command from the customer (PrechargeStartEnable_O = true). This signal must stay true until precharge is complete, to ensure Proper operation of the precharge. Failure to maintain the enable throughout the sequence is detected as a precharge fault by precharge abort.

2. After the Precharge command is received, contactor M2 is closed (PrechargeM2Close_I = true). At this point, the secondary side voltages and the primary voltage begin to increase. If M2 does not close (PrechargeM2CloseAck_O remains false), then the primary side voltage will not increase, and this is used to abort Precharge via a precharge fault (PrechargeFault_I = true) due to precharge timeout.

3. Once primary voltage reaches 100% and all communicating cells have their internal vavail_ok_f signal set (CellBusLowFlag_I = false), contactor M3 is closed (PrechargeM3Close_I set true). After M3 is closed, the

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primary voltage should stabilize and should not increase any further. If the primary voltage increases beyond 110% at any point in the precharge sequence, the control aborts Precharge via a Precharge Fault, due to Precharge Over-voltage.

4. After acknowledge from M3 is received (PrechargeM3CloseAck_O = true), contactor M2 is opened (PrechargeM2Close_I = false).

5. After acknowledge from M2 is received (PrechargeM2CloseAck_O = false), a Precharge command to pick up M1 (PrechargeM1Close_I = true) is issued, which is used to energize the main contactor M1.

6. Acknowledge from M1 (PrechargeM1CloseAck_O = true) is used to open M3. If acknowledge from M1 is not received, then Precharge will be aborted.

7. Acknowledge from M3 (PrechargeM3CloseAck_O = false) is used to set Precharge Complete (PrechargeComplete_I = true).

8. The Precharge command from the customer must be removed after Precharge Complete is set and when VFD Ready (not shown in Fig. 5-30) is issued. Failure to remove the command will result in a Precharge timeout Precharge Fault.
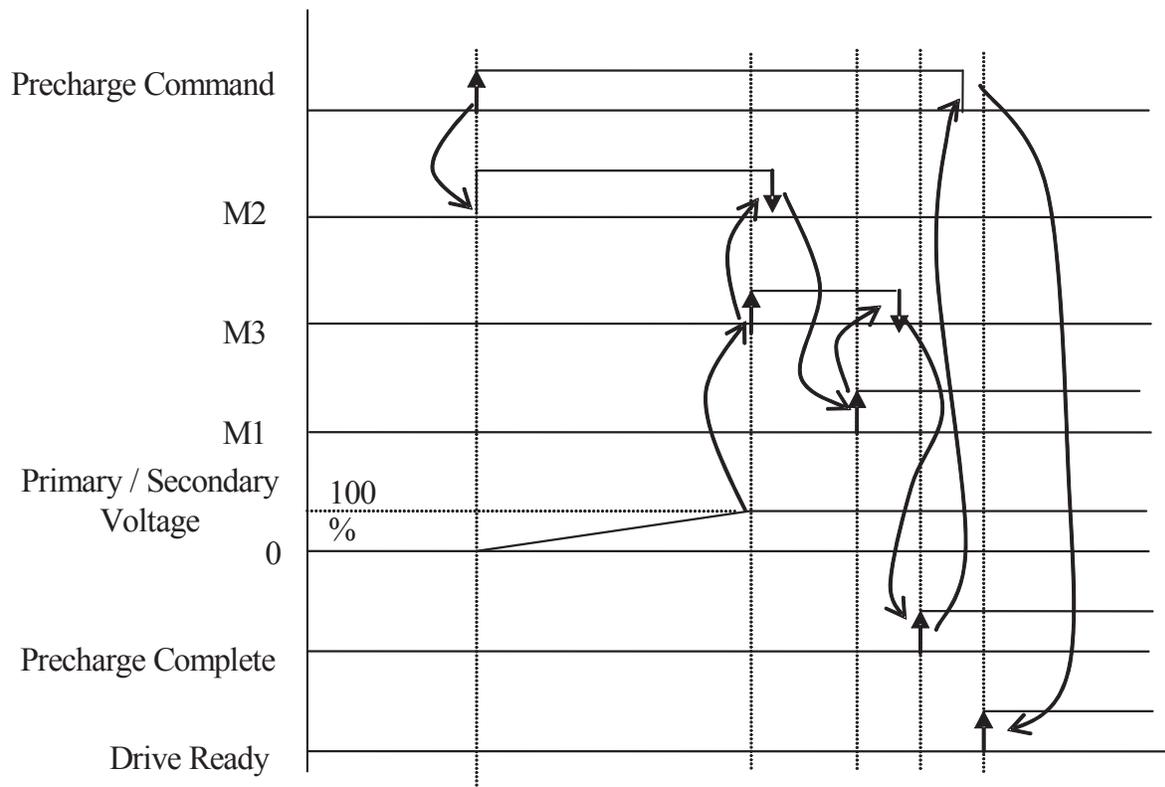
Figure 5-30: Type 1 Precharge

5.19.3 Type 2 Precharge

The second method of Precharge is similar to Type 1 in that it is also employs a resonant circuit. It, however, will avoid inrush into the cells only, and will **not** prevent input transformer inrush. This method will use only one contactor, M2, in addition to M1. This method will be referred to as Type 2 Precharge. This type has a *break-before-make* contactor sequence that does not require close synchronization between the input voltage to the precharge circuit and the input voltage to the transformer primary. By breaking the connection to the precharge source after the

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cells are fully charged, the flux in the transformer collapses almost immediately, so that when the main input contactor is closed, the only inrush is for magnetizing the transformer itself, and not for charging the cell capacitors. One implementation of this method is shown in Figure 5-31, with an additional precharge secondary winding employed to be able to reach full-rated voltage of the transformer primary and cell connected secondaries.

In this precharge method, the cells are precharged in the same manner as in Type 1, with the same time constants to reach the end of this part of precharge. The difference comes with what occurs at the time the input primary voltage reaches rated (1.0 PU). Instead of connecting a damping circuit as in type 1, Type 2 simply opens the connection to the resonant circuit (PrechargeM2Close = false). When the contactor open acknowledge is received (PrechargeM2CloseAck = false), the main contactor is commanded to close (PrechargeM1Close = true). Once the main contactor is closed (PrechargeM1CloseAck = true) and the primary voltage is re-established, precharge is complete. With the removal of the precharge enable, the drive is now ready to run.

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Figure 5-31: Type 2 Precharge Component Connections Diagram

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The following sequence describes Type 2 Precharge. Figure 5-31 shows contactor states and secondary voltage during Precharge.

1.   Precharge begins with a Precharge command from the customer (PrechargeStartEnable_O = true).

2.   After the Precharge command is received, contactor M2 is closed (PrechargeM2Close_I = true). At this point, the secondary side voltages and the primary voltage begin to increase. If M2 does not close (PrechargeM2CloseAck = false), then the primary side voltage will not increase and this is treated as a Precharge Fault, indicated by a timeout.

3.   Once primary voltage reaches 100%, contactor M2 is opened (PrechargeM2Close_I = false). After M2 is opened, the primary voltage will not increase any further. If the contactor fails to open and the primary voltage increases beyond 110%, then the control will abort Precharge with a precharge fault, and the precharge source must be removed by the system to prevent overvoltage on the cells. The precharge fault is indicated as a precharge overvoltage fault in the event log.

4.   After acknowledge from M2 is received (PrechargeM2CloseAck_I = false), the main contactor is commanded to close (PrechargeM1Close_O = true).

5.   Acknowledge from M1 (PrechargeM1CloseAck_O = true) is used to set Precharge Complete (PrechargeComplete_I = true). If acknowledge from M1 is not received, then Precharge will be aborted with a precharge fault indicated by timeout.

The Precharge Enable from the customer must be removed after Precharge Complete is true, so that PrechargeDriveEnable_I can be set true, and VFD Ready is set.
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5.19.4   Precharge for Parallel Drives

Precharge in Parallel Drives, or other selected drives, is known as Type 3 Precharge. It may use either a 3PCI controller or a fixed source with a resistive element, instead of the resonant capacitor in Fig. 5-32, to increase the cell voltage gradually. The sequence for such a Precharge will be similar to the Type 2 Precharge described above. Precharge of this type requires that the input source (output of 3PCI or independent source) be rated with high enough voltage to reach at least 90% of rated input voltage under all conditions, without exceeding the precharge trip voltage.

Since two sources can be used, each will be addressed according to its constraints. In the case of the 3PCI source, a resistor may not be required. This depends on the current needed from the source to charge the capacitors, and also on any stability issues with the current loop of the 3PCI. The only real requirement is that it is able to charge the cell capacitors in the timeframe allotted.

For this description, it will be referred to as Type 3 Precharge. Contactor status M2 will represent the contactor status in series with the 3PCI **and** the enable signal to the 3PCI. In the case of a constant source, the M2 contactor will be connected to the precharge secondary winding through the series resistor. The only difference will be in the threshold signal of the primary voltage. For Type 3 Precharge, the threshold will be 90% instead of 100%, and the resistor (if used) must be rated to handle the power dissipation during the precharge cycle. This requires that the resistor be sized much larger than that used in Type 1 precharge, which is used only to maintain charge on the capacitors during the contactor operation. The resistor must carry all of the charging and magnetizing current of the drive.
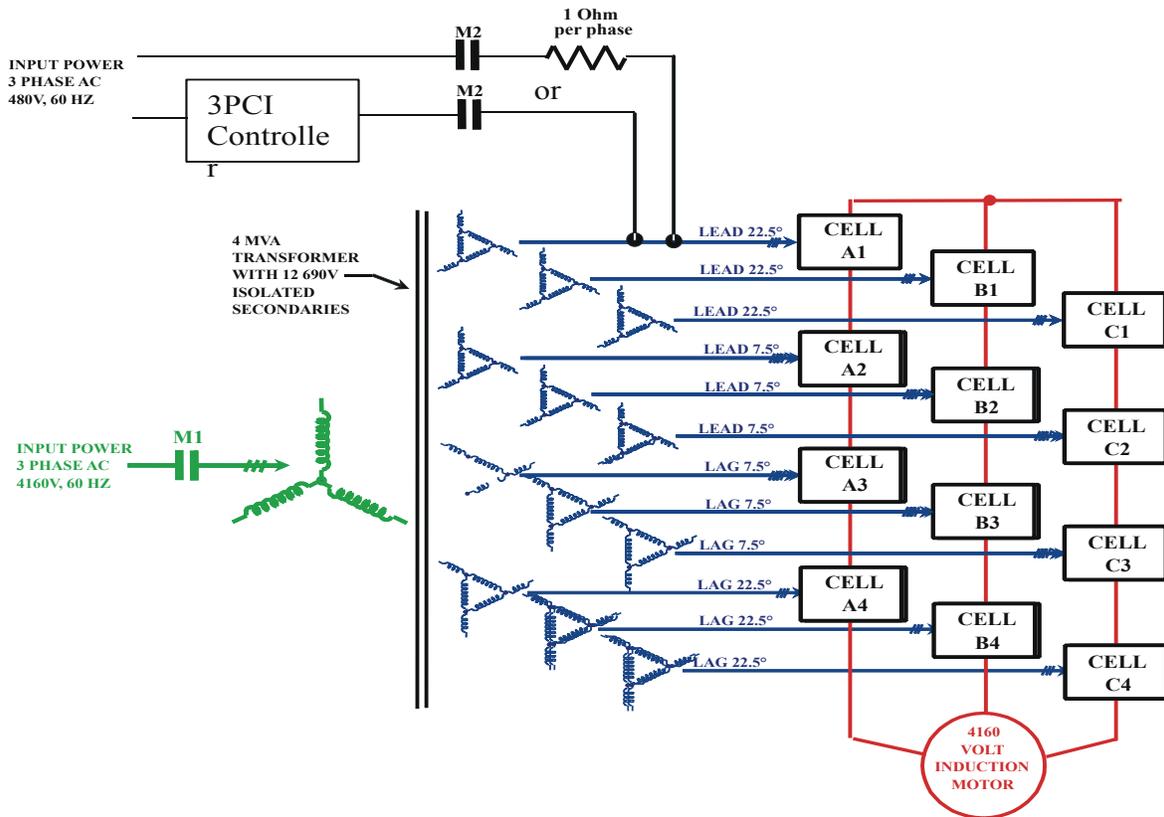
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Figure 5-32: Type 3 Precharge Component Connections Diagram

5.19.5 Precharge for Micro-Harmony Drives

Precharge for MicroHarmony Drives uses SCRs in the rectifier of each cell. Such a method will not need a (Precharge) permissive for the Main Contactor. The customer can directly energize the main contactor M1. Once medium voltage is applied, the SCRs in each cell are automatically gated to gradually increase cell DC-bus voltage. Such a Precharge method does not need any monitoring from the NXG Control. The only requirement may be for an increased delay between the application of medium voltage and when NXG starts communicating with the cells. This can be accomplished by having a Precharge delay item in the menu. Today's (internal) setting of 1.0 second in NXG Control can be the default value.

This Precharge method is referred to as Type 4 for implementation purposes. There are no other special requirements for this type of precharge.

5.19.6 Precharge Faults

Precharge faults for Type 4 precharge (MicroHarmony) are handled like any other cell fault. In fact, it uses the obsolete downbit (information bit from the cell) for Output Power Fuse Blown to generate a precharge fault on a per-cell basis. For precharge Types 1 to 3, the algorithm controls the application of MV on all cells simultaneously, so the following faults apply in these cases.

Total time to precharge must not exceed 30 seconds from the issuance of the precharge start enable to the completion of the precharge cycle. Failure to complete the cycle in time results in a precharge fault. The message, "**Precharge timeout - too long to complete**" is logged in the event log after the fault.

Precharge voltage must never exceed 1.10 PU (110%) rated input voltage. Should the voltage exceed this level at any time during precharge, a precharge fault is initiated. The message, "**Precharge - Voltage too high**" is logged in the event log after the fault.

Removing the precharge start enable prematurely results in an abort of the precharge cycle and a precharge fault. The command can only be removed after precharge is complete. The message, "**Precharge command removed before complete**" is logged in the event log after the fault.

If a precharge fault occurs, all SOP flags are re-initialized to the following states:

- PrechargeDriveEnable_I = false;
- PrechargeComplete_I = false;
- PrechargeM1Close_I = false;
- PrechargeM2Close_I = false;
- PrechargeM3Close_I = false;

The precharge fault must be reset before another attempt at precharge.

5.19.7 Loss of MV and Precharge Reset

With the loss of input MV from the drive, the cells start to discharge. Until they reach a low level (low DC bus alarm), the cells can be energized directly, without precharge. This allows for MV ride-through capability, utilizing inertial load to keep the cells energized so that the drive can recover quickly. For this reason, the following flags remain true until precharge is reset, indicating that precharge is still complete and the main contactor enable is held in (MV is lost due to another source or other control). On the reapplication of MV upstream from the drive, the MV input can safely be brought on immediately, saving valuable down time for the recovery of a process.

- PrechargeDriveEnable_I
- PrechargeComplete_I
- PrechargeM1Close_I

Once the DC bus on any cell is below the warning level, precharge must be reinitialized with the reapplication of input power. The precharge cycle must be repeated to protect the cells. This is true for any reason that precharge is reset.

Three things reset precharge once complete. These are listed below, assuming the absence of MV input power:

- 45 seconds have transpired since MV was removed
- Any cell experiences a DC bus low alarm
- Precharge is reset manually by setting the SOP flag "**PrechargeReset_O**" true, based on any system conditions defined by the SOP.

Resetting precharge has the same effect as a precharge fault, with the exception that a drive reset is not required before precharge is reinitialized.

5.19.8 Conditions for Precharge

Aside from safety concerns, and assuming that input power is available, logically only the following conditions need to be met to initiate precharge:

- Precharge must be in the reset or initial state (**PrechargeComplete_I** must be false) – (the state machine is reset to initial condition on precharge complete or precharge fault)

- Absence of a Precharge fault – fault reset first if a fault exists

- Absence of the Precharge Reset command (**PrechargeReset_O** must be set to false)

- Precharge start command issued (**PrechargeStartEnable_O** set to true)

When all these conditions are met, precharge will start. You must remove the Precharge start command at the end of the precharge sequence (**PrechargeComplete_I** = true) to get a drive ready permissive. (PrechargeDriveReady_I) is only one of several conditions for drive ready, but will not be set true until Precharge complete is in effect, and the precharge cycle is completed with the removal of the precharge start enable.

5.19.9 Other Considerations

The Precharge flag for closing the MV breaker (**PrechargeM1Close_I**) must be allowed to operate the MV contactor or breaker, both in turning on the MV at the proper time, and in tripping the MV in the event of a precharge fault. This, however, does not preclude the drive input protection. Drive input protection must have priority over precharge for protection of the drive, while still allowing precharge to control the application of the MV when no input protection faults are active.

Although there is no direct interlock between input protection and precharge, if properly installed, precharge will simply not be able to apply MV if the input protection is in effect, with the result of a precharge timeout fault after 30 seconds. The event log will record that the drive was waiting for voltage when a precharge fault occurred. Due to the independent nature of precharge and input protection, no special interlock between the two is required if properly implemented. However, if an interlock is desired, this can be done in the drive SOP or in external logic. The key is to allow input protection to operated independent of precharge state. The best means to accomplish this is through independent, series-connected contactors or pilot relays.

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5.19.10 Type 5 Precharge

Precharge has been modified to accommodate the WCIII cells and the precharge Enable (Parameter ID 2635) "Type 5." The purpose is to protect the cells from damaging voltage overshoot during power up.

The following is a description of the precharging sequence (refer to Figure 5-33). The sequence can be observed using the 'Drive Misc Status Flags (cont.)' debug screen to view the precharge states, or also by using the ToolSuite graphing variable "Precharge State Variable." Also, after each state, a short message is entered into the event log, describing the precharge state that just occurred.

All contactors have feedback or status signals that are checked at each step of the sequence.
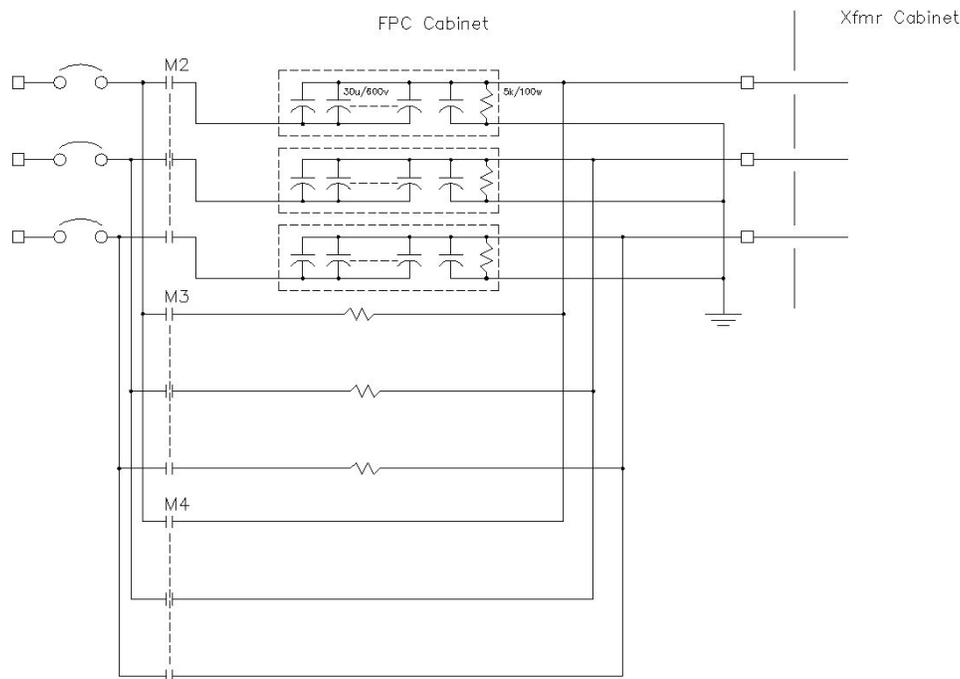
Figure 5-33: Type 5 Precharge Circuit

1. First contactors M2, M3, M4, and M1 will be opened if closed.

2. M2 closes, which switches in the charging capacitor bank. If 90% rated input voltage is not achieved in 30 seconds, the precharge sequence aborts and the drive will have a precharge fault.

3. At 90% rated input voltage, M3 closes for approximately 1 second, which switches in the resistor bank in parallel with the capacitor bank.

4. M2 opens, disconnecting the charging capacitor bank.

5. M4 closes to connect power directly to the precharge winding.

6. M3 opens, disconnecting the resistor bank.

7. If cell fault occurs, press manual reset. Cell diagnostics will begin to run.

8. When cell diagnostics is complete, M4 will open, disconnecting the precharge winding.

9. M1 closes main contactor.

The use of dedicated I/O has been integrated into the precharge circuit. Using the dedicated I/O, the contactors are checked during the precharging sequence. The sequence is started by SOP flag 'StartCellPrecharge_O,' and can be

interrupted using SOP flag MainInputVoltageDisable_O, but all contactors that are connected to the precharge components are controlled via the digital outputs.

5.19.11 Precharge Service Mode

Precharge service mode can be used for initial testing of the precharge circuit itself, as well as the cells. The main contactor will not close in this mode. Once M4 closes (refer to Figure 5-33), the cells are fully charged from the secondary winding of the transformer.

Turn on Precharge service mode by setting mode to "On." Start or stop the sequence by using the Precharge service start menu. If precharge completes when using this mode, the start menu will automatically return to stop. Select the start again to retry the service mode. To turn off this mode, set Precharge service mode to "Off."

The precharge sequence for service mode follows:

1. First contactors M2, M3, M4, and M1 will be opened if closed.

2. M2 closes, which switches in the charging capacitor bank. If 90% rated input voltage is not achieved in 30 seconds, the precharge sequence aborts and the drive will have a precharge fault.

3. At 90% rated input voltage, M3 closes for approximately 1 second, which switches in the resistor bank in parallel with the capacitor bank.

4. M2 opens, disconnecting the charging capacitor bank.

5. M4 closes to connect power directly to the precharge winding.

6. M3 opens, disconnecting the resistor bank.

5.20 Precharge for Advanced Protocol Cells Software Description Introduction

The software provides the WCIII cells with dedicated I/O for precharge and input protection.

> **Note:**
> - As with the WCIII, dedicated I/O input protection (only) is also provided for the GenIV drive.
> - Mapping of internal digital I/O follows assignments as specified in the document: "*GENIV + HV + WCIII HARMONY NXGII BREAKOUT BOARD*" standard assignments document *Rev "E"* at time of writing (12 June 2006).

5.20.1 Added Menu Parameters

These parameters may be viewed by using the Keypad and/or the ToolSuite software. Using the ToolSuite program, (refer to the *ToolSuite Manual* -- P/N 902291), perform to the following steps:

To access the new menu parameters

1. Go to the MENU PATH

2. Choose: Cells (2520) $\rightarrow$ Cell voltage (2550)
   Select Type 750V AP from Pick List

3. Choose: Cells (2520) $\rightarrow$ Precharge Enable (2635)
   Select Type 5 Open from Pick List

> **Note:** The WCIII 750V AP type cells **must** use "Type 5 Open" precharge.

4. Return to MENU PATH to run in Maintenance mode (for testing).

5. Choose: New Menu: Cells (2637) $\rightarrow$ Precharge Service Mode
   Cells (2638) $\rightarrow$ Precharge Service Start

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Refer to Figures 5-34 through 5-37 to view a graphic depiction of these steps, using the ToolSuite Program.

Figure 5-34: Selecting 750V AP from Pick List

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Figure 5-35: Selecting Type 5 Open from Pick List

Figure 5-36: Precharge Service Mode (On/Off)

☞ **Note:** For testing Precharge, setting service mode to "On" allows the drive to be precharged on the secondary winding of transformer. *M1 cannot be switched on in this mode*. Set the precharge service start to "Start" to begin the precharge process.

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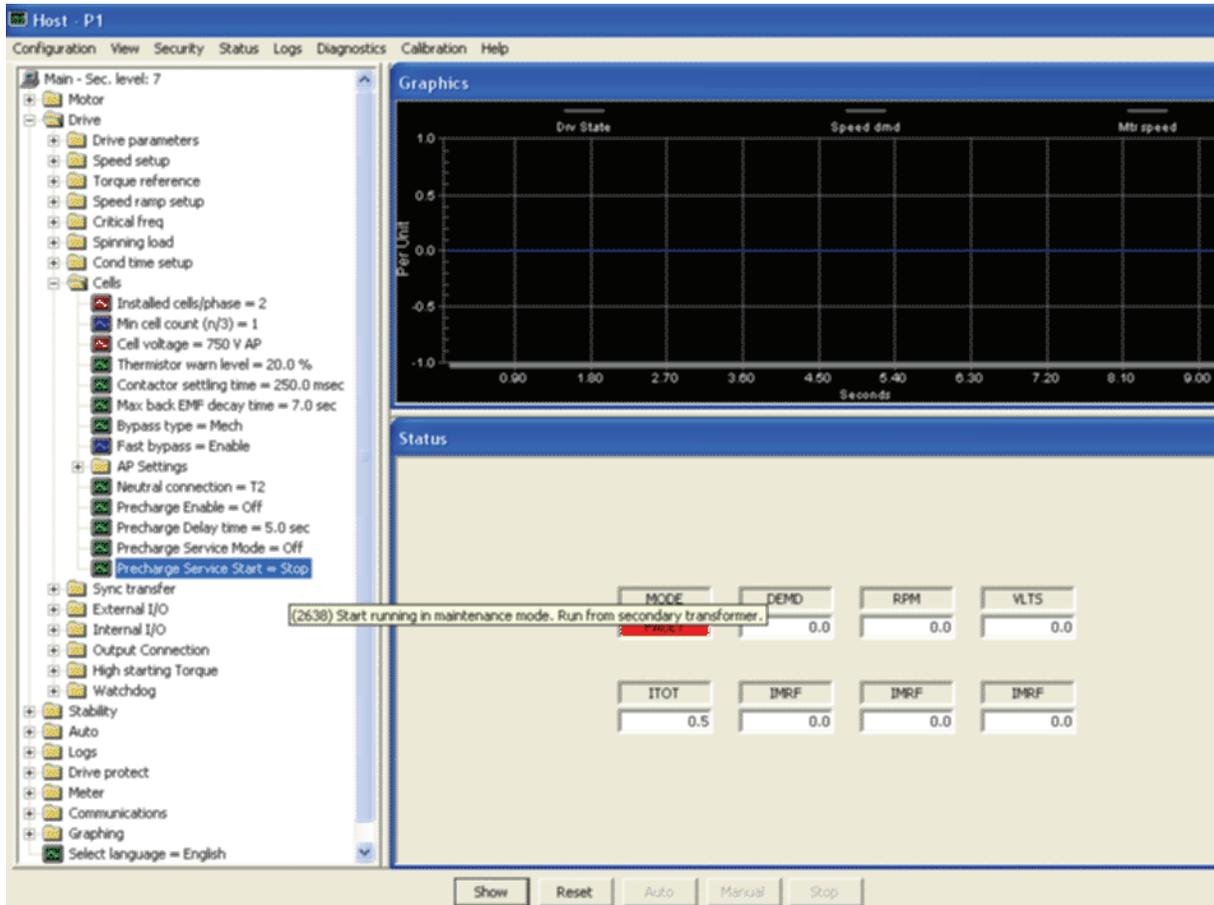
Figure 5-37: Precharge Service Start (Start/Stop)

☞ **Note:** Set the precharge service start to "Start" to begin the precharge process.

5.21 Sop Flags

Refer to Tables 5-16 and 5-17 for SOP flags and conditions.

Table 5-16: SOP Flags Table

Flag	Function
StartCellPrecharge_O	Starts or Aborts precharge
MainInputVoltageDisable_O	Prevents the main voltage contactor from closing. Setting this flag aborts the precharge if it is in progress.
SetIPFault_O	Forces an input protection fault

Table 5-17: Conditions Table

Conditions (To:)	Description	Action(s)
Open M1	Outputs: Command and Permissive	Setting the Sop flag MainInputVoltageDisable_O to true. • Medium voltage fault opens M1. • Low DC bus on a cell detected and no medium voltage present. Setting SetIPFault_O to true. At start of precharge sequence. At CPU reboot.
Open Input Circuit Breaker	Causes Circuit Breaker Open Fault	• M2 fails to open • M3 fails to open • M4 fails to open • Over voltage condition (>110%)
Cause Input Protection Fault	Triggers FLR	• DSP detected arc occurred by cell detection hardware • DSP detected bus over voltage while cell is in bypass • DSP detected input over current while cell is in bypass • DSP detected critical fatal fault • One cycle fault occurred • Excess drive losses fault occurred • Setting SetIPFault_O to true
Get Medium Voltage Fault	Additional Fault Causes	• Waiting for M1 permissive. Received Low DC Bus Indication. • M1 closed and no voltage present

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5.22 Debugging Tools

Refer to Table 5-18 to view the added precharge states and their respective descriptions.

The added precharge states can be tracked in ToolSuite, and on the debug screen via the "Drive Misc Status Flags (Cont.)" located under the item PrechgThreadState (current real time thread state), and under the PrechargeExitState, (uses the same state definitions described in Table 5-19 but is saved as the last state of the precharge thread when exited). Table 5-20 provides a list of additional Status Flags.

Table 5-18: Precharge States/Descriptions

State	DESCRIPTION
INIT_PRECHARGE2	Precharge has started
M1_OPEN	M1 commanded to open
M2_CLOSE	M2 commanded to close
WAIT_FOR_VOLTS2	Waiting for input voltage to build up to 90% of rating, or fault after 30 secs
SOP_KILL	SOP flag set ends the precharge process
WAIT_FOR_VOLTS3	Precharge process failed while waiting for voltage to build to 90%.
M3_CLOSE	M3 commanded to close
M2_OPEN	M2 commanded to open
M4_CLOSE	M4 commanded to close
M3_OPEN	M3commanded to open
WAIT_FOR_RESET	Cell fault detected during precharge, user must issue reset to continue precharge. **Note**: No timeout fault, will wait indefinitely.
WAIT_FOR_CD_FINISH	Process is waiting for cell diagnostics to complete
CELL_DIAG_FINISH	Cell diagnostics has finished
M4_OPEN_MAINT	Precharge is in maintenance mode and completed with no errors
M4_OPEN	M4 commanded to open
MAIN_USER_OPEN	SOP flag or fault latch relay has opened the main input
M1_CLOSE	M1 commanded to close
WAIT_FOR_M1_PERMIT	System is waiting for the acknowledge from the M1 contactor
SOP_KILL_M1_CLOSE	SOP flag killed the process after M1 commanded close
M1_CLOSE_LOWDC	Low DC bus was detected while waiting for M1 close acknowledge
M1_CLOSE_WITH_NOMV	M1 closed, but no medium voltage detected
M1_CLOSE_WITH_FAULT	Fault occurred during the wait for M1 close acknowledge
INPUT_OV	Input voltage has exceeded 110% rated
PC_COMPLETE	Precharge is finished

Table 5-19: Drive Miscellaneous Status Flags

Flags	Value	Flags	Value
CellLinkFaultExists_I	0	MainInputVoltDisable	0
CellBusOvervoltageInBypass_I	0	PrechargeTimeoutFailure	0
CellInputOvercurrentInBypass_I	0	Cell Diags	FINISHED
CellBlockingFaultExists_I	0	PrechgThreadState	FINISHED
GeneralCellProtectionFault_I	0	MedVolts	1.003
ArcDetectedInCell_I	0	Precharge State	M1_OPEN
CellInputOCInBypassDSP_I	0	PrechargeExitState	NO_ERRORS
CellBusOVInBypassDSP_I	0	CellTypeIsPrecharge	0
M1 Permissive	0	Misc	Reserved
M2 Close	0	MaintModeTest	0
M3 Close	0	MaintStartTest	0
M4 Close	0	PrchCompleteM1Close	0
M1 ACK	0	CellBusLowFlag	0
M2 ACK	0	CircuitBreakerOpen	0
M3 ACK	0	PrechargeReady	0
M4 ACK	0	M1OpenWithoutCmd	0
StartCellPrecharge_O	0	OutputProcess.Enable	0
PCMediumVoltageFault	0	DSPInputProtectFault	0
PCContactorFailure	0	Misc1	Reserved

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Table 5-20: Additional Flags / Function Cell Diagnostics Changes

Flag	Description
M1 Permissive	Permissive to close M1
M2 Close	Command to close M2
M3 Close	Command to close M3
M4 Close	Command to close M4
M1 ACK	M1 closed indication
M2 ACK	M2 closed indication
M3 ACK	M3 closed indication
M4 ACK	M4 closed indication
StartCellPrecharge_O	State of SOP flag to initiate precharge process
PCMediumVoltageFault	If set, triggers a medium voltage fault that was caused in pre-charge process
PCContactorFailure	If set, causes a precharge fault because it did not receive a contactor acknowledge signal
MainInputVoltDisable	State of SOP flag to disable the main input voltage
PrechargeTimeoutFailure	Did not build up the 90% voltage within 30 secs, causes a pre-charge fault
Cell Diags	State of cell diagnostics thread
PrechgThreadState	Current state of precharge thread Three possible states: • "IDLE: – thread is not running, • "RUNING" - thread is running, • "FINSHD" – thread has completed, precharge process is complete, not necessarily without errors
MedVolts	Input voltage scaled in per unit
Precharge State	Current state of precharge function, i.e., open M1, close M2

Flag	Description
Precharge ExitState	Exit state of precharge thread. **Notes:** State equal to "no errors" indicates thread exited at end of precharge with no errors. If state shows "M1_close," this means that the last state M1 was commanded to close, but an error occurred when cell is set to type "750V AP." Needs to be set to run type 5 precharge.
CellTypeIsPrecharge	Set when cell is set to type "750V AP." **Note**: Must be set to run Type 5 Precharge
MaintModeTest	Indicates the drive is in Maintenance Mode Menu Precharge Service Mode is turned "On"
MaintStartTest	Indicates Maintenance Mode Start has been issued. Menu Precharge Service start is set to "Start"
CellBusLowFlag_I	State of SOP flag that indicates low DC bus voltage on a cell Used to trigger precharge
CircuitBreakerOpen	State of the Main Input Circuit Breaker
PrechargeReady	All conditions are met to be able to start precharge
M1OpenWithoutCmd	Indicates M1 has opened, but was not commanded to be open
DSPInputProtectFault	The input protection fault latch relay has been triggered

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5.23 Cell Diagnostics Changes

This section provides various informational scenarios about how the Cell Diagnostics appear to run.

Cell diagnostics will start during precharge, once voltage on the cells is sufficient. If no cell faults occur, cell diagnostics thread will exit normally.

If cell faults:

1. If Fast Bypass is on:

   No fast bypass is possible during precharge state. If cell fault occurs during precharge, drive will wait until reset is issued, then precharge has the possibility of completing. If cell can by bypassed, it will be bypassed once M1 is closed.

2. If Fast Bypass is off, Mechanical Bypass is on:

   If cell fault occurs during precharge, drive will wait until reset is issued, then precharge has the possibility of completing. If cell can by bypassed, it will be bypassed once M1 is closed.

3. If Bypass is turned off:

   If cell fault occurs during precharge, drive will wait until reset is issued, then precharge has the possibility of completing. The faulted cell will not be bypassed.

4. If no cell faults:

   Precharge will complete.

5.24 Synchronous Motor with DC Brushless Exciter

5.24.1 Introduction

A different control mode is required to support startup and operation of a synchronous motor (SM) with a DC brushless exciter compared to the use of an AC exciter.

This control mode is used for all applications with synchronous motors that have a brushless DC exciter. Unlike synchronous motors with an AC exciter, synchronous motors with a brushless DC exciter need a different starting strategy to pull the motor into synchronization. For normal synch motor operation with brushless AC excitation, the full flux is already established when the VFD Starts. The DC exciter cannot provide any main field current, and hence the flux when at standstill. To start such a machine, the VFD applies the magnetizing current to the motor stator at standstill. The drive will begin by spinning the motor asynchronously. Once the motor is rotating, the drive will pull the motor into synchronization and transition to normal synchronous motor control.

Startup is based on the high starting torque method already implemented in NXG code. It adds a separate starting state machine that requires only the selection of the SMDC drive control mode. High starting torque mode is set internally, automatically.

Once operational, the machine will continue in operation as a standard SM motor.

5.24.2 Startup Sequence

This software feature requires a special drive control mode (SMDC) for a new starting methodology. This involves startup from the Idle through Magnetizing to run drive states. Once started, the motor will run as a normal SM machine.

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Following is an overview of the process:

To start the motor, the drive will begin by spinning the motor asynchronously. Once the motor is rotating, the drive will pull the motor into synchronism and transition to normal synchronous motor control. Figure 5-38 shows the various stages of drive operation in this mode.
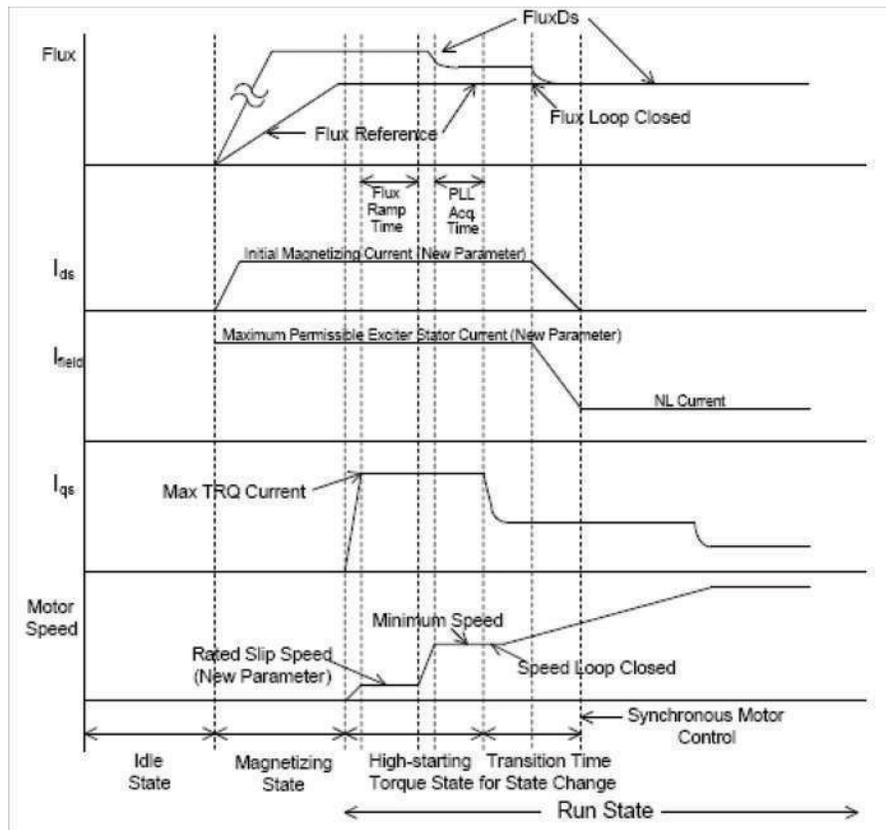
Figure 5-38: Perfect Harmony Operation with a Synchronous Motor with a Brushless DC Exciter

During the starting process, the drive control follows the steps as outlined below:

1. The motor is started as an induction motor by supplying the magnetizing current to the motor stator and to the exciter machine in the magnetizing state.

2. In the run state, the drive ramps output frequency to the rated slip speed while increasing the torque component (Iqs) of current to a value that allows the motor to generate sufficient breakaway torque to overcome any stiction.

3. Next the motor speed is ramped to the minimum speed to allow PLL to acquire the motor flux and the motor frequency. Eventually the control closes the speed and the flux loop.

4. Once the flux loop is enabled, it will receive the feedback on Fluxds, and will try to reduce Ids to zero.

5. By the time the magnetizing current (Ids) is reduced to zero, the field current will be at the NL (no load) level, and control will be synchronized. From this point, the drive will operate in normal synchronous motor control mode (SMC/CSMC).

6. The drive will be ready to ramp up to the desired Speed Demand.

The loss of field time out flag is set to a higher value (100 times the menu setting) during the magnetizing state and until the flux loop is enabled in the run state. It is reset to the user-specified value once the magnetizing current (Ids) is reduced to zero.

☞ **Note:** The motor must be protected during start-up in case the applied torque exceeds break-away torque. This results in a "SM Pole Slip" drive fault.

5.24.3 Parameters

Table 5-21: Synchronous Motor with DC Brushless Exciter Parameters

Parameter	ID	Units	Default	Min	Max	Description
Control loop type See Note below.	2050		OLVC			Brushless DC exciter mode (SMDC), which automatically sets High Starting Torque.
Max DC Exciter Curr	1105		0.25	0.00	1.00	Max allowed exciter stator current.
Initial Mag Current	1106		0.04	0.00	1.00	Initial mag current for starting SM with DC exciter.

5.24.4 Debug Screens

A debug screen, "SMDC Data," exists as an additional General status screen (<Ctrl>-G). Plus (+) and minus (-) keys toggle between this screen and the original.

5.25 Regen Braking (Six-Step)

Each cell has an active front end (AFE), which allows regeneration power to flow from the drive output to input. No drive input reactors are needed for this regeneration algorithm.

For this algorithm, cell DC bus voltage is not controlled. Therefore, when the line impedance is high and the drive is regenerating heavily at near-rated speed, where the primary regeneration current is highest, the drive input voltage may increase to the point where cells trip on the DC bus overvoltage fault. The 'OV rollback" function is to limit the rise in the drive input voltage produced by regenerative current to prevent a cell DC bus overvoltage fault. The output torque (power) reduces to a point that will not cause an overvoltage. After this point is reached, the torque limitation caused by the rollback is defeated, and full braking torque is available.

5.25.1 SOP Flags

Two system program (SOP) flags are required to utilize the AFE in these modes of operation for six-step regen.

- **AfeRunRequest_O** — is used to enable the AFE, provided that AfeReadyToRun_I is also true. This check is made within the drive logic and does not require SOP intervention. When set true, the AFE will be enabled continuously — running in six-step when in regen. It is required for any AFE operation. When enabled, the dual frequency braking enable is ignored.

- **RegenBrakingEnable_O** — is used to enable the six-step only for braking when the same conditions exist as for dual frequency braking. This flag requires AfeRunRequest_O to be true and the internal AFE run will be set true to provide functionality when the conditions for dual frequency braking are met (whether dual frequency braking is enabled or not). Since the AFE is only enabled internally when required, despite the AFE Run Request remaining true, it will provide ride-through capability. This flag is ignored until AfeRunRequest_O is set true via the system program.

If RegenBrakingEnable_O flag is set true (with the AfeRunRequest_O also set true) and AfeReadyToRun internal flag is true, the drive six-step front end will operate in the forward and reverse regen quadrants ONLY when dual frequency braking conditions are met. Since the AFE is only enabled internally when the dual frequency would normally run (if enabled), the drive will ride-through normally.

☞ **Notes:**
- When Regen Braking is enabled, Dual Frequency Braking is disabled.
- Regen braking will shut off when Torque Reference goes into motoring.
- Run request must be maintained during Regen Braking to allow Fast Bypass to work properly. This can be done by selecting a zero speed reference, and using the zero speed flag to remove the run request.

5.25.2 Limit Conditions

The regenerative capability is restricted when the line input voltage gets too high. The rollback limits output torque current regen capability when input voltage (Erms) reaches or exceeds 1.08 PU, and decreases it linearly to zero at 1.2 PU (see Figure 5-2).

The conditions for enabling this rollback are as follows by priority, with the first two to run the algorithm, and the third as calculated by the limiting overvoltage algorithm.

- Drive input power negative (drive in regen — only)
- Drive is running in six-step
- Drive input voltage is at or above 1.08 PU input voltage
- Precharge (Type 5) is complete

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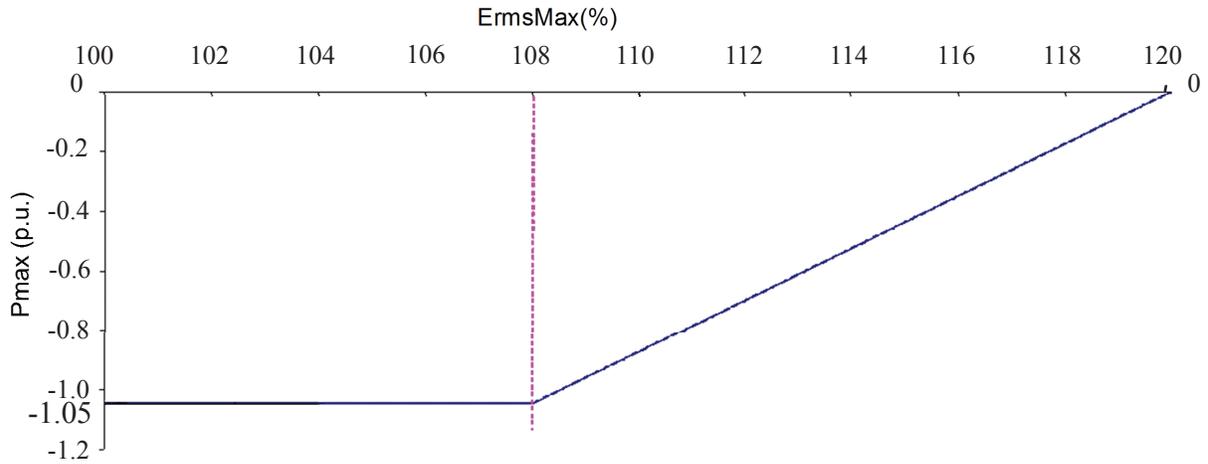
Figure 5-39: Pmax in Regen with Respect to Erms

When this limit routine is active and its output is being used to limit regen torque, the display will show the limit used as "OVLT" in the mode field of the keypad and Drive Tool, and "REGEN OV" on the debug screen.

5.25.3 Parameters

Table 5-22: Regen Breaking (Six-Step) Parameters

Parameter	ID	Units	Default	Min	Max	Description
Regen OV I gain	2623		0.0010	0.0001	1.000	Regen overvoltage rollback regulator integral gain *
Regen OV P gain	2624		0.0000	0.0000	10.0000	Regen overvoltage rollback regulator proportional gain *
Regen Shift Angle	2625	deg	0.00	-11.25	11.25	Regen angle adjustment *

* Default values are recommended

5.26 Torque Mode

Torque mode is added for applications needing this specialized feature. Torque reference is input through Analog input 3 or the Network. It is a modified, saturated speed loop algorithm allowing the torque to be controlled through the torque limit, with fall-back into speed mode, should the torque requirement suddenly drop. This prevents a dangerous runaway condition caused by applying a fixed torque with no speed control. The speed ramp is bypassed in this mode for faster response, and the torque ramp is enabled to control application of torque changes. Speed droop is disabled in torque mode.

If the VFD is used in Torque mode, the speed regulation must be done externally to the VFD. The input to the Drive in this type of application is a Torque Demand. Figure 5-40 depicts a generalized view of Torque Mode.
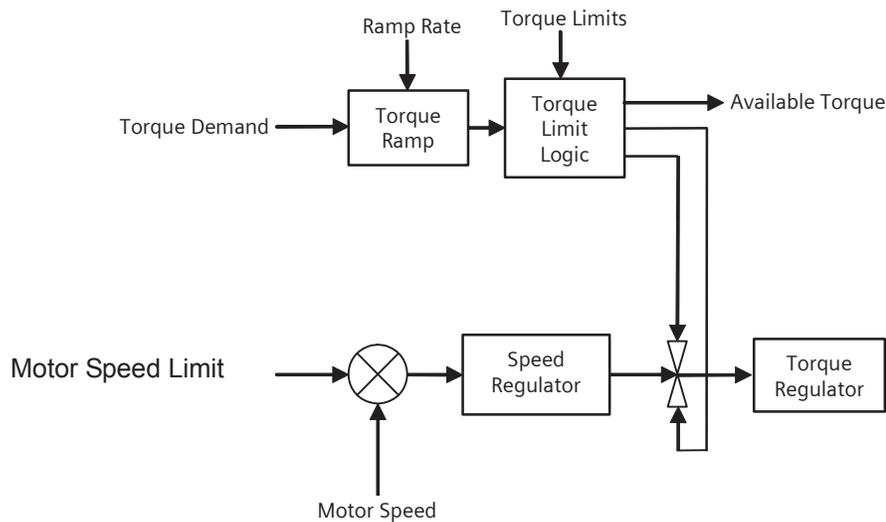
Figure 5-40: Torque Mode

☞   **Note:** The Speed Demand is set to the motor speed limit as shown in Figure 5-40.

The Torque Demand can be sent to the VFD in one of three ways: (see Figure 5-41).

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TorqueDemandFromAnalog_O

Analog Input #3

TorqueDemandFromNetwork_O　　　TorqueMode_O

Industrial Network

TorqueDemandFromMenu_O
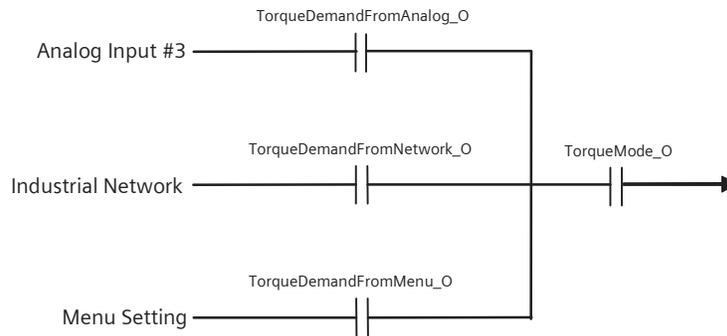
Menu Setting

Figure 5-41: Torque Demand Options

Depending on the source of the Torque Demand, the appropriate SOP flags and menu settings must be configured. See SOP and Parameter sections below. In all cases the "TorqueMode_O" flag must be set TRUE to use torque mode, and the necessary torque command established through the selected source.

5.26.1　Parameters

Location: Drive $\rightarrow$ Drive Parameters $\rightarrow$ Torque Reference

Parameter	ID	Units	Default	Min	Max	Description
Torque Reference	2210		Sub-Menu			Contains torque mode settings - Under Drive Menu
SOP/Menu Control	2211		SOP Flag SOP Flag or Menu			Controls the source of the torque demand - either SOP flag or Menu. To utilize an Analog or Network source, SOP flag must be selected. The default torque demand is always the Menu, regardless of this setting, unless one of the SOP flags is set true as described in the SOP section below.
Torque Setpoint	2220	%	0	-125	125	Sets the desired torque demand when Menu is selected, or if no SOP is selected.

Parameter	ID	Units	Default	Min	Max	Description
Holding Torque	2230	%	0	-100	100	Holding torque is used to supply an offset to the torque ramp output. This could be used in an application that prevents the load from drifting backwards at zero speed, or to counter a fixed load against gravity where an offset in the torque is required.
Torque Ramp Increase	2240	Sec	1	0.01	10.00	Controls the rate of change of the torque ramp increase in terms of seconds from zero to rated torque.
Torque Ramp Decrease	2250	Sec	1	0.01	10.00	Controls the rate of change of the torque ramp decrease in terms of seconds from rated to zero torque.
Torque Command Scaler	2242		1.00	-1.25	1.25	Scales the torque command to compensate for system offsets and gain changes.

5.26.2   SOP Flags

System Program flags used to control various aspects of the torque mode.

Flag Name	Description
TorqueMode_O	Set 'TRUE' for use of torque mode
TorqueDemandFromMenu_O	Set 'TRUE' for selecting Torque demand from Menu
TorqueDemandFromAnalog_O	Set 'TRUE' for selecting Torque demand from Analog Input #3
TorqueDemandFromNetwork_O	Set 'TRUE' for selecting Torque demand from a Network

☞ **Note:** If an Industrial network or Analog Input #3 is to be used, the menu "SOP / Menu control" must be set to 'Sop flag' menu ID = 2211 (see above). If all three flags are evaluated as true for some reason, the default will be the 'Menu Setting.'

5.27 Flux Feed-Forward

Flux Feed-Forward is a compensation input to increase performance of the flux loop. First it presets the flux reference to the no-load flux command as soon as it is enabled, thereby eliminating the delays of the response of the flux loop that would occur if starting from zero. Next, it compensates the flux based on the load by feeding a reference proportional to the torque command to the output of the flux regulator. This compensates for the reduction of flux resulting from interaction with the torque current, increasing the Id (reactive) current as a linear function of Iq (torque) current.

The functionality of Flux Feed-forward is essentially the same for both Induction Motors (IM) and Synchronous Motors (SM). The difference between the two motor types has to do with the inductance for which we are compensating. In the IM, we compensate for losses due to the leakage inductance only, and this is the parameter (Leakage inductance) that affects the amount of compensation.

In the SM, we must compensate for the leakage inductance and a part of the mutual inductance. This is the purpose of parameter - "Saliency Constant" (ID 1091). It only applies to SM control, and is used instead of the leakage inductance parameter. Zeroing the Saliency Constant still provides the No Load FF term, which essentially provides the no load flux reference.
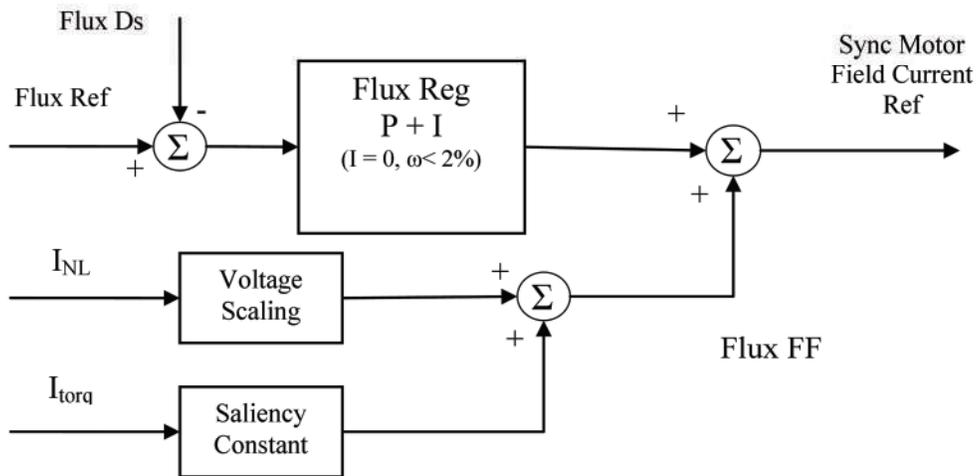
Figure 5-42: SM Flux FF

5.27.1 Parameters

Location: Motor $\rightarrow$ Motor Parameters

Parameter	ID	Units	Default	Min	Max	Description
Leakage Inductance	1070	%	16	0	30	Motor leakage inductance based on percent of drive base impedance. If given will be on nameplate or motor sheet - else it can be calculated by Auto-tune level one.
Saliency constant	1091	%	1.4	0	2.5	Ratio of total q-axis inductance to d-axis mutual inductance. Entered as percent of base drive impedance.

5.28 CPU Watchdog

The RTOS of the drive is a complex, multi-level program with a lot of processes working seemingly simultaneously. Should any of these processes fail to run, others may still appear to function, but critical functions may not be. This feature, enabled by "Enable Watchdog" monitors the state of all processes, and trips the drive after a fixed 20 seconds, if any processes are non-functioning. Since the CPU has stopped functioning properly, no fault condition can be displayed but the power electronics will shut down via the modulator watchdog.

5.28.1 Parameters

Location: Drive → Drive Parameters → Watchdog

Parameter	ID	Units	Default	Min	Max	Description
Watchdog	2970		Sub-menu			Found under parent menu - Drive parameters
Enable Watchdog	2971		Off			Enables the CPU watchdog with a fixed 20 second trip time

5.29 High Torque Starting Mode

Special applications and motors require a special high torque starting mode. PMM's (Permanent Magnet Motors), due to their fixed flux source from the magnets, present a challenge as they must be moving in order to lock on to the flux phase. SM's (Sync Motors) have an externally generated flux source which can be pulsed to provide enough feedback to lock onto the flux angle at standstill, and IM's (Induction Motors) have a flux created through coupling across the air gap and so can be controlled directly.

When starting a PMM from standstill, the flux vector cannot be determined until motion is established. It is necessary to apply an adequate amount of torque current for a short period of time to overcome the inertia of the rotor and to produce movement. Once movement occurs, the PLL can lock onto the flux vector.

SM's and IM's (in V/Hz mode only) require this mode to overcome static friction (stiction) that is high in either the motor or the load, or when a large inertial load is connected, or when operating a motor on long cables in which a significant amount of load impedance is in the cables.

For long cable applications, the Minimum Speed Limit should be set to be approximately the same as % value of the total resistance in series with the motor. For example, if in a long cable application the total series resistance is about 30% of motor base impedance, a minimum speed limit of 30% (or higher) should be set.

5.29.1 SM and PMM

During magnetizing state, the flux on the SM must be ramped on. It achieves rated flux at the end of this state. Since the field is externally excited, there is no Magnetizing current applied by the drive - just the reference from the drive goes to the field exciter. This is unnecessary for the PMM, as it is at rated flux all the time.

At the end of Magnetizing state, the frequency of the output is ramped and held at the minimum speed, set by the active Minimum speed parameter in the "Speed Setup" menu (ID 2060). If using this feature, ensure that the minimum speed is set to a non-zero number, as the application requires.

The applied torque current is ramped from zero to a programmed level (torque current - 2962), and then maintained for a programmed time to allow the motor to begin spinning. At the end of this time, the torque is controlled by the speed loop. See Figure 5-43 for the speed and torque profiles.
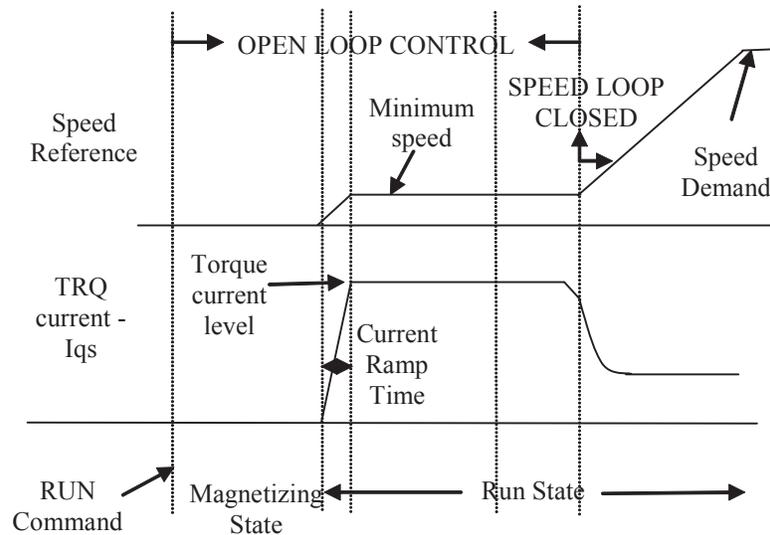
Figure 5-43: High Starting Torque - SM and PMM

5.29.2 IM (V/Hz Mode)

For induction machines in V/Hz mode, the current loops are not as responsive. To provide high starting torque, a slight variation must be made in the algorithm, as indicated in Figure 5-44. Note that the speed reference starts at rated slip rather than at minimum speed.

For induction motors:

1. The Minimum Speed Limit should be greater than the rated slip of the motor, and

2. The magnetization time or the Flux Ramp Time should be set to at least twice the rotor time constant of the motor (if this is known).

The main differences with this start is that no-load magnetizing current is applied at the start of the Magnetizing State while the flux reference is ramped as in the SM case.
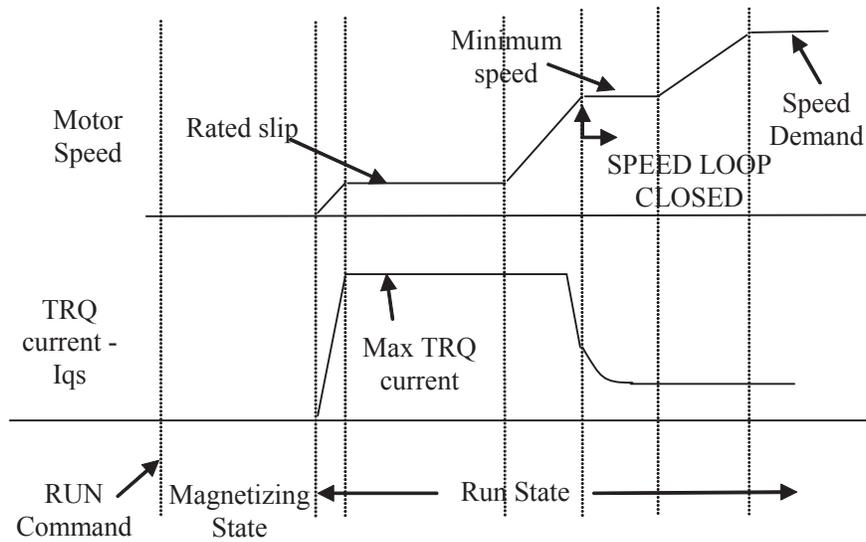
Figure 5-44: High Starting Torque - IM (V/Hz)

5.29.3 Parameters

Parameter	ID	Units	Default	Min	Max	Description
High Starting Torque	2960		Sub-menu			Sub-menu that contains parameters concerning high starting torque operation.
Enable High Torque	2961		Disable			Enable for high starting torque mode of operation.
Torque Current	2962	%	50	0	125	Sets the value of torque current during this mode of operation. This value is determined by the stiction or breakaway torque that is needed for the application.
Current Ramp Time	2963	Sec	0.5	0	5	Sets the time for torque current to ramp from zero to the Torque current level (parameter # 2962). Default value is acceptable in most cases.
PLL Acq Time	2964	Sec	2.0	0	5	Sets the time allowed for the phase-locked loop to acquire the motor flux and frequency. Default value is acceptable in most cases. However, less time may be needed if the Minimum Speed Limit is lower than 1% of rated speed.

5.30 Excess Drive Loss Protection Changes

This algorithm has been improved for greater effectiveness in the detection of some of the faults which can produce excessive losses within the drive - primarily when a cell power device fails. Also, the values established for running and idle conditions of the drive were hard-coded and set according to worst case scenarios to avoid nuisance trips.

Now both the running and idle setpoints can be adjusted separately via parameters. Further, the detection algorithm gain has been increased a hundredfold over the running gain after initial power-up. This allows detection of a catastrophic cell fault during cell bypass that could result in collateral damage to other adjacent cells if not immediately acted upon by the removal of input voltage from the source of the drive. This algorithm is an integral part of the input protection of the drive.

The run and idle setpoints are found in the "Input Protection" menu (ID 7000).

5.30.1 Parameters

Location: Drive → Drive Protect → Input Protection

Parameter	ID	Units	Default	Min	Max	Description
Excess Loss Idle	7084	%	5	1	5	Sets the power loss level in percent of input power when the drive is in Idle (in particular when cell is fast bypassing). The default is 5 %, which was the hard-coded value in previous releases.
Excess Loss Running	7086	%	7	3	9	Sets the power loss level when the drive is running. The default is 7 % of input power, which is the hard coded value of previous releases.

5.30.2 SOP Flags

This detection is always enabled and defaults to an alarm - not a fault.

Flag Name	Description
ExcessiveDriveLossesWn_O	Set 'TRUE' to set this fault as an alarm - false to make it fatal
ExcessiveDriveLosses_I	Indicates that the losses within the drive are outside of the acceptable range

5.31 Cable Inductance Compensation

Long cable applications present a challenge as the cables become a significant contribution to the overall load imped-ance. Compensation for Cable inductance affects the output voltage during transient conditions of current based on the output fundamental frequency.

Previously compensation had been performed for cable resistance only. Drive base impedance is calculated as:

$$Zbase = [Vrated/\sqrt{3}] * [1/Irated]$$

where:

Zbase - Drive base impedance
Vrated - Drive Rated output voltage
Irated - Drive Rated output current

5.31.1 Parameters

Location: Drive $\rightarrow$ Drive Parameters $\rightarrow$ Output Connection

Parameter	ID	Units	Default	Min	Max	Description
Cable Inductance	2941	%	0	0	50	Cable inductance - entered in percent of drive base impedance (as calculated above)

5.32 Loss of Field Fault for SM Operation

SM control utilizes a similar means to correlate failure to magnetize as in an IM. When operating with one of these motors, the Loss of Field fault fills this need by providing for a drive trip when the field current reference is above the loss of field threshold for the time set by the menu. Essentially the flux regulator is requesting too high a field current (excessive reactive current) in the attempt to produce the rated flux of the machine in the time allowed. For the IM, the level is fixed at 80% of full load current, but for the SM, it is this loss level multiplied by the full load current level that is used to trigger a fault.

This fault is always enabled for SM control, and defaults to a fatal fault when SM control is used. The following parameters control this functionality and are found in the Motor Limits Menu (ID 1120).

5.32.1 Parameters

Location: Motor $\rightarrow$ Limits

Parameter	ID	Units	Default	Min	Max	Description
Loss of Field Level	1141	%	40	5	50	Sets the limit used in detecting excessive reactive current reference (IdRef) which, if exceeded, points to the failure to magnetize the motor. The limit is set as limit = Loss of field level * Maximum Load Current (maximum allowable motor current limited by cell capability) for drive trip.

Parameter	ID	Units	Default	Min	Max	Description
Loss of Field Timeout	1142	sec	10	0.5	5	Sets the time to trip if the reactive current reference (IdRef) exceeds the limit for this time period.

5.32.2 SOP Flags

This detection is always enabled when SM control is selected and defaults to a fault.

Flag Name	Description
LossOfFieldFault_I	Indicates that the field control of a synch motor has failed
LossOfFieldFaultWn_O	Set 'TRUE' to make this event an alarm - false is fault

5.33 External Flux Reference

For certain SM types, the flux must be reduced for startup. This is mostly a thermal problem with large inertial loads and virtually no cooling when the rotor is stationary. This feature is enabled via a system program flag that, when enabled, allows the flux demand to come through a network register instead of using the internally computed value. This feature can also be used to import a flux profile from an external (PLC or PC) device and transfer to the motor via the network register.

5.33.1 Parameters

Location: Drive → Drive Protect → Input Protection

Parameter	ID	Units	Default	Min	Max	Description
Global Data to Drive	9200		Sub-menu			Menu for Global registers for data sent to drive from the network.
Data to Drive 01 - Drive 32	2201 to 2231		None <picklist>			Global register that contains data sent from the network to drive. One of these registers must be set to "Flux Demand" from the picklist to use the register value.

5.33.2 SOP flag

Only one flag is required in the SOP to use this feature.

Flag Name	Description
FluxDemandFromNetwork_O	Set 'TRUE' for use of flux demand through the network register

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6   Startup Procedure

6.1 Introduction

This chapter outlines the steps required to successfully startup a Perfect Harmony drive from inspection to a complete medium voltage motor test. These checks are discussed individually within the separate sections of this procedure. Following any introductory text and precautions, each section contains a series of individual steps. Tables may be included in some sections. Some tables are used to record parameter settings, test point data, and any errors or deviations from expectations.

☞ | **Note: On NXG II, or if the System I/O board is used, the test points are the same; however, the amplitudes of all signals are 1/2 (50%) of what is stated for the NXG System Interface board.**

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6.2 Pre-power Visual Inspection

Before power is applied to the drive, pre-power visual inspections must be conducted. Verify the system specifications as detailed in Table 6-1.

Table 6-1: Pre-power Visual Inspection

Step	Description
1	Since the layout of each drive associated with this manual is physically different, refer to individual product manual for this part of startup.

☞ | **Note:** If any of the previous checks yield inconsistent or unusual results, cancel the startup procedure and notify the factory.

☞ | **Note:**
- Siemens HV cells utilize film capacitors. To protect these capacitors from overvoltage during power-up, a method referred to as precharge is *required* to power up the input voltage of the drive. Please refer to Section 5.19, *Precharge*, of this manual before bringing input voltage on to the drive through the input transformer. Ensure proper precharge type is selected via the menu settings.
- There is a separate section for the type of precharge supplied with your system.
- Control power must be energized before attempting to apply medium voltage (MV).

☞ | **Note: Precharge, if installed, MUST be successfully completed so that all cells are energized before proceeding This can include the maintenance mode of precharge in which MV is applied to the cells but the main (MI) contactor is not closed. Refer to Section 5.19, *Precharge* for more details, and check the product manual.**

The following steps verify operation of the drive (without a motor) in Open Loop Test Mode.

Table 6-2: Drive Test in Open Loop without Motor

Step	Description
1	To connect the PC/Laptop to the Pentium control processor, use an Ethernet cable with a RJ-45 standard jack along with a crossover cable.
⚠️	**Warning!** Do not connect a grounded PC or laptop to a communications board with an isolator or while the drive is running. To do so could damage the computer and/or the digital Control Rack.
2	Re-energize the AC control power.
3	Ensure the Drive Parameters (2000) match the rated values for the Drive. Set the Control Loop type (2050) to Open Loop Test Mode.
4	Verify that the Input Voltage (3030) and Input Current (3040) Scalars (stability → Input Processing) are set to the default values of 1.0.
5	Select the correct Transformer Tap setting using Drive Protect → Input Protect → Xformer Tap Setting (7050).
6	Energize system pre-charge only after precharge is **thoroughly** tested, see product manual for details.
⚠️	**Warning!** Any system that contains pre-charge must be energized following the pre-charge sequence **anytime** MV is applied.
7	DISABLE Spinning Load using Drive (2) → Spinning Load (2420) → Spinning Load Mode (2430).
8	Perform this test only if the Drive is equipped with Mechanical Bypass Contactors. Stop the drive by giving a STOP command. Once the drive is in the OFF or IDLE state, change the Control Mode (2050) to Open Loop Vector Control ENABLE Fast (cell) Bypass (2600). Access this parameter through Drive → Cells → Fast Bypass. Also make sure that in the Cells submenu, the Min. Cells/Phase Count (2540) is set to be one less than the installed rank of cells. On the keypad, select Bypass Status (2620). The display should show all "A" (available) characters. The order displayed is A-phase (1 through *n*), B-phase (1 through *n*), and C-phase (1 through *n*), where n represents the number of cells per phase. Pull a fiber-optic link for an A-phase cell (e.g., A1) out of the fiber-optic interface board. Check Bypass Status (2620). It will now display a "B" (bypassed) character in the location for the cell from which the fiber was removed. Repeat steps A and B for a cell from each of the other two phases (e.g., B1 and C1). Re-connect all fiber-optic links to their corresponding cells and reset their bypass status using Reset Bypassed Cells (2640). Repeat steps A through C until all bypass contactors have been verified. Make sure all fiber-optic links are connected back in the correct order before moving to the next step.
9	Make sure that Fast bypass (2600) is DISABLED. Access this parameter through Drive → Cells → Fast Bypass.
10	Configure the Keypad to display input voltage (VDIN), input frequency (FRIN), and motor voltage (VLTS).

Step	Description
11	Set the Motor Rated Voltage (1040) parameter (access it through Motor → Motor Parameters) to be equal to the Drive Rated Output Voltage and the Motor Frequency (1020) equal to 60Hz.
12	Verify that the Keypad or Drive Tool displays the correct value of input voltage and frequency. At rated primary voltage, the AC input voltage feedback on test points VIA, VIB, and VIC should be 10.80Vpp or 3.82Vrms. See Figure 6-1. These test points are on the system interface card. Perform the following corrective step if the input (or line) voltage is too high or too low. **Figure 6-1: AC input voltages at test-points VIA, VIB and VIC on system interface card** If the input voltage to the drive is too high, then this needs to be corrected. Harmony Drives are shipped with the transformer tap set to + 5%, which reduces the voltage by that percentage on the secondary side of the transformer. If the voltage is low (5% less than rated), then change the tap on the transformer to the neutral ("O") or the −5% tap. If the input frequency is displayed as a negative number, then one pair of input phases has to be switched to change the phase rotation.
☞	**Note:** If the drive will be used for synchronous transfer of a motor to the line, not only the phase rotation but the actual phase relationships must match from input to output.

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Step	Description
13	Enter a speed demand of 25% and give the RUN command. The AC output voltage on test-points VMA, VMB, and VMC should be 2.70Vpp ±0.27V (measure the average peak-to-peak voltage) or 0.96Vrms ±0.20V. See Figure for signals on test-points VMA and VMB at 25% speed (15Hz). **Figure 6-2: AC Output Voltages At Test-points VMA And VMB At 15Hz In Open Loop Test Mode**
14	Increase the speed demand to 50%. The output feedback signals should increase in proportion in both frequency and amplitude. Note that in Open Loop Test Mode, the flux regulator is not enabled and hence the output voltage will read higher or lower than the calculated value corresponding to 50% of rated voltage. Adjust the Flux Demand parameter (3150) so that the motor voltage (on the Keypad or Tool) is approximately equal to 50% of rated voltage. Further increase the speed demand to 100%. The AC output voltage on test-points VMA, VMB, and VMC should be 10.80Vpp ±0.27V or 3.82Vrms ±0.20V. The Motor Voltage on the Keypad should read the rated value of output voltage ±5%.

6.3 Drive Test in Open Loop Test Mode with Motor Connected

The following steps verify operation of the drive (**with** a motor connected at its output) in Open Loop Test Mode. This test is required only when the operation of the output Hall Effect Transducers and the polarity are required to be verified. During this test, the motor should be unloaded. If this test is not required, then proceed to the next test.

Table 6-3: Drive Test in Open Loop Test Mode with Motor Connected

Step	Description
1	Disconnect control voltage and medium voltage sources. Reconnect motor leads or enable motor contactor.
2	Energize the control circuit breaker. Energize input voltage.
3	Set the Motor Rated Voltage (1040) and Frequency (1020) parameters (access it through Motor $\rightarrow$ Motor Parameters) to be equal to the motor nameplate values.
4	Make sure that Spinning Load Mode (2430) and Fast Bypass (2600) are DISABLED.
5	Increase the Speed Ramp parameters to slow down drive acceleration and deceleration. Speed ramp setup (2260) Accel time 1(2270)60.0 sec or greater Decel time 1(2280)60.0 sec or greater
6	Reduce the Flux Demand parameter to 0.5. Stability (3) Output Processing (3050) Flux Control (3100) Flux demand (3150)0.5
7	Energize the medium voltage feed to the VFD AFTER the precharge is thoroughly tested. Push the Fault Reset Button on the Keypad to reset faults and push the Button a second time to acknowledge any alarms. If the Mode on the Keypad display reads RLBK, then change the Control Loop Type (2050) to Open Loop Vector Control and exit from the menu entry. This should force the RLBK on the Keypad to change back to Mode. Then change the Control Loop Type (2050) back to Open Loop Test Mode.
8	Configure the Keypad to display motor magnetizing current, motor torque current, and motor voltage.
9	Spin the motor at 1% speed and observe proper rotation.

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Step	Description
10	• Operate the drive with a Speed Demand of 10%. Observe the AC output voltage feedback and motor current for phase A on test-points VMA and IMA using an oscilloscope. • Since the motor is unloaded, the current waveform should lead the voltage waveform by almost 90° (see Figure 6-3). The Hall Effect Current Transducers introduce a negative sign since they are configured to measure the incoming current. Check test-points VMB, IMB and VMC, IMC for similar waveforms. • The Keypad display should read a positive average value for Ids (magnetizing current) and a small value for Iqs (the torque current). Note that the Keypad displays of Ids and Iqs will not show constant values. This is because in the Open loop Test Mode, the drive does not have good control of the currents. The average value of Ids should be equal to half the no-load current of the motor, while the average value of Iqs should be nearly zero. **Figure 6-3: Open Loop Test Mode Operation at 10% Speed With An Unloaded Motor (AC motor voltage and motor current at test-points VMA and IMA are shown)**

6.4 Drive Test in Open Loop Vector Control Mode with Motor Connected

At this point, the VFD is ready for actual (*induction*) motor operation. The following steps verify operation of the drive and the load induction motor in Open Loop Vector Control Mode. Additional steps are needed for setup and test with a synchronous motor, primarily in regards to field control. Follow the steps in the following section.

☞ **Note:** This procedure assumes MV and control power is off at this point. If control power is already applied it is necessary to shut off MV before proceeding. Before re-applying MV power, check the product manual to see if precharge is required.

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Table 6-4: Drive Test in Open Loop Vector Control Mode with Motor Connected

Step	Description
1	Reconnect motor leads or enable motor contactor, if required (MV **must** be left off for this step).
2	Energize the control circuit breaker. (The control needs to be on before MV.)
3	Change the drive Control Loop Type (2050) to Open Loop Vector Control.
4	DISABLE Spinning Load Drive (2) Spinning Load (2420) Spinning Load Mode (2430)Disabled [Enable]
5	Setup the Speed Ramp parameters according to the following recommendation: The acceleration and deceleration rate for a fan should be set to around 60 seconds, and for a pump to around 30 seconds. Speed ramp setup (2260) Accel time 1 (2270) 30.0 sec Decel time 1 (2280) 60.0 sec
6	Verify that Fast (cell) bypass is disabled at this time if you have that option Fast bypass (2600)Disabled
7	Setup the following motor parameters according to the nameplate values. Motor parameter (1000) Motor frequency (1020) Hz Full load speed (1030) RPM Motor voltage (1040) V Full load current (1050) A Motor kW Rating (1010) kW
8	Use default values for the other motor parameters as shown below. For this test, set the Stator Resistance to 0.1%. The entry within square braces refers to the no-load field current setting for Synchronous Motor Control. Leakage inductance (1070) 16.0% Stator resistance (1080) 0.1% No load current (1060) 25.0%[No load Field Current = 15.0%] Inertia (1090) 30.0 Kgm^2

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Step	Description
9	Set up the Motor Overload and Torque Limits as shown below. Set the Motor Trip Volts to be equal to 120% of the Motor Rated Voltage or to the value required by the customer. Set the Overspeed parameter to be 120% or to the value required by the customer. Limits (1120) Overload select(1130) Constant I overload Pending(1139) 100.0% I overload(1140) 110.0% Overload timeout(1150) 60.0 sec Motor Trip Volts(1160)4800 V or value required by customer Overspeed(1170) 120% or value required by customer Motor torque limit 1(1190) 100.0% Regen torque limit 1(1200) -0.3%

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Step	Description
10	Verify that the control loop gains are at their default values as shown below. Entries within square braces refer to settings for Synchronous Motor Control. •Stability(3) •Output Processing(3050) •Flux Control(3100) •Flux reg prop gain(3110) 1.72 [0.50] •Flux reg integral gain(3120) 1.00 [0.50] •*Flux filter time const(3130)* *0.0667 sec* *[0.022 sec]* •Flux demand(3150) 1.0 •Flux ramp rate(3160) 0.5 sec •Energy saver min flux(3170) 100% •Speed Loop(3200) •Speed reg prop gain(3210) 0.02 •Speed reg integral gain(3220) 0.046 •Speed reg Kf gain(3230) 0.60 •Speed filter time const(3240) 0.0488 sec •Current Loop(3250) •Current reg prop gain(3260) 0.50 •Current reg integral gain(3270) 25.0 •Braking(3350) •Enable braking(3360) Disable •Pulsation frequency (3370)275.0 Hz •Output Processing (3050) •Output current scaler(3440) 1.0 •Output voltage scaler(3450) 1.0 •Stability(3) •Dead time comp(3550) 12.0 μsec •Feed forward constant (3560)0.0 •Carrier frequency(3580) 600.0 Hz (See limitations on NXG in Chapter 5) **Note**: Auto-Tuning Stage I modifies the italicized menu items in the above list
11	For **synchronous motors,** ensure that the WAGO Analog Output module providing the command for the Field Supply, is correctly selected. Select the appropriate Analog Module # within the Analog Outputs sub-menu (4660). For this analog module select: • Synch Motor Field as the Analog Variable • Unipolar as the Module Type • 100% for the Full Range
12	Verify the System Operational Program and Customer Interface.
13	Energize the medium voltage feed to the VFD. Push the Fault Reset Button on the Keypad to reset faults and push the Button a second time to acknowledge any alarms. Spin the motor at 1% speed, and observe proper rotation if this was not verified in the previous test.

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Step	Description
14	Configure the Keypad to display motor magnetizing current, motor torque current, and motor voltage
15	Operate the drive with a Speed Demand of 10%. Observe the AC output voltage feedback and motor current for phase A on test-points VMA and IMA using an oscilloscope. • If the motor is unloaded, then the current waveform should lead the voltage waveform by almost 90° (see Figure 6-4 [top frame]). The Hall Effect Current Transducers introduce a negative sign since they are configured to measure the incoming current. The Keypad display should read a positive value of Ids (magnetizing current) equal to the no-load current of the motor, and Iqs (the torque current) should read a small value (typically 1-3% of rated current). • If the motor is loaded, then the current waveform will lead the motor voltage by an angle smaller than 90° (see Figure 6-4 [bottom frame]). Ids would still read a positive value that is larger than the no-load current, while Iqs would read a value larger than zero. The sign of Iqs directly depends on the direction of torque application, which is positive while motoring in the forward direction See Chapter 5, section 5.2). • The motor voltage should be 10% of the motor rated voltage.
16	Increase the Speed Demand while monitoring the motor voltage. The motor voltage should read according to the following table. See Figure 6-6 for waveforms at 100% speed (60Hz). Table 6-5 shows the drive voltage scaling for signals on test-points VMA, VMB, and VMC as a function of speed. Table 6-6 lists the scaling for the currents and voltage feedback signals available on the Signal Conditioning Board at the rated operating point of the drive.

Table 6-5: Scaling of Drive Output Voltage as a Function Of Speed (60 Hz Rated)

Speed Command (%)	Motor Speed (Hz)	Motor Voltage Feedback (V, pp)	Motor Voltage Feedback (V, rms)
10	6	1.08	0.38
25	15	2.70	0.96
50	30	5.40	1.91
75	45	8.10	2.87
100	60	10.80	3.82

Table 6-6: Scaling of Drive Input and Output Voltages and Currents on Signal Conditioning Board

Variable	Rated value (rms) at drive terminals	Feedback value under rated conditions (Vpeak)	Feedback value under rated conditions (Vrms)
Input Current	Primary Current Rating of Input CT	5.0	3.54
Input Voltage	(Rated Input Voltage L-L) / 1.732	5.4	3.82
Output Current	Output Current Rating ($\equiv$ Cell Rating)	5.0	3.54
Output Voltage	(Rated Output Voltage L-L) / 1.732	5.4	3.82
ExamplesOutput Current Scaling: Cell current rating $\equiv$ 3.54 Vrms			
Output Voltage Scaling: [(Rated output voltage L-L) / 1.732] * 1.414 $\equiv$ 5.4 Vpeak			

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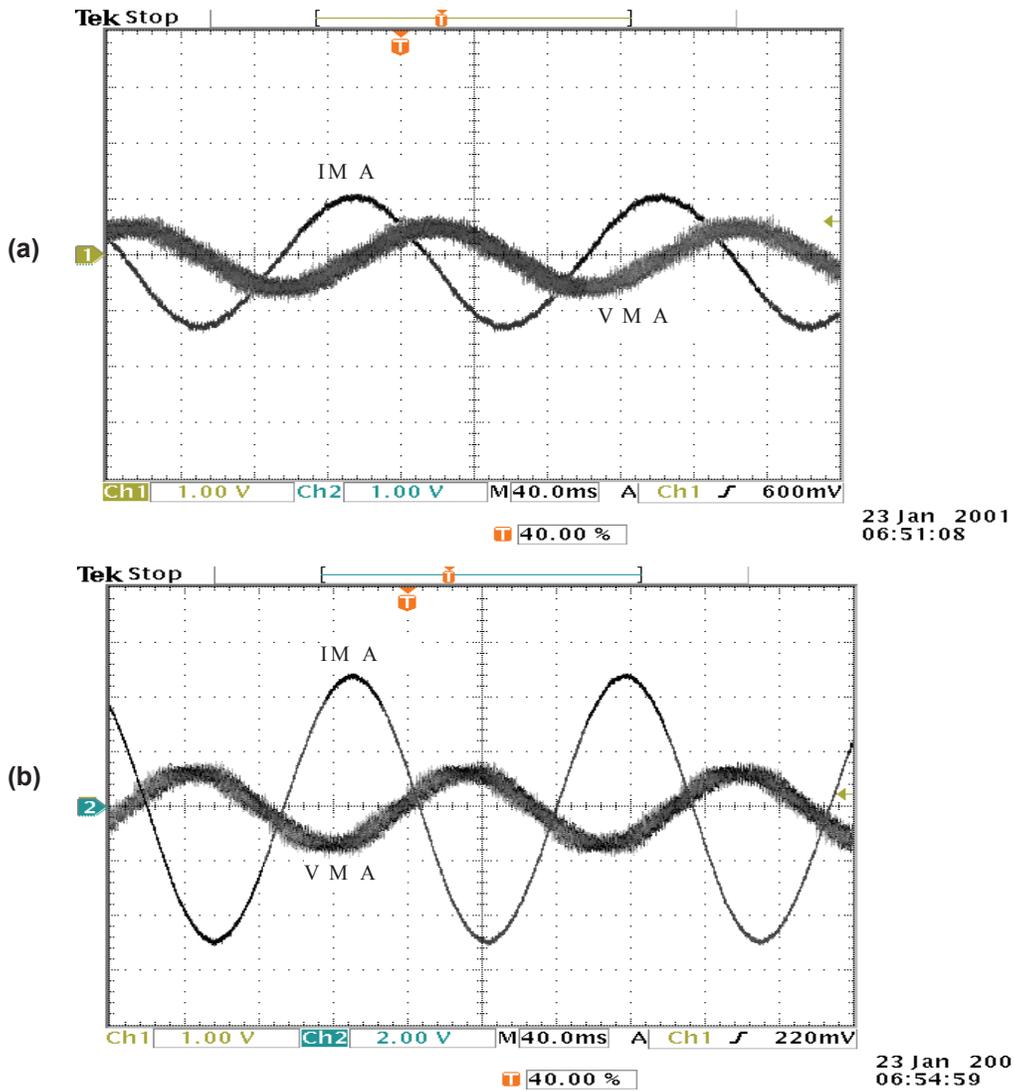
**Figure 6-4: AC motor voltage and Motor Current at Test-points VMA and IMA at 10% speed in Open Loop
Vector Control (a) Unloaded Operation and (b) Full Load Operation**

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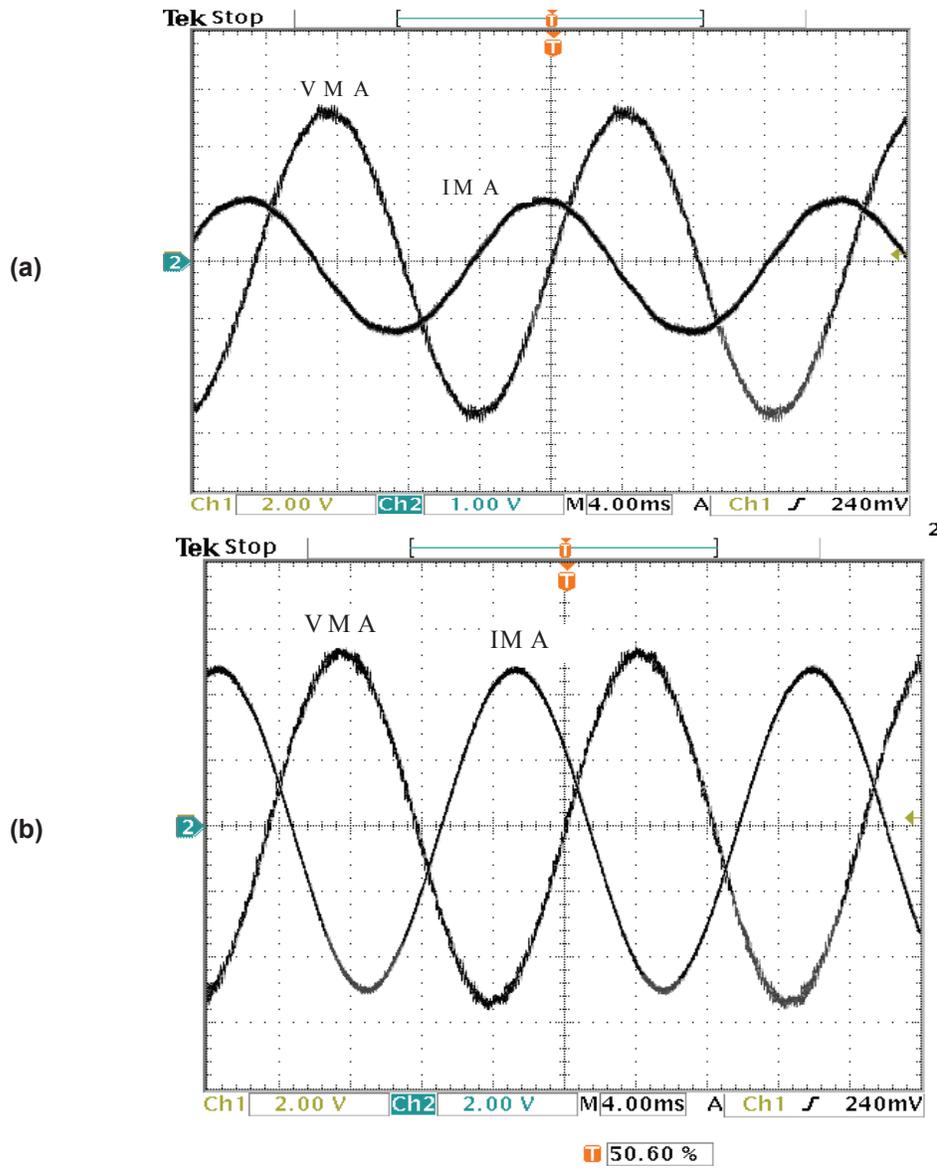
Figure 6-5: AC Motor Voltage And Motor Current At Test-points Vma And Ima At 100% Speed In Open Loop Vector Control (a) Unloaded Operation, And (b) Full Load Operation

6.5 Drive Test with Synchronous Motor

The following procedure verifies operation of drive with a synchronous motor in Synchronous Motor Control Mode.

Table 6-7: Drive Test with Synchronous Motor

Step	Description
1	Connect the synchronous motor to the drive. Enter motor parameters and use default gains except for the following parameters: (1) Enter Synch Motor Field no-load current as the No-load Current setting (1060). This parameter should be calculated (in %) on the basis of the actual no-load field current and the maximum capability of the field excitor. Example: Drive with a synchronous motor that requires 24A of no-load field current and a field supply that is tuned so that 75A is the maximum output (at 20mA command input), then the No-Load Current Parameter should be set to: No-Load Current setting = 100% * 24/75A = 32.0% (2) Enable Spinning Load (2430). (3) Change the drive control loop type (2050) to Synchronous Motor Control. (4) Use default control loop gains except for the flux loop gains that should be changed as follows: Flux reg prop gain(3110) 0.50 Flux reg integral gain(3120) 0.50 Flux filter time coast(3130) 0.022 sec (5) The SOP should have been modified to include the logic for controlling the field supply output contactor. The contactor should be ON as soon as the Start command to the drive is given, and should be turned OFF immediately when the drive trips on a Fault or when the drive goes to Coast State (while stopping).
2	Energize medium voltage to the drive. Run the drive with a speed demand of 10%.
3	Verify that after Start command is given, the field supply first starts by applying current and building motor flux. During this time, Ids and Iqs should be zero.
4	After a time period equal to the Flux Ramp Rate parameter (3160), the drive starts by increasing the Speed Reference to the Speed Demand.
5	With Synchronous Motors, the drive current is always in phase with the voltage, i.e., Ids ≈ 0 under steady-state conditions. At no-load, there is very little current supplied from the drive (on the Keypad, motor current display, ITOT ≈ 0).
6	Run the drive to 10% speed. Verify that the no-load and full load (if possible) current waveforms, along with the drive voltage waveforms, are as shown in Figure 6-6.
7	Run the drive to 100% speed. Verify that the no-load and full-load (if possible) current waveforms, along with the drive voltage waveforms, are as shown in Figure 6-6. Note that the drive output currents at 100% speeds are distorted. This is due to the shape of the poles in the synchronous motor. At low speeds, the current regulator bandwidth is sufficient to correct for the distortion introduced by the motor poles as shown in the second figure of Figure 6-6. However, at high speeds, the current regulator gains are insufficient to maintain sinusoidal output currents when the distortion is due to motor pole construction.

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Figure 6-6: AC Motor Voltage and Motor Current at Test-points VMA and IMA at 100% speed with Synchronous Motor Control (a) Unloaded and (b) 75% torque operation
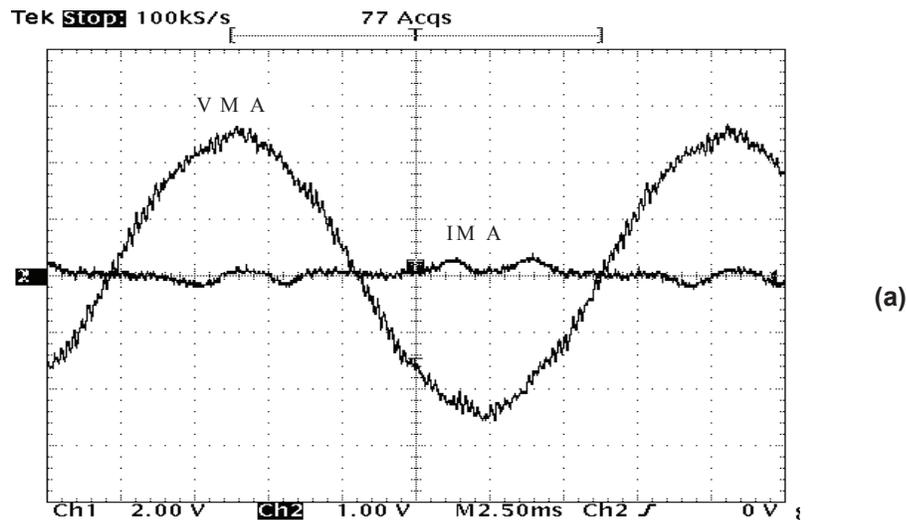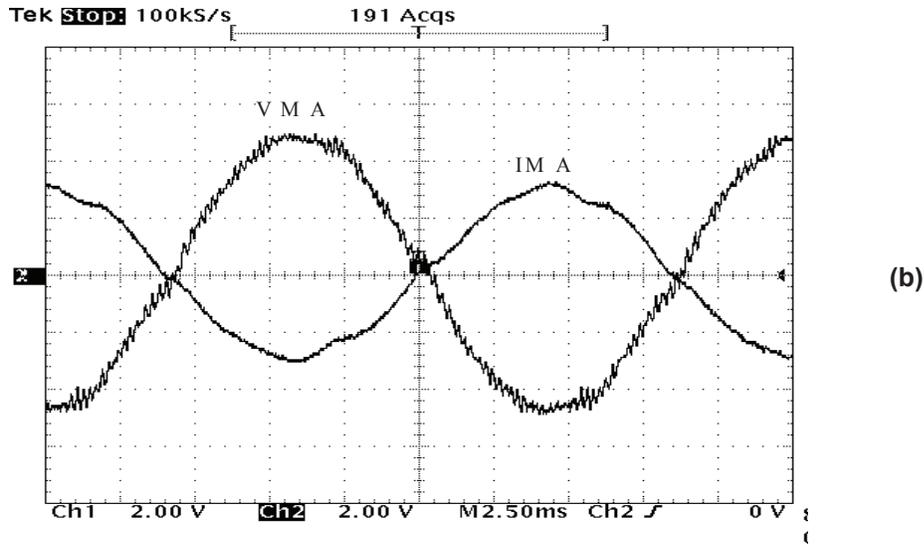
Figure 6-7: AC Motor Voltage and Motor Current at Test-points VMA and IMA at 100% speed with Synchronous Motor Control (a) Unloaded and (b) 75% torque operation

6.6 Drive Tuning

Use the following sections to complete the startup of the drive. The first section describes Auto-Tuning and its use in determining motor and control parameters. The second section describes the setup of the Spinning Load Menu. This feature is used by the drive control to detect motor speed by scanning the output frequency over the operating range of the application. The last section lists the other menus that may need adjustment for completing the drive setup.

6.6.1 Auto-Tuning

☞ | **Note: In most general-purpose applications (such as pumps and fans), default data for the motor equivalent circuit is sufficient, and auto-tuning is neither necessary nor recommended.**

The basic motor parameters can be divided into two categories - nameplate data and equivalent circuit data. Nameplate data, as the name suggests, is readily available (such as Motor Rated Voltage, Full Load Current, etc.). However, equivalent circuit data (such as Stator Resistance, No-load Current, etc.) is available only from the motor manufacturer.

When operating an induction motor, the drive control has the capability to perform Auto-Tuning. This feature allows the drive to estimate parameters of the motor equivalent circuit. There are two stages of auto-tuning; each stage being selected individually. Apart from measuring the motor equivalent circuit parameters during auto-tuning, the control uses the measured motor parameters to adjust the control loops for best possible control bandwidth (the bandwidth for each control loop is fixed internally in software), and hence provides good performance in demanding applications.

☞ | **Notes:** (1) Auto Tuning is **optional**, but is recommended for applications in which high performance, as stated below, is required. (2) The correct equivalent circuit data is *required only when* good control performance, such as high starting torque or very low speed operation, is desired. Auto-Tuning is NOT recommended for most standard operations.

Such a feature provides drive tuning without the need for an extensive adjustment procedure. Although the auto-tuning feature can be used with all induction motors, there are some limitations. Both stages of auto-tuning can be performed with induction motors (OLVC or CLVC).

> **WARNING!** *Only Stage 1* should be performed with Synchronous Motors (SMC or CSMC) or when Output Filters are connected. Stage 2 should **NEVER** be used for these applications.

- **Auto-tune Stage 1 (1260)**
  Stage 1 determines the Stator Resistance and Leakage Inductance. This stage of auto-tuning does not require the motor to be de-coupled from the load. The motor does not rotate during this Stage. The data obtained from stage 1 are used to tune the inner regulators that control motor current. The current loop gains are automatically calculated and saved by the control.

> **DANGER—LETHAL VOLTAGES!** Lethal voltages will appear on the drive outputs during **both** stages (1 and 2) of Auto-Tuning.

- **Auto-tune Stage 2 (1270**)
  Stage 2 determines the no-load motor current and the motor inertia. The motor rotates at 30% of rated speed during this stage. Generally, this stage of auto-tuning requires the motor to be decoupled from the load. Make sure that it is OK with the customer to spin the motor before this test is enabled. Data obtained in Stage 2 are used to optimize the operation of the outer loops that control motor speed and motor flux. The speed and flux loop gains are automatically calculated and saved by the control.

> **DANGER! The motor will spin during Stage 2 of Auto-Tuning.**

> **Note**: Quadratic loads, such as pumps and fans, do not require the motor to be de-coupled. The control is designed to minimize the errors introduced by such loads.

6.6.2 Spinning Load

Spinning Load should be enabled if one or more of the following operating modes/features are selected:

- Fast Bypass
- Auto-Restart (controlled through the auto reset parameters (7120-7150) and the SOP)
- Synchronous Motor Control (SMC and CSMC)
- Closed Loop Vector Control (CLVC)

> **Note:** Spinning Load is disabled with V/Hz and OLTM control. It is automatically enabled if fast bypass is enabled regardless of menu setting.

> **Note:** With synchronous motors, spinning load is almost instantaneous, i.e., the drive will only go into an abbreviated scan mode until flux is established. Then the PLL locks onto the output frequency.

Perform the following steps to tune the scan mode of Spinning Load. Use the Drive Tool to monitor Motor Flux (FluxDS), Motor Speed, and Speed Reference.

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Table 6-8: Tuning the Scan Mode of Spinning Load

Step	Description
1	Enable Spinning Load and make sure the following parameters are set to the values shown.
2	Spinning Load (2420) Spinning Load Mode(2430)Forward or Reverse, whichever is appropriate Scan end threshold (%)(2440)20% Current level set point (%)(2450)25% [or equal to the no-load current setting] Current ramp (s)(2460) 0.01 s Max current (%)(2470) 50% Frequency Scan rate (s)(2480) 3.0 s (scan time)
3	Operate the drive with a demand of 30%
4	Trip the drive by using ESTOP
5	Wait for the motor flux to decay below 4%. This can take more than a few seconds for large horse-power or high efficiency motors.
6	Reset ESTOP (and hit Fault Reset if required) and give a RUN command
7	On the Drive Tool monitor, the speed reference and motor speed at the moment the drive 'catches' the motor. If the speed reference is higher than the motor speed, then the drive has 'caught' the motor too soon. In this case, increase the Scan End Threshold parameter (2440). If the speed reference is lower than the motor speed, then the drive has 'missed' the motor. In this case, reduce the Scan End Threshold parameter (2440).
8	Repeat steps 3 through 7 until the speed reference and motor speed (at the moment the drive 'catches' the motor) are within a few percent of each other.

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6.7 Application Menus

Set up the following Menus according to user/application requirements:

- Motor Limits (1120) including Phase Imbalance Limit (1244) and Ground Fault Limit (1245)

- Speed Profile Menu (4000)

- Bypass Type (2590) and Fast Bypass (2600)

- Critical Frequency Menu (2340)

- Drive Protection Menu (7)

- Display Parameters Menu (8000)

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6.8 Synchronous Transfer Procedure (if applicable)

This section of the startup procedure involves optional synchronous transfer checks. The Perfect Harmony may be configured for optional synchronous transfer operation, in which the drive can be used to control multiple motors, one motor at a time. If such a configuration is not defined for the application, then this section may be skipped.

Use the following steps to set up the drive control for Synchronous Transfer:

Table 6-9: Drive Control Setup for Synchronous Transfer

Step	Description
1	Configure Synchronous Transfer Menu parameters as shown below. Synchronous Transfer (2700) Phase I gain (2710) 2 Phase P gain (2720) 4 Phase offset (2730) 2 deg Phase error threshold (2740)1.5 deg Frequency Offset (2750)0.5% Up Transfer Timeout (2760) 0 sec Down Transfer Timeout (2770) 0 sec
2	ENABLE Spinning Load by setting Spinning Load Mode (2430) to Forward.
3	Set the Speed Fwd Max Limit1 (2080) to at least 105%.

Go through the following checklist to complete the setup for Synchronous Transfer:

Table 6-10: Synchronous Transfer Check List

Step	Description
1	Configure the drive control as described above.
2	Ensure that PLC-related hardware is properly connected (for information, see the respective PLC communications network manuals supplied by the vendor) to the analog I/O modules.
3	Verify wiring of all VFD control and line control electrical contactors.
4	Ensure that the system operating program for the "up transfer" and "down transfer" process logic is implemented as described in Chapter 5.
5	The state machines for up and down transfers reside in the Perfect Harmony's control program. These interface with the control system integrator's PLC network via the VFD system operating program to handle handshaking between each motor control center (MCC) and the VFD. All controls for the VFD and line reactors are controlled from the system integrator's PLC. Verify that these controls are operational.
6	Verify all communications flags.
7	For Synchronous Motor (SM) synchronous transfer, an external field controller source is required when the SM is connected to the line and the drive is disabled. This analog source and the source from the drive must be switched via external logic and in a digital manner; 4-20ma current loops are used for the analog sources (**current loops cannot be switched via a relay**). The final output from the PLC must be connected to the field excitor directly. Verify that there are two sources to the PLC (one of which may be internal), and that the PLC logic is set to switch between the two sources at the appropriate time. The PLC also controls the enable of the field exciter any time the motor is active.

6.9 Output Filter Setup (if applicable)

An output filter is typically used to prevent the output cable dynamics from interfering with the drive output. The Output Connection submenu (2900) should be used when an output filter is connected at the drive output (refer to Table 6-11).

The Filter CT secondary turns parameter (2910) represents the secondary side turns on the filter CT, assuming primary turns are 5. The percent filter inductance (2920) and capacitance (2930) can be calculated from the inductor value (in Henries) and capacitor value (in Farads), respectively, using the following formula. Typical values for the filter inductance and capacitance are 5.0% and 10.0%, respectively. The cable resistance (in ohms) can be estimated from the total cable length and the cable resistance per foot. For this parameter entry (2940), an estimate is sufficient. Use the last formula to convert from ohms to percent of drive output impedance.

The formulas below are all based on a 60 Hz output filter:

Drive_base_impedance [in ohms] = Drive_output_rated_voltage / (1.732 * Drive_output_rated_current)

%Filter_inductance = 100.0 * 377.0 * Filter_inductance [in Henries] / Drive_base_impedance [in ohms]

%Filter_capacitance = 100.0 * 377.0 * Filter_capacitance [in Farads] * Drive_base_impedance [in ohms]

% Cable_resistance = 100.0 * Cable_resistance [in ohms] / Drive_base_impedance [in ohms]

> **Note:** Entries in the Output Connection submenu are related to the drive and not to the motor. Hence, changes in motor parameters do not affect the parameters in this submenu.

Table 6-11: Output Connection Menu (2900)

Parameter	ID	Units	Default	Min	Max	Description
Filter CT secondary turn	2910		0	0	250	Secondary side turns (assuming primary turns = 5) of the CTs used to measure filter capacitor currents.
Filter inductance	2920	%	0	0	16	Sets the output filter inductor value (impedance) as a ratio of the base output impedance of the drive (typically 5%).
Filter capacitance	2930	%	0	0	96	Sets the output capacitor value (admittance) as a ratio of the base output admittance of the drive (typically 10%).
Cable resistance	2940	%	0	0	64	Sets the output cable resistance value as a ratio of the base output impedance of the drive.
Filter damping gain	2950	p.u.	0	-5.0	5.0	Adjusts the active damping gain.

A new parameter called Filter Damping Gain (2950) in the Output Connection submenu is available in NXG versions 2.20 and higher. This allows an adjustment of the damping gain that is used by the control to damp the output frequencies amplified by the filter. For long cables (length > ~ 30000 feet) the damping gain is required to be a negative number, normally between –1.0 and 0.0. For shorter cable lengths, the gain should be in the range of 0.0 and +1.0.

☞ **Note:** For versions 2.02 and 2.11, there is no direct parameter that can be adjusted to control damping. An indirect way of adjusting the internal damping gain is to change the Motor Leakage Inductance parameter. The internal damping gain is directly proportional to the square root of the motor leakage inductance.

For active damping, the sample rate should be above the 4.0 – 4.5 kHz range. Depending on the number of ranks in the drive, use the following table to adjust the carrier frequency (3580).

Table 6-12: Recommended Value of Carrier Frequency as a Function of Cell Stages in the Drive

Number of Ranks	Carrier Frequency (Hz)
3	800
4	600
5	600
6	500

6.9.1 Adjusting Current Regulator Gains with Output Filters

When output filters are used, the current loop gains (3260 and 3270) should be below 0.30 (for proportional gain) and 30.00 (for integral gain), respectively.

If the drive repeatedly trips on IOC when the start command is given, then the wiring of the filter CTs must be checked for correct connections using the procedure described in the following subsection. After the connections are verified, both visually and by operating in OLTM, then the next step is to reduce current loop gains. Reduction of the current loop gains (in steps on 0.05 and 5.00, respectively) must be performed until IOC-free operation is obtained. The Filter damping gain should then be adjusted to reduce the high frequency oscillations in the drive output current waveforms. A proper setting of filter damping will allow the current loop gains to be adjusted upwards towards the desired 0.30 and 30.00 values.

6.9.2 Verification of Filter CT Wiring

Three CTs are used for measuring the filter capacitor currents, one CT for each phase. The CTs are placed on the star-point (or wye connection) of the capacitors so that the CTs are not subject to high common-mode voltages. For each CT, two wires, one from each secondary, go back to the control section. This results in a total of six wires coming from the CTs to the control section. Perform a visual inspection of the filter cabinet (with Medium Voltage off) to verify CT placement and connections.

The capacitor current feedback signals are available on test-points IFA, IFB, and IFC, located on the System Interface Board. To check the CT connections, the drive should be operated without the motor in Open Loop Test Mode. Run the drive to at least 50% speed and observe the drive output voltage, VMA, and filter capacitor current, and IFA on a scope. The filter capacitor current should lead the drive voltage as shown in Figure 6-8, where the waveforms were measured at 100% speed.
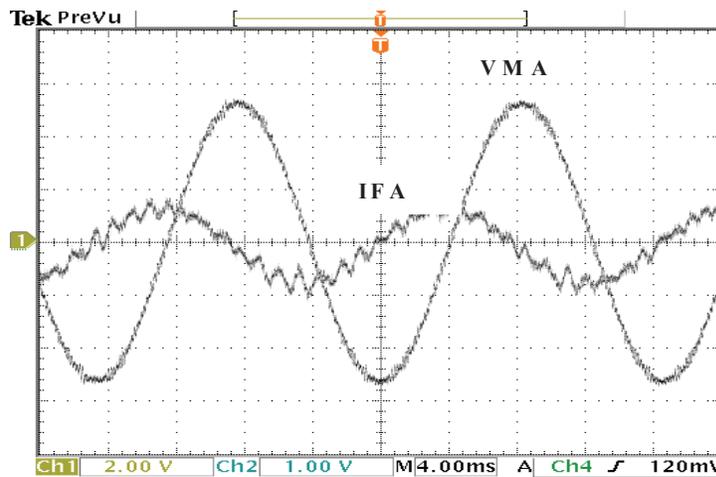
Figure 6-8: Drive Output Voltage And Filter Capacitor Current On Test-points VMA and IFA, Respectively, To Determine If Filter CT Wiring Is Correct

6.9.3 Determining Stator Resistance in Long Cable Application

If cable resistance data is not available, then an alternate way of determining cable and motor resistance (total resistance in series with the drive) is to use Auto-Tuning Stage 1. Use this feature **only** when the motor current rating is **at least 50%** of the drive current rating. If cable resistance (2940) has already been entered as a value less than the actual resistance value, then the drive will subtract the entered cable resistance value from the estimated (total) stator resistance and save the difference as the motor stator resistance (1080). If cable resistance is entered as 0.0, then the drive will assign the total (measured) resistance as the stator resistance parameter.

☞   **Note**: Stator resistance is percentage of motor impedance, while cable resistance is percentage of drive output base impedance. The drive does the conversion of the internal units only after Auto-Tuning Stage 1.

☞   **Note:** After Auto-Tuning Stage 1, the current loop gains have to be manually adjusted so that they are below 0.30 and 30.0, respectively.

6.10 Verification of Encoder Operation

Use the following steps to determine if the encoder is operating correctly.

Table 6-13: Verification of Encoder Operation

Step	Description
1	Run the drive in Open Loop Vector Control.
2	Compare the (estimated) motor speed with the encoder speed (measured) value for different speed demands. They should track each other very closely. If tracking is greater than the rated slip of the motor, then check the Encoder PPR parameter to see if it is correct. To change the polarity of the encoder feedback, switch the pair A, A′ with B, B′.

6.10.1 Encoder Setup (if applicable)

An encoder is used in applications that require very tight speed control, especially at low speeds (see note). Use the following steps to set the drive that is equipped with an encoder.

Note: Drive is not capable of sustained running of a motor at zero speed.

Table 6-14: Encoder Setup

Step	Description
1	Set the drive Control Loop Type (2050) to CLVC (for Closed Loop Vector Control). Choose CSMC (Closed Loop Synchronous Motor Control) if the motor is a synchronous type.
2	Enable Spinning Load by choosing the appropriate direction in menu 2430.
3	Enter the parameters in the Encoder Menu (1280) as shown: Encoder PPR1290- Enter PPR value from encoder Encoder filter gain13000.75 Encoder loss threshold13105.0% Encoder loss response1320Open loop

6.11 Verification of Input Monitoring

This section provides steps to verify the monitoring capabilities of the drive. The following steps should be performed after drive operation in one of the (motor) control modes has been verified.

Table 6-15: Verification of Input Monitoring

Step	Description
1	Check and verify the input voltage accuracy before running the drive.
2	Run the drive to a speed at which output power is greater than 20 – 25% of rated drive power.
3	Check if the calculated values of input and output power are reasonably close, in other words, the drive efficiency should read 95% or higher. If this is not the case, then an adjustment of voltage and/or current scalars (input or output) may be required.

Determination of the voltage/current scaling requires independent means of measuring these quantities. In some drives, PQMs are already installed. PQM readings can be compared with the calculated values from the drive control to determine the actual scaler setting (default setting is 1.0). If a PQM is not available, then a PT/CT can be used to make the independent measurement.

Table 6-5 provides values of voltage/current signals on the test points at rated conditions. For each signal, note the drive display reading, the reading from the independent measurement, and the value measured at the test point. Compare these three readings to determine the cause of the error. A (drive) scalar adjustment should be made until the measurements are within 1% of each other.

☞   **Note:** Increasing the scalar value (for voltage or current) increases the value of the measured quantity in the control.

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7   Troubleshooting and Maintenance

7.1   Introduction

Siemens has designed, built, and tested the Perfect Harmony variable speed drive for long, trouble-free service. However, periodic maintenance is required to keep the drive working reliably, to minimize system down time, and to maintain safety.

> **DANGER-Electrical Hazard!** Always switch off the main input power to the equipment before attempting inspection or maintenance procedure.

> **Warning:** Only qualified service personnel should maintain Perfect Harmony equipment and systems.

This chapter contains information that can be categorized as:

- Fault and Error troubleshooting (beginning)
- Supporting (technical) information (middle)
- Maintenance information (end).

The sections at the beginning of this chapter explain faults, how they are annunciated, fault messages, fault logging, and troubleshooting techniques. The sections in the middle of this chapter provide supporting information such as technical data, test point locations, and internal operations. Finally, the sections at the end of this chapter provide maintenance information such as inspections, replacement parts, etc.

> **Note:** Refer to **Chapter 2: Control Descriptions** for locations and details of major hardware components of the Perfect Harmony control. Refer to separate product manuals for all other details.

7.2   Faults and Alarms

If a fault or alarm condition exists, it will be annunciated on the keypad. The NXG Control software and hardware sense faults and alarms and store them within the fault logger and the event logger. Faults are either detected via direct hardware sensing or by software algorithm.

Cell faults are sensed by the cell control system logic located on the Cell Control Board in each output power cell. Each power cell has its own sense circuitry. The NXG Control software interprets the cell faults and displays them and logs them based on the faulted cell and the specific fault within the cell.

Generally, all faults will immediately inhibit the drive from running and remove power from the drive to the motor. Some faults that are user-defined can control the drive response via the system program. Alarms are annunciated and logged but usually do not inhibit the drive from operation.

Refer to Table 7-1 for a determination of the drive response for the various fault and alarm conditions.

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> ⚠️ **Warning:** Disabling the drive does not necessarily remove voltage from the motor terminals! The motor, especially if spinning, may have residual voltage on the terminals and anything connected to them.

Table 7-1: Fault/Alarm Type and Drive Responses

Type	Drive Responses
Fault	• All IGBT gate drivers are inhibited. • Motor coasts to stop. • The fault is logged. Refer to the Fault Log Menu (6210). • The fault is displayed on the front panel. • The Keypad Fault LED is ON. Refer to Section 4.2.1 for information about the LED. • Most faults are logged to the event log.
User Faults	• The motor either ramp stops or coast stops, depending on the content of the System Program. • The fault is logged. Refer to the Fault Log Menu (6210). • The fault is displayed on the front panel. • The Keypad Fault LED is ON. Refer to Section 4.2.1 for information about the LED. • User defined faults are logged to the event log.
Alarm	• Drive does not necessarily revert to the idle state via a coast or ramp stop unless specifically required to by the system program. • The alarm is logged. Refer to the Fault Log Menu (6210). • The alarm is displayed on the front panel. • The Keypad Fault LED flashes. Refer to Section 4.2.1 for information about the LED.

The [FAULT RESET] key on the Keypad can be used to *manually reset* a fault. The drive must be returned to the run condition by manual start or by forcing the *RunRequest_I* equal to "true" (refer to **Chapter 8: System Programming**).

Certain faults can be reset *automatically* if enabled by the auto fault reset enable (7120). Refer to Table 7-2 for a list of auto re-settable faults. These are fixed and not adjustable. If reset is successful, then drive will return to the run state automatically only if the *RunRequest_I* is maintained at the value "true" (refer to **Chapter 8: System Programming**). The [FAULT RESET] key of the Keypad can acknowledge alarms.

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Table 7-2: Auto Re-settable Faults

Back EMF Timeout	Over speed fault
Encoder Loss	Under load fault
Failed to magnetize	Loss of Signal 1-24
IOC	Loss of Signal Internal
Keypad communication	Loss of Drive Enable
Line over voltage	Loss of Field (SM)
Medium voltage low	
Menu initialization	
Motor over voltage	
Output ground fault	
Network 1 communication fault	
Network 2 communication fault	

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7.3 Drive Faults and Alarms

The NXG Control senses all drive faults and alarms, either from direct hardware or via software algorithms. Use Table 7-3 to quickly locate major causes of fault conditions. The table also lists the type of drive response, if it is a fault (**F**), alarm (**A**), or both (**F/A**), and whether it can be enabled or disabled using the SOP program (**SOP**), or if it is permanently enabled (**Fixed** in software).

☞   **Note:** All voltage values on the System I/O board are 50% of the listed values.

Table 7-3: Cell Defaults

Fault Display	Type	Enable	Potential Causes and Corrective Actions
Input Line Disturbance			
Input Phase Loss	A	Fixed	**Cause** Loss of input phase. **Action** 1. Check the input fuses and connection to verify that the input phases are connected properly. 2. Using an Oscilloscope, verify the presence of all 3 input voltages on test points **VIA/TP1, VIB/TP2, VIC/TP3** of the System Interface board.
Input Ground	A	Fixed	**Cause** Estimated input ground voltage is greater than limit set by the Ground Fault Limit (in the Drive Protection Menu). **Action** 1. Using an Oscilloscope, verify the symmetry (L-L and L-N) of the 3 input voltages on test points (**VIA/TP1, VIB/TP2, VIC/TP3**) of the System Interface board. 2. Use a voltmeter to check for common mode DC to neutral.
Line Over Voltage 1	A	SOP	**Cause** The drive-input RMS voltage is greater than 110% of the drive rated input voltage. **Action** Using a voltmeter, verify the input voltages on test points (**VIA/TP1, VIB/TP2, VIC/TP3**) of the System Interface board are ~3.8 VRMS. This is the expected value for rated input voltage. Values greater than ~4.2 VRMS will trigger over voltage conditions. **Note:** This alarm can be caused by a transient condition, and may not be present when making the measurements.
Line over voltage 2	A	SOP	**Cause** The drive-input RMS voltage is greater than 115% of the drive rated input voltage. **Action** Refer to Line over voltage 1 section, above. Values >4.37 VRMS will trigger this alarm.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Line over voltage fault	F	SOP	**Cause** The drive-input RMS voltage is greater than 120% of the drive rated input voltage. **Action** Refer to Line over voltage 1 section, above. Values >4.56 VRMS will trigger an alarm or trip, depending on the SOP.
Medium voltage low 1	A	SOP	**Cause** The drive-input RMS voltage is less than 90% of the drive rated input voltage. **Action** Using a voltmeter, verify the input voltages on test points (**VIA/TP1, VIB/TP2, VIC/TP3**) of the System Interface board are ~3.8V RMS. This is the expected value for rated input voltage. Values less than ~3.4v RMS (90% of rated) will trigger Medium voltage low conditions. **Note:** This alarm can be caused by a transient condition, and may not be present when making the measurements.
Medium voltage low 2	A	Fixed	**Cause** The drive-input RMS voltage is less than 70% of the drive rated input voltage. **Action** Refer to Medium voltage low 1 section above. The threshold is 2.66 V.
Medium voltage low Flt	F	Fixed	**Cause** The drive-input RMS voltage is less than 55% of the drive rated input voltage. **Note:** The fault will not occur, even after the threshold condition is met, until the first cell fault occurs. This fault is then logged and associated cell faults are ignored. **Action** Refer to Medium voltage low 1 section, above. The threshold is 2.09 V.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
Input One Cycle (or excessive input reactive current)	F/A	Fixed	**Cause** (1) Possible fault on the secondary side of the transformer, or (2) inrush current is too high and creating a nuisance fault. **Action** (1) Remove medium voltage and visually inspect all the cells and their connections to the transformer secondary; contact Siemens LD A for field support. (2) Reduce the 1 Cyc Protect integ gain (7080) and the 1 Cycle Protect Limit (7081) to avoid nuisance trips.
Input Phase Imbal	F/A	SOP	**Cause** Drive input (line) current imbalance is greater than the setting in the Phase Imbalance Limit parameter (in Drive Protection Menu). **Action** 1. Verify proper symmetry of the input voltages and currents on test points **VIA/TP1, VIB/TP2, VIC/TP3, IIB/TP12** and **IIC/TP13**. 2. Check the values of the input attenuators. **Note:** During pre-charge, if so equipped, it is normal for phases to be imbalanced.
Motor/Output Related			
Over Speed Alarm	A	SOP	**Cause** The motor speed is greater than 95% of the Overspeed parameter setting (1170) in the Limits Menu (1120). An improperly set up or mis-tuned drive usually causes this fault. **Action** Verify that the motor and drive nameplate settings match the corresponding parameters in Motor Parameter Menu (1000) and Drive Parameter Menu (2000).
Over Speed Fault	F	Fixed	**Cause** The motor speed exceeds the Overspeed setting (1170) parameter in the Limits Menu (1120). An improperly set up or mis-tuned drive usually causes this fault. **Action** Verify that the motor and drive nameplate settings match the corresponding parameters in Motor Parameter Menu (1000) and Drive Parameter Menu (2000).

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Output Ground Fault	A	Fixed	**Cause** This fault is caused (due to an output ground fault condition) when the estimated ground voltage exceeds the Ground Fault Limit parameter (1245) in the Motor Limits Menu. **Action** 1. Verify proper symmetry of voltages on test points **VMA/TP5, VMB/TP6,** and **VMC/TP7**. If voltages are not a problem, check the divider resistors in the Motor Sense Unit or replace the System Interface Board. 2. Disconnect the motor from the VFD. Use a Megger to verify motor and cable insulation.
Encoder loss	Menu	Menu	**Cause** The software has detected an encoder signal loss due to a faulty encoder or faulty encoder interface. **Action** 1. Verify that the information in the Encoder menu (1280) is correct for the encoder being used. 2. Run the drive in Open Loop Vector Control mode (select OLVC in the Control loop type, ID 2050) of the Drive parameter menu (2000). 3. Go to Meter Menu (8). Select Display Parameters Menu (8000) and set one of the display parameters (8001-8004) to ERPM or %ESP, and observe if ERPM follows motor speed.
Mtr Therm Over Load 1	A	SOP	**Cause** Motor temperature (or motor current, depending on choice of overload method) above Overload pending setting. **Action** 1. Verify if the Overload pending parameter (1139) is set correctly. 2. Check load conditions and, if applicable, verify that the speed derate curve (submenu 1151) matches the load conditions.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Mtr Therm Over Load 2	A	SOP	**Cause** Motor temperature (or motor current, depending on choice of overload method) above Overload setting. **Action** Check if the Overload parameter (1140) is set correctly. Refer to Mtr Therm Over Load 1 section, above.
Mtr Therm Over Ld Fault	F	Fixed	**Cause** Motor temperature (or motor current, depending on choice of overload method) has exceeded the Overload setting for the time specified by the Overload timeout parameter. **Action** Check if the Overload timeout parameter (1150) is set correctly. Refer to Mtr Therm Over Load 1 section, above.
Motor Over Volt Alarm	A	SOP	**Cause** If motor voltage exceeds 90% of the Motor over voltage limit in the Motor limit menu. **Action** Check menu settings for correct motor rating and limit setting.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Motor Over Volt Fault	F	SOP	**Cause** The measured motor voltage exceeds the threshold set by the Motor trip volts (1160) parameter in the Limits Menu (1120). An improperly set up or tuned drive usually causes this fault. This could include the secondary tap setting. A high line condition can also cause this. **Actions** 1. Verify that the motor and drive nameplate settings match the corresponding parameters in Motor Parameter Menu (1000) and Drive Parameter Menu (2000). 2. Verify that the signals on the **VMA/TP5, VMB/TP6,** and **VMC/TP7** test points on the System Interface Board are operating properly within ±6V. If an incorrect voltage is noted, check the voltage divider in the Motor Sense Unit or replace the System Interface Board. 3. Also, check the tap settings on the transformer. The tap setting may have to be changed to accommodate a high input line.
IOC	F	Fixed	**Cause** Drive instantaneous over-current (IOC) faults usually result when the signal from test point IOC on the System Interface Board exceeds the level set by the Drive IOC setpoint (7110) parameter in the Input Protect Menu (7000). **Actions** 1. Verify that the motor current rating (1050) is below the Drive IOC setpoint (7110) in the Drive Protect Menu (7). 2. Check if the output current scalar (3440) is set to a number that is close to 1.0. 3. Verify that the signals on test points IMB and IMC on the System Interface Board match the percentage of full-scale signals.
Under Load Alarm	A	SOP	**Cause** The torque producing current of the drive has dropped below a preset value set by the user. **Actions** This alarm usually indicates a loss of load condition. If this is not the case, verify the settings in I underload menu (1182) within the Limits menu (1120).

Fault Display	Type	Enable	Potential Causes and Corrective Actions
Under Load Fault	F	Menu	**Cause** This fault usually indicates a loss of load condition when the torque producing current of the drive has dropped below a preset value set by the user for the specified amount of time. **Actions** If this is not an unexpected condition, then verify the setting of the I underload (1182) and the Under Load Timeout (1186) parameters within the Limits Menu (1120).
Output Phase Imbal	A	Fixed	**Cause** The software has detected an imbalance in the motor currents. **Action** Verify proper symmetry of the motor currents on test points **VMA/TP5, VMB/TP6, VMC/TP7, IMA/TP21, IMB/TP22,** and **IMC/TP23**. If the currents are unsymmetrical, verify if the burden resistors for the Hall Effect Transducers are connected correctly on the Signal Conditioning board.
Output Phase Open	A	SOP	**Cause** The software has detected an open phase condition at the drive output to the motor. Generally, if this occurs, the problem is with the feedback. A true open output phase will result in an IOC trip. **Action** 1. Verify all connections to the motor are secure. 2. Verify the presence of motor voltages and currents on test points **VMA/TP5, VMB/TP6, VMC/TP7, IMA/TP21, IMB/TP22,** and **IMC/TP23** during drive operation.
In Torque Limit	A	SOP	**Cause** This alarm is issued when the drive is in speed rollback (due to a torque limit condition) for more than one minute. **Action** 1. Check load conditions. 2. Check proper settings for drive and motor ratings.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
In Torq Limit Rollback	F/A	SOP	**Cause** This fault or alarm (depending on the SOP program) is issued when the drive is in speed rollback (due to a torque limit condition) for more than 30 minutes. **Action** 1. Check load conditions. 2. Check proper settings for drive and motor ratings.
Minimum Speed Trip	F/A	SOP	**Cause** Motor speed is below the Zero speed setting (2200). This is either due to a motor stall condition (if speed demand is higher than the Zero speed setting) or a low speed demand condition (where speed demand is lower than the Zero speed setting). **Action** Increase motor torque limit (ID 1190, 1210 or 1230) if it is a stall condition, or adjust the Zero speed setting to avoid the desired low speed operating region.
Loss of Field Current	F/A	SOP	**Cause** This occurs only with synchronous motor control due to field exciter failure or loss of power to the exciter. **Action** Check if the power supply to the exciter is energized To determine if the field exciter is operating correctly, reduce Flux demand (3150) to 0.40, increase Accel time 1 (2260) to a larger value, and run the motor with 5% speed demand. If the drive magnetizing current reference (Idsref) does not go to zero, then the field exciter is not working (or is not adjusted) properly.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Failed to magnetize	F/A	SOP	**Cause** This occurs only with induction motors due to high magnetizing current (or poor power factor). The trip occurs when I_{ds} (or magnetizing current) is greater than 80% of rated current for a duration greater than 5 times the flux Ramp Rate parameter setting. With induction motors, this trip should normally occur only when starting, either due to incorrect stator resistance (ID 1080) and cable resistance (ID 2940) settings (settings that are higher than actual value are not good), or due to the incorrect setup of the Spinning Load. Once the motor is magnetized and running, such an event is unlikely to occur. **Action** 1. Increase the flux ramp time to give more time for magnetizing current to settle down at startup. 2. Verify if the motor stator resistance parameter (1060) is not set too high for the application; reduce it if continuous operation at very low speed is not desired. Check that Spinning Load is set correctly. 3. Review procedure for adjusting the Spinning Load routine if necessary.
Back EMF Timeout	F	Fixed	The software timed out waiting for the Motor Back EMF Voltage to decay to a safe level for bypass or turn-on (drive enable). The safe voltage is the amount of voltage that the drive can support. The back EMF is the motor voltage when the drive is not active. If an induction machine has a long time constant, or if a synchronous machine has not disabled its field, and in either case the machine is spinning, the timeout threshold will cause a fault. This is also possible for parallel drives connected to a single motor.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
System Related			
Excessive Drive Losses	SOP	Fixed	**Cause** Estimated drive losses are too high due to (1) internal problem in the cells, or (2) scaling error in voltage and current measurement on input and output side. **Action** 1. Remove medium voltage and visually inspect all the cells and their connections to the transformer secondary. Contact the factory for support. 2. With the drive operating above a 25% power rating, verify if estimated drive efficiency is above 95%. If this is not the case, then voltage and current scaling needs to be checked.
Carrier Frq Set Too Low	A	Fixed	**Cause** The software detected that a menu entry for Carrier Frequency Menu (3580) was below the lowest possible setting, based on the system information. **Action** 1. Change the value entered in Carrier Frequency Menu (3580). 2. Check the value of the Installed Cells/phase Menu (2530). 3. Consult factory.
System Program	F	Fixed	**Cause** The software detected an error in the system program file. **Actions** 1. Reload system program. 2. Consult factory.
Menu Initialization	F	Fixed	**Cause** The software detected an error in one of the files stored on the CPU board Compact FLASH disk. **Action** Consult factory.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Config File Write Alarm	A	Fixed	**Cause** Occurs if the system is not able to write a master or slave config file. **Action** Consult factory.
Config File Read Error	F	Fixed	**Cause** Occurs if the system is not able to read data from a master of slave config file. **Action** Consult factory.
CPU Temperature Alarm	A	Fixed	**Cause** CPU Temperature is > 70 °C. **Action** 1. Check air flow and chassis fans. 2. Check CPU heatsink.
CPU Temperature Fault	F	Fixed	**Cause** CPU Temperature is > 85 °C. **Action** 1. Check air flow and chassis fans. 2. Check CPU heatsink.
A/D Hardware Alarm	A	Fixed	**Cause** A/D board indicated a hardware error. **Action** Replace A/D board.
A/D Hardware Fault	F	Fixed	**Cause** A/D board hardware error persists for more than 10 samples. **Action** Replace A/D board or System I/O board if installed.
Modulator related			
Modulator Configuration	F	Fixed	**Cause** The software detected a problem when attempting to initialize the Modulator. **Action** Replace Modulator board.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Modulator Board Fault	F	Fixed	**Cause** The software detected a Modulator board fault. **Action** Replace Modulator board.
Cell Fault/Modulator	F	Fixed	**Cause** Modulator has an undefined fault from a cell. Cell shows fault but the fault is undetectable. **Action** Check fiber links.Check cell, modulator board.
Bad Cell Data	F	Fixed	**Cause** Cell data packet mode bits incorrect. **Action** 1. Check fiber links - both ends. 2. Check cell control board and modulator board.
Cell Config. Fault	F	Fixed	**Cause** Modulator Cell configuration does not agree with Menu setting of installed cells. **Action** 1. Ensure correct number of cells are entered into menu setting. 2. Check modulator board. 3. Check that all fibers are connected.
Modulator Watchdog Flt	F	Fixed	**Cause** Modulator detected that the CPU stopped communicating with it. **Action** 1. Reset drive control power. 2. Check that all boards are seated properly. 3. Check for proper grounding practices.
Loss of Drive Enable	F	SOP	**Cause** Modulator detected loss of drive enable. **Action** 1. Reset drive control power. 2. Check for proper grounding practices.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Modulator Battery Low	A	Fixed	**Cause** The software detected a weak battery on the Modulator board. This battery is used to power the memory for the fault and historical logger. **Actions** 1. Replace battery on Modulator board. 2. Replace Modulator board. 3. Consult factory.
Low Voltage Power Supply Related			
Hall Effect Pwr Supply **Note:** NXG II has a single power supply.	F	Fixed	**Cause** One or both of the supplies that power the Hall Effects on the drive output has failed. **Actions** 1. Verify ±15V on the Hall Effect Power supplies. 2. Verify ±15V on the System Interface Board Connector P4 pins 31 and 32. If ±15V is not present, check wiring from Hall Effect Power Supplies to the System Interface Board. If these signals are incorrect, replace the System Interface Board.
Power Supply	F	Fixed	**Cause** The chassis power supply has indicated a loss of power. This can either be due to loss of AC or a failed power supply. **Action** Verify control power outputs.
System I/O Related			
Loss of Signal (1-24)	A	Menu/ SOP	**Cause** The software detected a Loss of Signal on one of the 0-20mA inputs (1 through 24). This is usually a result of an open circuit or defective driver on the current loop. **Actions** 1. Check connection to the Wago 0-2 0mA input corresponding to the Loss of signal message and associated wiring. 2. Replace affected Wago module. 3. Consult factory.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Wago Communication Alarm	A	Fixed	**Cause** The software was unable to establish or maintain communication with the Wago I/O system. The fault is triggered when the lack of communication exceeds timeout. **Actions** 1. Verify that the cable between the CPU board and Wago Communication alarm module is connected properly. 2. Replace Wago Communication module. 3. Replace the CPU board. 4. Consult factory.
Wago Communication Fault	F	SOP	**Cause** The software was unable to establish or maintain communication with the Wago I/O system. The alarm is triggered when the lack of communication exceeds timeout. **Actions** 1. Verify that the cable between the CPU board and Wago Communication alarm module is connected properly. 2. Replace Wago Communication module. 3. Replace the CPU board. 4. Consult factory.
Wago configuration	F	Fixed	**Cause** Number of Wago modules does not equal number set in menu. **Action** 1. Ensure correct number of Wago modules are set in the menu. 2. Check Wago modules and placement on the DIN rail.
External Serial Communications Related			
Tool communication	SOP	SOP	**Cause** Tool is not communicating to drive **Action** Check PC connecting cable, CPU BIOS settings, and that correct TCP/IP address agrees in Tool and Drive.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Keypad Comm Loss or Drive Not Communicating	SOP	SOP	**Cause** Drive is not communicating to keypad. **Action** 1. Check keypad cable, connections. 2. Check for CPU crash.
Network 1 Communication	SOP	SOP	**Cause** The drive is not communicating with the active external network. **Actions** 1. Verify all network connections are secure. 2. Verify that the UCS board #1 and Communications board are properly seated. 3. If the source of the problem is not found, then replace the UCS board #1 and then the Communications board.
Network 2 Communication	SOP	SOP	**Cause** The drive is not communicating with the active external network 2 **Actions** 1. Verify all network connections are secure. 2. Verify that the UCS board #2 and Communications board are properly seated. 3. If the source of the problem is not found, then replace the UCS board #2 and then the Communications board.
Synch Transfer Related			
Up Transfer Failed	A	SOP	**Cause** Time-out has occurred from request to up synch transfer complete. **Action** 1. Check input line for voltage and distortion. 2. Check status of InsufficientOutputVolts_O flag or the output voltage versus safe voltage to see if transfer is prohibited. 3. Increase menu setting, or set to zero to disable time out.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Down Transfer Failed	A	SOP	**Cause** Time-out has occurred from request to down synch transfer. **Action** 1. Check feedback voltage waveform. 2. Check status of InsufficientOutputVolts_O flag or the output voltage versus safe voltage to see if transfer is prohibited. 3. Increase menu setting, or set to zero to disable time out.
Phase Sequence	F/A	SOP	**Cause** Sign of input frequency and operating frequency are opposite. This will prohibit a transfer but is not fatal for normal operation. This fault needs to be enabled via the system program flags for transfer operations. **Action** Swap one pair of motor leads and change sign of speed command if needed.
User Defined Faults			
User Defined Fault (64)	F/A	SOP	**Cause** The *UserFault_1* through *UserFault_64* flags in the system program have been set to the value "true". Refer to **Chapter 8: System Programming**. These can be set up as either faults or alarms, and the message can be defined via the SOP. **Action** Refer to the section on User Faults (Section 7.5).

Fault Display	Type	Enable	Potential Causes and Corrective Actions
Cooling Related			
One Blower Not Avail	A	SOP	**Cause** Drive initiated alarm set when the OneBlowerLost_O SOP flag is set true and the alarm is enabled by setting OneBlowerLost_EN_O true. On an air cooled drive, when one of the cell blowers or transformer blowers is not functioning, this is triggered via the SOP. This is part of the Standard SOP for air cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check for faulty blowers or obstruction.
All Blowers Not Avail	F/A	SOP	**Cause** Drive initiated alarm or fault when AllBlowerLost_O SOP flag is set true and the alarm/fault is enabled by setting the AllBlowerLostEn_O flag true. This defaults to a fault with no way to change to a warning with this release. If an alarm is desired, then the flag AllBlowersLostWn_O must also be set true. This is triggered by the SOP when 2 of 3 cell banks or both transformer banks of blowers is not functioning. This is primarily used as a trip alarm preceding an over temperature trip, used on air cooled drives as part of the Standard SOP. **Action** 1. Check physical input connected to SOP flag. 2. Check for faulty blowers or obstruction.
Clogged Filters	F/A	SOP	**Cause** Drive initiated fault/alarm when the CloggedFilters_O SOP flag is set true and the CloggedFiltersEn_O flag is set true to enable it. The default is a fault. If you desire an alarm, then the flag CloggedFiltersWn_O must be set true. This is used to warn of reduced air flow when an air filter becomes clogged. This is not part of the Standard SOP. **Action** 1. Check physical input connected to SOP flag. 2. Change filter or check for obstruction.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
NOTE: On more recent drives, a separate PLC controls the cooling. If this is the case, refer to that documentation. The following faults will not occur within the drive if a separate cooling PLC is used.			
One Pump Not Available	A	SOP	**Cause** Drive initiated alarm when the OnePumpFailure_O SOP flag is set true and the OnePumpFailureEn_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used as an alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check for faulty pumps, tripped circuit breakers, or obstruction.
Both Pumps Not Available	F/A	SOP	**Cause** Drive initiated fault/alarm when the AllPumpsFailure_O SOP flag is set true and the AllPumpsFailureEn_O flag is true to enable it. The default is a fault, but it can be changed to an alarm by setting the AllPumpsFailureWn_O flag true. This is used as a trip alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check for faulty pumps, tripped circuit breakers, or obstruction.
Coolant Cond > 3 µS	A	SOP	**Cause** Drive initiated alarm when the CoolantConductivityAlarm_O SOP flag is set true and the CoolantConductivityAlarmEn_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used as an alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check conductivity level. 3. Check ionizer.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
Coolant Cond > 5 uS	F/A	SOP	**Cause** Drive initiated fault/alarm when the CoolantConductivityAlarm_O SOP flag is set true and the CoolantConductivityAlarmEn_O flag is true to enable it. The default is a fault, but it can be changed to an alarm by setting the CoolantConductivityAlarmWn_O flag true. This is used as a trip alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check conductivity level. 3. Check ionizer.
Coolant Inlet Temp > 60° C	F/A	SOP	**Cause** Drive initiated alarm when the InletWaterTempHigh_O SOP flag is set true and the InletWaterTempHighEn_O flag is true to enable it. The default is an alarm but it can be changed to a fault by setting the InletWaterTempHighWn_O flag to False (true is an alarm). This is used as an alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check coolant temperature. 3. Check for flow.
Coolant Inlet Temp < 22° C	F/A	SOP	**Cause** Drive initiated alarm when the InletWaterTempLow_O SOP flag is set true and the InletWaterTempLowEn_O flag is true to enable it. The default is an alarm but it can be changed to a fault by setting the InletWaterTempLowWn_O flag to False (true is an alarm). This is used as an alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check coolant temperature. 3. Check for flow.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Cell Water Temp High	F/A	SOP	**Cause** Drive initiated alarm when the CellWaterTempHigh_O SOP flag is set true and the CellWaterTempHighEn_O flag is true to enable it. The default is an alarm but it can be changed to a fault by setting the CellWaterTempHighWn_O flag to False (true is an alarm). This is used as an alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check coolant temperature. 3. Check for flow.
Coolant Tank Level < 30 inches	A	SOP	**Cause** Drive initiated alarm when the LowWaterLevelAlarm_O SOP flag is set true and the LowWaterLevelAlarmEn_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used as an alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check sensor. 3. Check and fill tank.
Coolant Tank Level < 20 inches	F/A	SOP	**Cause** Drive initiated fault/alarm when the LowWaterLevelFault_O SOP flag is set true and the LowWaterLevelFaultEn_O flag is true to enable it. The default is a fault, but it can be changed to an alarm by setting the LowWaterLevelFaultWn_O flag true. This is used as a trip alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check sensor. 3. Check and fill tank.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Low Coolant Flow < 60%	A	SOP	**Cause** Drive initiated alarm when the LowWaterFlowAlarm_O SOP flag is set true and the LowWaterFlowAlarmEn_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used as an alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check sensor.
Low Coolant Flow < 20%	F/A	SOP	**Cause** Drive initiated fault/alarm when the LowWaterFlowFault_O SOP flag is set true and the LowWaterFlowFaultEn_O flag is true to enable it. The default is a fault, but it can be changed to an alarm by setting the LowWaterFlowFaultWn_O flag true. This is used as a trip alarm in the Standard SOP for water-cooled drives. **Action** 1. Check physical input connected to SOP flag. 2. Check sensor.
Loss One HEX Fan **Note:** Hex fans are used on a water to air heat exchanger on water cooled drives.	A	SOP	**Cause** Drive initiated alarm when the LossOneHexFan_O SOP flag is set true and the LossOneHexFanEn_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used as an alarm in the Standard SOP for water-cooled drives. **Action** Check physical input connected to SOP flag. Check sensor. Check for faulty fan. Check for obstruction.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Loss All HEX Fans	F/A	SOP	**Cause** Drive initiated alarm/fault when the LossAllHexFan_O SOP flag is set true and the LossAllHexFanEn_O flag is true to enable it. The default is an alarm but it can be changed to a fault by setting the LossAllHexFanWn_O flag to False (true is an alarm). This is used in the Standard SOP for water-cooled drives as an alarm. **Action** 1. Check physical input connected to SOP flag. 2. Check sensor. 3. Check for faulty fan. 4. Check for obstruction.
All HEX Fans On	A	SOP	**Cause** Drive initiated alarm when the AllHexFansOn_O SOP flag is set true and the AllHexFansOnEn_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used in the Standard SOP for water-cooled drives as an alarm. **Action** 1. Check physical input connected to SOP flag. 2. Check sensor. 3. Check for faulty fan. 4. Check for obstruction.
Input Transformer Temperature Related			
Xformer OT Alarm	A	SOP	**Cause** Drive initiated alarm when the XformerOverTempAlarm1_O SOP flag is set true and the XformerOverTempAlarm1En_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used in the Standard SOP for water-cooled drives as an alarm. **Action** 1. Check physical input connected to SOP flag. 2. Check sensors. 3. Check blowers if air cooled – flow and water temperature if water-cooled.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Xformer OT Trip Alarm	A	SOP	**Cause** Drive initiated alarm when the XformerOverTempAlarm2_O SOP flag is set true and the XformerOverTempAlarm2En_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used in the Standard SOP for water-cooled drives as an alarm. **Action** 1. Check physical input connected to SOP flag. 2. Check sensors. 3. Check blowers if air cooled – flow and water temperature if water-cooled.
Xformer OT Fault	F/A	SOP	**Cause** Drive initiated fault/alarm when the XformerOverTempFault_O SOP flag is set true and the XformerOverTempFaultEn_O flag is true to enable it. The default is a fault, but it can be changed to an alarm by setting the XformerOverTempFaultWn_O flag true. This is used in the Standard SOP for water-cooled drives as a trip alarm. **Action** 1. Check physical input connected to SOP flag. 2. Check sensors. 3. Check blowers if air cooled – flow and water temperature if water-cooled.
Xfrm Cool OT Trip Alarm	A	SOP	**Cause** Drive initiated alarm/fault when the XformerWaterTempHigh_O SOP flag is set true and the XformerWaterTempHighEn_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used in the Standard SOP for water-cooled drive as an alarm. **Action** 1. Check physical input connected to SOP flag. 2. Check flow and water temperature.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Input Reactor Temperature Related			
Reactor OT Alarm	A	SOP	**Cause** Drive initiated alarm when the ReactorTemperature1_O SOP flag is set true and the ReactorTemperature1En_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used in the Standard SOP for water-cooled drives as an alarm. **Action** 1. Check output current waveform for sinusoidal shape. 2. Check sensor. 3. Check physical input connected to SOP flag.
Reactor OT Trip Alarm	A	SOP	**Cause** Drive initiated alarm when the ReactorTemperature2_O SOP flag is set true and the ReactorTemperature2En_O flag is true to enable it. The default is an alarm and it cannot be changed. This is used in the Standard SOP for water-cooled drives as an alarm. **Action** 1. Check output current waveform for sinusoidal shape. 2. Check sensor. 3. Check physical input connected to SOP flag.
Reactor OT Fault	F/A	SOP	**Cause** Drive initiated fault/alarm when the ReactorTemperatureFault_O SOP flag is set true and the ReactorTemperatureFaultEn_O flag is true to enable it. The default is a fault, but it can be changed to an alarm by setting the ReactorTemperatureFaultWn_O flag true. This is used in the Standard SOP for water-cooled drives as a trip alarm. **Action** 1. Check output current waveform for sinusoidal shape. 2. Check sensor. 3. Check physical input connected to SOP flag.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
Cell Bypass Related			
Cell Bypass Com Fail	F	Fixed	**Cause** The NXG Control system is not communicating with the MV Bypass board. **Action** 1. Verify the Fiber Optic connection between the Modulator board and MV Bypass board is intact. 2. Replace Modulator board. 3. Replace MV Bypass board.
Cell Bypass Acknowledge	F	Fixed	**Cause** The NXG Control issued a command to bypass a cell, but the MV bypass board did not return an acknowledgement. **Action** 1. Verify that the bypass contactor is working properly. 2. Check wiring between MV bypass board an contactor. 3. Replace MV bypass board or contactor.
Cell Bypass Link	F	Fixed	**Cause** The NXG Control system is not communicating with the MV Bypass board—i.e., the MV Bypass board is either not receiving commands, or is getting parity errors in the messages from the modulator boards. **Action** Refer to "Cell Bypass COM Fail" above.
Cell Bypass COM Alarm	A	Fixed	**Cause** The NXG Control system is not communicating with the MV Bypass board, but the bypass system is not in use. **Action** Refer to "Cell Bypass COM Fail" above.
Cell Bypass Link Alarm	A	Fixed	**Cause** The Modulator board is not communicating with the MV Bypass board, but the bypass system is not in use. **Action** Refer to "Cell Bypass COM Fail" above.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Cell Bypass Fault	F	Fixed	**Cause** The cell failed to go into bypass when commanded to do so. **Action** Check bypass system, contactor MV Bypass board, and Modulator board. Refer to "Cell Bypass COM Fail" above.
xx Bypass Verify Failed xx=cell that is faulted	F	Fixed	**Cause** Bypass contactor closure verify failed **Action** Check bypass system, contactor MV Bypass board, and Modulator board.
xx Bypass Ack Failed xx=cell that is faulted	F	Fixed	**Cause** Bypass contactor closure acknowledge failed. **Action** Check bypass system, contactor MV Bypass board, and Modulator board.
xx Bypass Avail Warning xx=cell that is faulted	A	Fixed	**Cause** Cell level bypass available alarm. Only if bypass is not used. **Action** Check bypass system, fiber optic cable, MV Bypass board, and supply.
Cell Related			
Cell Count Mismatch	F	Fixed	**Cause** The software detected a difference in the number of cells detected versus the Installed Cells/phase Menu (2530). **Action** 1. Verify that the Installed Cells/phase Menu (2530) matches the actual number of cells in the system. 2. Verify all fiber optic cable connections are correct. 3. Replace Modulator board. Replace Fiber Optic board(s).

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
Cell DC Bus Low	A	Fixed	**Cause** Cell DC bus below alarm level. This is set by the cell control board and comes back from the cell as /Vavail_ok flag. **Action** 1. Check for single phase input, low input line conditions, blown input fuses. 2. Check for a cell control board failure.

7.4 Cell Faults/Alarms

Cell originating faults/alarms are logged by the PC board following a power cell fault indication. These faults are available for inspection through the keypad display or can be uploaded to a PC via the serial port. All active cell faults/alarms are displayed on the keypad display. Use the arrow keys to scroll up and down through the faults. The Alarm/Fault log upload function (Parameter ID 6230) in the Alarm/Fault Log Menu (6210) can be used to upload the log to a PC for analysis, and for sending to the appropriate Siemens or plant personnel.

All cell faults are generated by circuitry located on the Cell Control Board (CCB) of each power cell and are received by the Microprocessor Board through circuitry on the Digital Modulator Board. Table 7-5 can be used as a quick troubleshooting guide to locate the cause of the fault condition. This table lists faults that may occur in all Perfect Harmony drives unless otherwise noted. All cell faults are initiated by the Cell Control Board or CCB located in each power cell.

Table 7-5: Cell Faults

Fault Display	Type	Enable	Potential Causes and Possible Corrective Actions
Power Fuse Blown	F	Fixed	**Cause** One or more of the input power fuses to a cell are open. **Action** Determine the reason for the fuse failure, then repair (if required), and replace the fuse.
xx Over Temp Warning xx=cell that has alarm	A	SOP	**Cause** Cell temperature is above the programmable alarm limit. Each cell sends a PWM signal to the Modulator Board. This signal represents the heat sink temperature. The temperature has exceeded the alarm level (20% duty cycle default setting). **Action** Check condition of the cooling system. Check motor load conditions.

Fault Display	Type	Enable	Potential Causes and Possible Corrective Actions
Over Temperature xx=cell that is faulted	F	Fixed	**Cause** Each cell sends a PWM signal to the Modulator Board. This signal represents the heat sink temperature. The temperature has exceeded the fixed fault level (80% duty cycle). **Action** 1. Check the condition of the cooling system. 2. Refer to the individual product manual for details.
xx Control Power	F	Fixed	**Cause** MV is okay, but control power to the cell is below an acceptable level. One or more of the control power fuses is blown and/or the DC bus is low possibly due to power fuses. **Action** 1. Check and replace blown cell control fuse or input power fuses. 2. Repair or replace the Cell Control Board.
xx IGBT OOS n (n=1,2,3,4)	F	Fixed	**Cause** Each Gate Driver Board includes circuits that verify that each IGBT has fully turned on. This fault may indicate a bad gate driver, an open IGBT, or a failure in the detection circuitry (i.e., logic low signals on opto-couplers on Gate Drive Board usually as a result of a $Q1$, $Q2$, $Q3$, or $Q4$ collector-to-emitter short in the cell's power bridge). **Action** Check the cell's power components and Gate Driver Board.
xx Cap Share	F	Fixed	**Cause** A capacitor share fault usually indicates that the voltage shared by the two or three DC link capacitors in series is not being shared equally (i.e., the voltage on an individual capacitor in a cell has been detected over 1/2 or 1/3 rated cell DC bus voltage). This can be caused by a broken bleeder resistor (or wire) or a failed DC link capacitor ($C1$ and/or $C2$). **Action** Refer to the individual product manual for details.

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Fault Display	Type	Enable	Potential Causes and Possible Corrective Actions
xx Link xx=cell that is faulted	F	Fixed	**Cause** Cell communication link failure—the cell failed to respond to a modulator command packet. **Action** 1. Check fiber optic cable connection on both ends. 2. Cell may need to be serviced. 3. Change out fiber optic cable or modulator board. 4. Change cell control board.
xx Communication	F	Fixed	**Cause** An error in the optical communications from the modulator was detected by a cell. This is usually a parity error caused by noise, but can also be a time-out error caused by a faulty communications channel on the Cell Control Board. **Action** Refer to the individual product manual for details.
xx Control Fuse Blown xx=cell that is faulted	F	Fixed	**Cause** Cell control power fuse blown. This is rarely seen since the cell control board has a dual source of power. **Action** Check cell fuses, replace if necessary.
xx DC Bus Low Warning xx=cell that has alarm	A	Fixed	**Cause** Cell DC bus is below alarm level. **Action** Check for single phase input, low input line conditions, blown input fuses.
Cell DC Bus Low	A	Fixed	**Cause** Cell DC bus below alarm level. This is set by the cell control board and comes back from the cell as /Vavail_ok internal flag ("CellBusLowFlag_I" SOP flag). **Action** Check for single phase input, low input line conditions, blown input fuses. Check for a cell control board failure.
xx DC Bus Over Volt	F	Fixed	**Cause** The bus voltage in a cell has been detected over limit (i.e., the signal on the V_{DC} test point is >8.0 VDC). This is usually caused by a regeneration limit that is too high, or improper tuning of the drive. **Action** Refer to the individual product manual for details.

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Fault Display	Type	Enable	Potential Causes and Possible Corrective Actions
xx DC Bus Under Volt	F	Fixed	**Cause** The DC bus voltage detected in a cell is abnormally low (the signal on test point VDC on the Cell Control Board is <3.5 VDC). If this symptom is reported by more than one cell, it is usually caused by a low primary voltage on the main transformer **T1**. **Action** 1. Check input line voltage. 2. Check for faults on other cells.

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The following cell faults will occur only during the cell diagnostic mode (immediately following initialization or reset). All IGBTs in each cell are sequentially gated and checked for proper operation (blocking/not blocking). See Table 7-6.

☞ | **Note:** Not every cell type has switching and blocking tests. Refer to the individual product manual for details.

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Table 7-6: Diagnostic Cell Faults

Fault Display	Type	Enable	Potential Causes and Possible Corrective Actions
xx Blocking Q*n* (*n* = 1,2,3,4)	F	Fixed	**Cause** During cell diagnostic mode, the Perfect Harmony checks the voltage across each IGBT under "gate off" conditions. A blocking failure is reported if insufficient voltage is detected when power transistors are gated. This may indicate a damaged IGBT, or a malfunctioning gate driver board or cell control board. **Action** Refer to the individual product manual for details.
xx Switching Q*n* (*n* = 1,2,3,4)	F	Fixed	**Cause** During cell diagnostic mode, the Perfect Harmony turns each IGBT on one-by-one, and verifies the collapse of voltage across the devices. A switching failure is reported if a device is supporting voltage while it is gated on (i.e., voltages on test points **VT1** and **VT2** on the Cell Control Board are > ±0.5 VDC when power transistors **Q1-Q4** are gated). Usually, this fault is caused by a malfunctioning gate driver board, IGBT, or cell control board. **Action** Refer to the individual product manual for details.
xx Blocking Timeout xx=cell that is faulted	F	Fixed	**Cause** Blocking Test timeout. A cell failed the blocking test. **Action** Check cell, or back EMF too high
xx Switching Timeout xx=cell that is faulted	F	Fixed	**Cause** Switching Test timeout. A device failed the switching test after successfully passing blocking. **Action** Check cell, or back EMF too high to run the test.

7.4.1   Troubleshooting General Cell and Power Circuitry Faults

This section is typical, but may vary with product. Refer to the individual product manual for more specific details.

The types of faults addressed in this section include the following:

- AC fuse(s) blown faults
- Control power faults
- Device out of saturation (OOS) faults
- Capacitor sharing faults
- Bypass failed faults
- VDC undervoltage faults
- Blocking failure faults
- Switching failure faults.

AC Fuse(s) Blown Faults

These faults are caused by the blowing of the power fuses on the front end of the cell. Check the fuses and replace any that are blown—more than one could be out. Replace defective or damaged parts.

Control Power Faults

This fault is caused when one or more of the control fuses that supply power to the CCB (Cell Control Board) are blown. This is rarely seen because the CCB is supplied by two circuits: the control power supply bridge and the DC link. If Control Power Fault is observed, the AC fuses might also be blown. Replace the defective or damaged parts.

Capacitor Sharing Faults

The Cell Capacitor bank is made up of from two to three series capacitor banks. Circuitry on the CCB measures the voltage on each section and if the voltages are off by any amount, the fault is set. This indicates that under load the capacitors are not sharing load evenly, and this could be the result of faulty capacitors or loose connections. Fix or replace damaged or defective components.

Q1-Q4 OOS (Out Of Saturation) Faults

Out of Saturation faults occur when the transistor junction is depleted of charge carriers, resulting in a higher junction resistance. This in turn creates a larger voltage drop and more losses in the transistor, which can lead to premature failure. The cause of the OOS can be a defective gate driver board or a high di/dt transition on the device. The gate board is designed with circuitry to detect the larger voltage drop when the device should be on, shutting down the device in a fault condition. The fault can also be caused by a defective CCB or noise on the CCB. The exact cause needs to be determined before pulling a power cell out of service.

Bypass Failed Faults

This fault results from the failure of a cell to go into bypass when faulted. The cause can be from a defective modulator board, bad link between the modulator and the MV bypass board, a defective MV bypass board or supply, or a defective bypass contactor. Find and replace the faulty components.

VDC Undervoltage Faults

The undervoltage fault occurs when the voltage drops below the threshold of the detection circuitry on the CCB. This can be the result of a low MV level coupled with a high current drainage by the load, or simply as an excessive load that may give a momentary dip in current. It can also occur if one of the AC power fuses fails under load. Check the cell fuses and check the historic log for line dips. Correct the problem before continuing operation. A faulty CCB could give a false indication as well. Replace defective or faulty parts.

Blocking Failure Faults

Blocking failures occur when IGBTs short due to perforation of their junction caused by excessive current (high current density). This may be a result of out of saturation conditions and frequent trips. The device will need to be replaced when the cell is removed for service. A defective gate driver may be the root cause. A faulty CCB or bad data from the CCB could give a faulty indication of this fault. Replace damaged or defective parts.

Switching Failure Faults

Switching failures occur when a device opens or fails to turn on. It could also be caused by a defective gate drive or a damaged device. Also, a defective CCB or modulator board could give a faulty indication. Replace defective parts.

7.4.2 Troubleshooting Cell Over Temperature Faults

Water Cooled

Cell Over Temperature faults are typically caused by problems in the cooling system. Use the following steps to troubleshoot this type of fault:

1. Check the cooling system for proper flows and temperatures.
2. Inspect cell cooling paths for kinked hoses or major leaks.
3. Be sure all Cell Cabinet manifold valves are fully open.
4. Check that the blowers are working properly.
5. Check ambient temperature. Verify that all cabinet doors are shut to ensure proper air flow.
6. Check for faulty RTD on cell or bad cell control board.

7.4.3 Troubleshooting Overvoltage Faults

This fault is usually caused by an improperly set-up or tuned drive. Use the following steps to troubleshoot this type of fault.

1. Verify that the motor and drive nameplate settings match parameters in the Motor Parameter Menu (1000) and Drive Parameter Menu (2000).
2. Reduce the regen torque limit parameters (1200, 1220, 1240) in the Limits Menu (1120).
3. Reduce Flux Regulator Proportional Gain (3110) and Flux Regulator Integral Gain (3120) parameters in the Flux Control Menu (3100).
4. If the failure is occurring in bypass mode, increase the Energy Saver Minimum Flux (3170) parameter in the Flux Control Menu (3100) to at least 50%.
5. If the measured signals (from the previous section) seem to be correct, change the Modulator board.

7.4.4 Troubleshooting Cell Communications and Link Faults

Faults of this variety can be the result of circuit failures on either the Digital Modulator Board or Cell Control Board.

1. Check fiber optic links—replace if defective.
2. Check or replace cell control board.
3. Reseat fiber optic board and modulator board. Replace if necessary.
4. If the fault indication persists after replacing the Digital Modulator Board, call the factory.

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7.4.5   Status Indicator Summaries for MV Mechanical Bypass Boards

The MV Mechanical Bypass Board includes 3 LEDs that provide complete status of the MV board. These LEDs are summarized in the following table.

☞   **Attention!** User faults and alarms are closely tied to the system program configuration and will be designated here generically as faults, although they can be programmed as alarms only. Refer to **Chapter 8: System Programming** for more information.

Table 7-7: MV Mechanical Bypass Board Status LEDs

LED Function	Color	Description
CommOK	Green	Indicates active communication link established with Modulator Board
Fault	Red	Indicates that a bypass fault is active
PwrOK	Green	This LED is hardware controlled and indicates that the 5 / 15 VDC supplies are in tolerance.

7.5 User Faults and Alarms

User faults occur due to conditions defined in the system program. User faults are displayed on the keypad in the form of user defined fault #n, where n equals 1 to 64. The faults can also be displayed using user-defined text strings. Most user-defined faults are written to respond to various signals from the Wago I/O, such as the analog input modules (through the use of comparators), as well as the digital input modules.

A copy of the system program is required to specifically define the origin of the fault. In the example program found in the **Chapter 8: System Programming**, the *UserFault_1* flag is used to display the event of a blower fault. Note that the *UserText1* string pointer is used to display the specific fault message. If this string pointer is not used, then the fault displayed would be "user defined fault #1."

7.6 Unexpected Output Conditions

In some cases, the Perfect Harmony VFD will revert to operating conditions which limit the amount of output current, output speed, or output voltage, but with no apparent fault condition displayed. The most usual causes of these conditions are described in the subsections that follow.

The keypad mode displays can sometimes be used to troubleshoot the cause of the output limitation. The modes are displayed in two lines at the left of the keypad display (see Figure 7-1):

```
First Line ──────►  MODE   DEMD   FREQ   RPM    ITOT

Second Line ─────►  HAND    70     70    1260    40
```
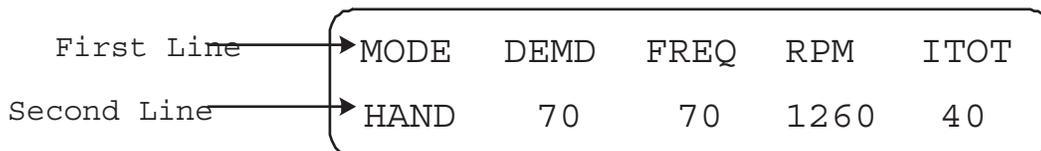
Figure 7-1: Keypad Mode Display

Tables 7-7 and 7-8 list the mode displays for the first and second lines, respectively. The first column of the tables lists the abbreviated message that is shown on the display of the drive. The second column lists descriptions of the operating modes. Further descriptions of possible limit situations and troubleshooting tips are listed in the subsections that follow.

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Table 7-7: Summary of Operation Mode Displays, Line1

Display	Description
FRST	Fault reset is active.
TLIM	Menu torque limit is active.
SPHS	A single phase on the MV input has occurred, drive limited.
UVLT	The drive is experiencing an input under-voltage torque limit.
T OL	The thermal overload is active, limiting drive torque.
F WK	Motor is operating in a field-weakened condition. Torque is limited but current is not.
C OL	A cell overload limit has been reached.
NET1	A torque limit from Network1 is active.
NET2	A torque limit from Network2 is active.
ALIM	A torque limit from analog input is active.
EALM	A torque limit from an external analog input is active.
ENLM	A torque limit from a network input is active.
EMLM	A torque limit from a menu setting is active.
RLBK	A torque limit is active and the speed demand input from the ramp has been rolled back.
RGEN	A motor is in regen mode—power dissipated in motor losses.
F WK	The motor is operating in a field—power dissipated in motor losses.
BRKG	The motor is in dual frequency braking mode.
BYPS	At least one cell is in bypass.
PRCH	Drive Precharge is active.
OLTM	Open loop test mode control algorithm used.
MODE	Default for display line 1 if no other conditions exist.

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Table 7-8: Mode of Operation Mode Displays, Line 2

Display	Description
NOMV	Medium voltage is off or there is no feedback.
INH	The drive is in an inhibit mode (CR3 signal is missing).
OFF	The drive is in the idle state—ready to run.
MAGN	The motor is being magnetized—no torque output.
SPIN	The drive is performing a spinning load catch of the motor (startup with motor turning).
UXFR	The drive is performing a synchronous transfer of the motor to the line.
DXFR	The drive is performing a synchronous transfer of the motor from the line.
KYPD	The drive is in the run state with speed command from the keypad.
TEST	The drive is in the speed test mode.
LOS	The drive is running with the primary speed reference signal lost.
NET1	The drive is running with the speed signal from Network1.
NET2	The drive is running with the speed signal from Network2.
AUTO	The SOP "AutoDisplayMode_0" flag is set to true—speed reference is usually from an analog signal selected by the SOP.
HAND	Default running mode—speed reference is selected by the SOP and "AutoDisplayMode_0" is set to false.
BRAK	The drive is in the stop state with dual frequency braking active.
DECL	The drive is in the ramp stop state—speed is ramping down.
COAS	The drive is in the coast stop state—drive output is forced off.
TUNE	The drive is in the auto-tune state—auto-tuning is active.

If the mode display shows RLBK (rollback mode), then the Perfect Harmony VFD is attempting to reduce the output speed due to a torque limit condition. Use the following steps to troubleshoot this type of fault:

1. Check the motor torque limit (1190, 1210, 1230) parameters in the Limits Menu (1120).

2. Check all motor and drive nameplate ratings against parameters set in the Motor Parameter Menu (1000) and the Drive Parameter Menu (2000).

> **Note:** Spare parts are available through our Customer Service Center by calling (724) 339-9501. Check product manual for parts identification.

7.7 Drive Input Protection

This section describes the routines used to detect abnormal conditions due to an internal drive failure and thus provide protection to the drive. The faults generated by the routines may be used with suitable interlocking, via a relay output and/or serial communication, to disconnect medium voltage from the drive input.

7.7.1   One Cycle Protection (or Excessive Input Reactive Current Detection)

NXG Control utilizes input reactive current to determine whether a 'hard' fault on the secondary side of the transformer has occurred. For example, a short-circuit in one of the secondary windings will result in poor power factor on the high-voltage side of the transformer. A model of the transformer based on the power factor at rated load (typically 0.95) is implemented in the control processor. The drive input reactive current is continuously checked with the predicted value from the model. An alarm/trip is generated if the actual reactive current exceeds the prediction by more than 10%. This check is avoided during the first 0.25 seconds after medium voltage power-up to avoid the inrush current from causing nuisance trips.

7.8 Excessive Drive Losses

The Excessive Drive Loss protection guards against low-level fault currents. Drive losses are calculated as the difference between the measured input and output powers, and compared against reference losses. The reference losses are fixed at 5.0% during "Idle" State and at 7.0% during "Run" State. When the calculated losses exceed the reference losses, a drive trip is issued and this condition is annunciated as an "Excessive Drive Loss Alarm." In addition to this response, a digital output is set low in the System Operating Program (SOP), which in the default drive configuration is used to open the input disconnect device. The fixed reference limit is low enough to detect a fault in one set of transformer windings, and at the same time is large enough to avoid nuisance trips. When the drive is not supplying power to the motor, the losses in the system are primarily due to the transformer; the fixed limit is then lowered to increase the sensitivity of the protection routine.

In earlier software versions up to version 2.22, the protection was such that when the calculated losses exceeded the reference losses for more than one second, a trip was generated. For software versions 2.30 and higher, an inverse power loss function is implemented for Excessive Drive Loss protection. The plot in Figure 7-2 shows the time to trip as a function of calculated losses for Liquid and Air Cooled Drives. The plot contains two curves, one of which is used when the Drive is in "Idle" State (i.e. medium voltage is applied, but the motor is not being operated) while the second curve (slightly longer time to trip) is used during the "Run" State.

Newer cells with the AP protocol may have additional cell-based input projection sensing. Please refer to the product manual for details.

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Excessive Drive Loss Protection
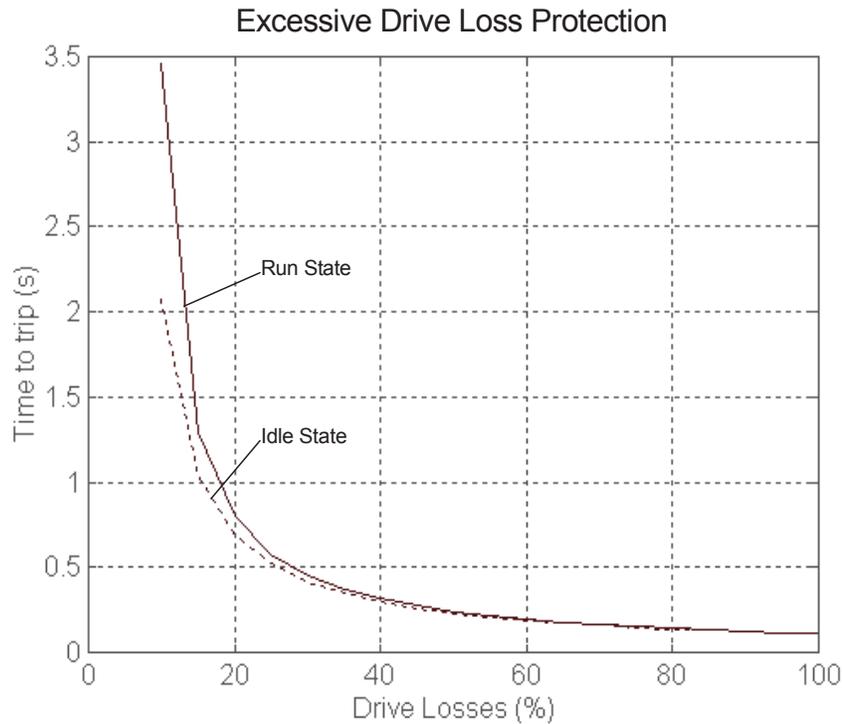
Figure 7-2: Excessive Drive Loss Protection

7.8.1   Transformer Over-Temperature and Loss of Cooling

The temperatures of all the secondary windings are monitored using two (series-connected) sets of (normally closed) thermal switches. The first set opens when the temperature exceeds 150°F (or 65°C) while the second set opens above 180°F (or 82°C). Two outputs, one output corresponding to each set, are read through the WAGO by the control logic. A Xfrmr Temperature Alarm 1 is issued when one or more 150°F switches open, and a Xfrmr Temperature Alarm 2 is issued when one or more 180°F switches open. When both these conditions exist for 30 seconds, a Xfrmr Over Temp Fault is generated that causes the drive to trip.

A vortex flow sensor monitors liquid coolant flow through the Water Cooled Drive. This sensor is connected to a display unit on the door of the Coolant Section, which displays flow rate, among other parameters, and outputs a 4-20 mA signal to the WAGO. A software comparator, interacting with the control logic, monitors this 4-20 mA signal. As a standard default, the alarm "Loss of Coolant Flow" is issued whenever the detected flow rate is below 40 percent of rated for 7 seconds.

The SOP program can be used to trip the input Medium Voltage Breaker when the conditions of Xfrmr Temperature Alarm 1, Xfrmr Temperature Alarm 2, and Loss of Coolant Flow exist simultaneously.

7.9 Flash Disk Corruption

While copying files to the flash disk from Windows, an incomplete write function can corrupt the flash disk contents without any visible warnings.

To avoid this corruption:

1. When the copy function is complete, right-click on the drive letter representing the flash disk.

2. Select the Eject option from the pop-up menu.

This forces Windows to flush the write cache and complete the write to the flash disk.

If you are going to disconnect the flash disk, wait a few seconds after selecting the Eject command before you disconnect the flash disk.

It is advisable to utilize the Configuration Update Tool (refer to the *ToolSuite Manual,* 902291), to update drive software or to copy or clone drive settings. Proper utilization of this tool can help prevent corruption of the flash media.

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8   System Programming

8.1 Introduction

Siemens Perfect Harmony series of Medium Voltage (MV) Pulse Width Modulated (PWM), Variable Frequency Drives (VFD) contain customized programmable logic functions that define many features and capabilities of the drives. These logic functions are combined into a system program (SOP) that can be edited either at the factory or in the field. Examples of logic functions include start/stop control logic, input and output control logic (e.g., annunciators, interlocks, etc.), drive-to-machinery coordination, and more). The system program is stored on the drive's flash disk. Upon power-up, it is executed continuously by the drive's run-time software in a repetitive fashion, causing the intended logic statements to perform their functionality.

To fully understand the system program operation, it is necessary to look at various aspects of the System program and its purpose. To determine the details of designing and creating a System program, refer to the SOP utilities in the *ToolSuite Manual* (902291) and the associated sections on Ladder Logic and Boolean Identities.

8.2 System Program Terminology

To understand system programs, it is helpful to understand the process by which these programs are created, edited, translated, and transferred to the drive. These processes use certain terms, which are summarized below:

Source file - the ASCII text file containing the logic statements and I/O assignments performing the desired operations for the drive.

Compilation - the operation performed on the source file, by the SOP Utilities, to convert the textual file into a machine readable file format. Compilation strips the comments from the file and sorts the true and false statements to the top of the file. The source file can optionally be attached for retrieval of complete source information.

Hex file - the downloadable file resulting from the compile process. It can optionally contain the entire source file for complete recovery of the source, including comments.

Reverse compilation - either of two methods to convert an uploaded hex file from a system back into an ASCII text source file for reading and/or editing. If the source file is attached to the hex file, the reverse compilation process simply extracts the text. If it is not attached, then the process must reconstruct the source for the internal data structures, producing a correct source file, but with all comments removed.

Text editor - a program used to edit or create the source file. A normal word processor can be used provided that no formatting characters are embedded, or the file is saved as pure ASCII printable characters. The SOP Utilities by default uses Windows Notepad for the text editor.

Upload/Download - communications between the drive and the host PC for transferring files from the drive (upload) or to the drive (download). If the SOP Utilities tool is used, then the transfer is through an RS232 cable connected to the drive's serial communications port. Alternately, the Drive Tool can also be used. Please refer to the *ToolSuite Manual* (902291).

System Interpreter - the program internal to the drive firmware that reads and acts upon the machine readable code produced by the SOP Utilities. This program runs at the lowest scheduled multitasking level of the drive controls, and time-shares system resources with other non-critical operations, and is therefore dependant on system loading for cycle time. This means that the system program running on the drive runs in a non-deterministic fashion, much the same as a standard Programmable logic controller.

8.3 SOP Development Process

The Siemens LD A SOP Development Process for the NXG control is detailed in Controlled document EPI-001.

The general process consists of:

The textual description is created in the SOP text templates. The templates are a series of spreadsheets that textually define the TB2 designation, the WAGO assignment, the sequence of operation, etc. Templates are available for both air-cooled and water-cooled systems.

The standard logic diagrams and accompanying SOP function blocks are defined in Engineering Reports referred to as Standard SOP Templates. The Engineering Report provides a standard means to produce customer SOPs. The function blocks are used as a starting point to ensure standardized I/O assignment and algorithmic functionality. They can serve as a template for customer requests not specifically addressed by the blocks.

☞ **Note:** It is imperative that protection blocks be used as designed and the impact of altering these critical protections noted. Failure to follow protections as outlined in these critical blocks can result in damage to the drive and the voidance of system warrantee.

The SOP is first designed as a ladder diagram to work out any logic issues. Then, utilizing the direct correlation between ladder logic and Sum-of-Products notation, the source file is written. Working out the logic in ladder format before committing to text, reveals potential timing conflicts and perfects system flow.

The SOP input source file is composed in an ASCII text editor and compiled by SOP Utilities compiler. SOP testing is performed at the Siemens LD A facility.

For further details concerning the use of the SOP Utilities Tool, refer to the ToolSuite Manual (902291).

8.4 SOP Interpretation

System configuration and operational logic is depicted in the command generator diagram (Siemens drawing A5E01219450A) which displays (in a diagram format) the various input options, parameter sets, and modes of operation of the drive. All logic flags controlling the configuration and control flags used in the state transitions are shown, along with many internal variable names.

The SOP file is written by application engineering (and can be modified by factory-trained personnel), compiled to a tokenized, Intel hex formatted file, and then downloaded via an RS-232-C serial channel or via Ethernet by the Drive Tool to the drive. The drive initializes the file, and then begins to interpret the token codes and data structures. This is detailed in the next section.

The operation of the interpreter is repetitive, evaluating in the following order from start to finish. Then the process is repeated again. This goes on indefinitely, with each complete cycle referred to as a scan cycle, or the scan time of the system program.

The order of evaluation follows these steps:

1. Read and map all external inputs to internal flags.
2. Update Active front end variables used by comparators (AFE only).
3. Run the active comparator functions, setting the comparator internal flags accordingly.
4. Evaluate the SOP active config file flags, and process accordingly.
5. Run the input scan cycle. This maps all input flags to their associated logic table locations.
6. Evaluate the logic functions of the SOP statements.
7. Run the output scan cycle. This maps the logic table locations to output internal flags.
8. Run any cleanup and initialization, or reset functions associated with the changed logic.
9. Map and write all output flags to external discrete outputs.

10. Change context of updated logic en masse, to prevent partial changes.

11. When context is changed, repeat process evaluation. This is one complete scan cycle.

8.5 SOP Timing and Evaluation

The time to perform a scan cycle for running the compiled program is dependent on the length and complexity of the program and the available time left over from the control software. The control software timing includes any features that are running (based on the configuration information flags in the system program itself). The scan time for a simple drive configuration and usage is typically between 20 and 50 msec. This time is not guaranteed and can become much longer when the program is long and complicated and enables many drive features. As mentioned earlier, the timing is non-deterministic and can vary from cycle to cycle.

Evaluation of logic statements occur in a top to bottom, left to right manner as written in the source file. The only exception is the simple statements in which the output variable (flag) is set either true or false. These statements are evaluated once only at the initialization of the system program which occurs on power-up, or when a new system program is either downloaded or selected.

Once an output variable is set to either true or false, it is immediately available as an input in that logic state to any subsequent logic statements within the context of the logic tables. Also there is no limitation to how many times an output variable may change logic states within the context of the program. However, only the final evaluation is output to any assigned output flags or external I/O.

8.6 Statement (SOP) Format

The format for a system program source statement is as follows:

output_symbol = {unary_operator} input_symbol { [binary_operator {unary_operator} input_symbol] ... };

where:

output_symbol represents an output symbol defined in the symbol

directory file =the assignment operator (only one per source statement)

input_symbol represents an input symbol defined in the symbol

directory file unary_operator Boolean NOT operator (/ character)

binary_operator Boolean operators OR and AND (+ and *, respectively)

{ }represents optional syntax

[ ] represents required syntax

... the previous operation may be repeated

; statement terminator

The statement can span multiple lines and can contain spaces as needed for readability. The output_symbol is a required field, and can be any symbol that would be valid as an output variable. The output_symbol is followed by one or more optional spaces, and then the required single assignment operator.

The input side of the equation must equate to a simple Boolean form (either true or false) after evaluation. It is formed from either a simple input symbol (possibly negated with a NOT unary operator) or a combination of input symbols operated with binary operators.

8.7 Input Flags

Input flags are identified by variable_I. Input flags are symbols that are encountered on the right hand side of a source statement (to the right of the equals sign) that express the state of an input to the system. They may reflect the state of a digital input (e.g., ExternalDigitalInput01a_O, ExternalDigitalInput01b_O) or switch (e.g.,

KeypadManualStart_O), the state of a system process (e.g., Cells_I, OverloadFault_I, OutputPhaseOpen_I), internal variable, Comparator flag (e.g., Comparator_1), or a simple literal (TRUE, FALSE). These input flags are combined using the unary and binary operators to form logic expressions.

Digital input flags generally represent the state of a discrete digital input signal into the system. These may be a 24-volt logic input, a key switch or push-button in the system, or some form of a binary input. The inputs are scanned at the beginning of each execution cycle, but may reflect older information in some cases.

System constants TRUE and FALSE are predefined and can be used as input terms to an expression.

8.8 Output Flags

The output flags all have "_O" tagged onto the end of the variable name (variable_O). The output flags (the symbol placed on the left-hand side of the assignment "=" operator) direct the result of the input expression towards an output purpose. Output flags represent items such as digital outputs and system control switches.

Digital output flags generally represent some form of discrete digital output bit(s) from the system. These may be a relay coil driving contacts (NO or NC), direct digital outputs, or lamp controls. The digital output signals are updated at the completion of each system program execution loop.

The Perfect Harmony series of drives has a set of pre-defined symbols that describe control outputs or "switches" that can be controlled by the system program. These switches can control functions such as the source of the speed reference, a selection for the system acceleration rate, and a multitude of others. In most cases, to cause the system to perform in the intended manner, the proper control switches must be set (and others cleared) by the system program.

8.9 Timers

Some logic functions require a timing delay, or it becomes necessary to debounce a noisy input. The timer function provides this capability. The timer is defined similarly to an output flag in that the definition of the timer is to the left of the equals sign, followed by the logic that enables the timer. Also following the timer name in parentheses is the time in seconds for the timer. The range for an individual timer is approximately 16,300 sec with a resolution of 0.5 seconds.

When the right side of the timer, the timer enable, evaluates true, the timer begins to timeout. If the enable evaluates to false, the timer resets to zero. There is an output flag associated with each timer. Once the timer times out, and the enable stays true, the output flag (the timer name without the parentheses) becomes true, and can be used as an input flag in any following logic statement.

☞   **Note:** A timer must be defined first before its logic flag can be used as an input to any logic statement.

The time duration can be extended by cascading timers with additional timers or counters. The time associated with the timer is fixed in the source file, which must be edited and recompiled to change the duration.

There are a total of 64 internal timers within the SOP logic directory, labeled "Timer00" to "Timer63" respectively.

8.10 Menu Timers

For increased resolution and flexibility, Menu based timers are incorporated to work with the system programs. The enable is assigned to an output flag ("MenuTimerxEnable_O" where 'x' is the number of the timer from 1 to 16), and the timeout logic flag of the timer is also defined as an input flag ("MenuTimerxOutput_I"). These 16 timers are found in "Menu based Timer setup" menu ID 9111, and are labeled "MenuTimer1" through "MenuTimer16" (ID 9112 through 9128 respectively).

These timers have a range of from 0 to 39 seconds, with one decimal point of resolution. They tend to be more accurate than the associated SOP integrated timers, due to the increase in resolution.

There are no order placement restrictions on the use of the enable and timeout flags of these timers, and the time can be changed without having to recompile the system program. These should be used judiciously, since they are limited in number.

8.11 Counters

Counters are very similar to internal timers, in that there are 64 of them ("Counter00" to "Counter63"), and they are defined and used in a similar manner. There are two main distinctions though. A counter counts the number of low to high transitions of its enable logic, and must be reset explicitly in contrast to the implicit reset of the timer. A further difference is that the time base in the parentheses must be an integer, and the range is 32,767. The timeout flag (the counter name without parentheses) is set whenever the counts of low to high transitions of its enable reach or exceed the predetermined count.

The discrete reset flag for the counter has a name in the form of "CounterResetxx" in which the 'xx' corresponds to the associated counter, and is used in the output side of a logic statement. The reset is activated whenever the input to the flag evaluates to true.

The counter has the same restriction in usage as the timer, in that it must be defined before the timeout flag can be used. This is also true of the reset flag - it must not appear in any logic statement prior to definition of the counter.

8.12 Comparators

Sometimes a simple digital input is not enough to adequately control a system function, or establish a warning or protection scheme. Analog signals from various transducers may need to be monitored and compared to set thresholds to allow conditions to change. This is the purpose of the comparator functions. Any signal fed into the drive through an analog input, externally or internally, can be mapped to a system flag to use in any logic statement.

These comparators exist in Comparator *n* Setup Submenus (4810-4965) under the Comparator Setup Submenu (4800) in the Auto Menu (4). There are 32 comparators with individual setup menus. Each comparator has an 'A' and a 'B' input and a control setting. These are set up by selecting from a pick list - a scrollable listing that allows the selection of predetermined variables, or entry of variable addresses (only in RAM), or a fixed percentage of rated value or a fixed number entered in hexadecimal (the base 16 numbering system as opposed to decimal, which is base 10).

The comparators have a system program flag associated with each (*Comparator01_I* through *Comparator32_I*) that are controlled by the comparator functions. In essence, the logical state of the comparator flags (TRUE or FALSE) is determined by the equation: *Comparatorxx_I* = (A > B), which means that if input A is greater than input B, the flag is set true, and if A is less than or equal to B, the flag is set false.

The rest of the setup is accomplished by setting the control variable. This also is a pick list, but consists of the selections: signed, magnitude, and off or disabled. When the comparator is switched off, no further processing is done and the system flag retains its last value indefinitely. The flags (as are all system flags) are initialized to false on power-up, system program re-initialization, or hard reset.

8.13 Analog Inputs

Sometimes you may want to use an external analog signal as an input to a comparator. This can be accomplished by selecting an analog input source in the pick list. However, the analog input needs to be set up properly before it has any meaning to the system program comparator functions.

When the system program scans the comparators, the last analog sample is used. The analog inputs have a 12-bit resolution, which means that 12 bits are used to determine the sign and magnitude of the signal. Therefore, the voltage resolution for each step is approximately 5 mV.

To use the external or internal analog input modules as a reference to the drive, they need to be set up using the Analog inputs menu (4090). The sequential number used in Analog input #1 source (4105), or Analog input #2 source (4175) menu of the external analog inputs is determined by left to right orientation arrangement of the modules as they are placed on the DIN rail. The leftmost analog input module is the first input. It contains two ports, so analog

inputs one and two are within this module. Reading left to right, the second module contains the next two analog inputs. This module also contains two ports, so they are numbered three and four and so on. The remaining menus are filled in as required.

8.14 Software Tools

The tools for creating, modifying, uploading and downloading, and general maintenance of the SOP are contained in the Siemens ToolSuite of tools. Refer to ToolSuite Manual for more details in its use. The entire compilation of the SOP can be summarized in the following diagram (see Figure 8-1).
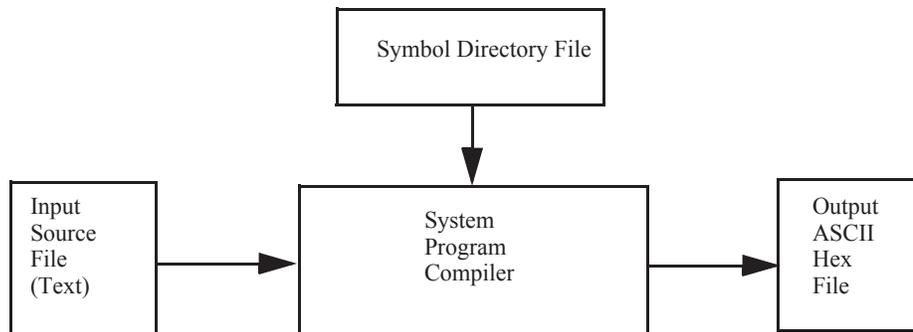
Figure 8-1: Block Diagram of the Compile Process

8.15 Downloading The SOP

The system program must be downloaded to the drive to be of any use. There are two means to download the program: through a serial RS-232 connection, or through an Ethernet connection.

The Serial connection requires the use of a serial communications program. Any Windows-based program will do, but one is included in the SOP Utilities. The drive must be set up to receive the new system program via the communication menu "SOP & serial functions" (ID 9110). With the drive connected to the PC running the communications program via a properly configured cable, start the download process by selecting the function "System program download" (9120). Once set to receive, start the transfer from the PC program. If using the SOP Utilities, refer to the *ToolSuite Manual* for details. Once the program is downloaded, it becomes the current active System program.

The Ethernet connection requires the use of the Drive Tool to download the program. The advantage is that nothing has to be set up through the drive menu, and it can be handled directly from the PC. Once downloaded, the file becomes the active System program. See the *ToolSuite Manual* for more details in using this tool.

8.16 Uploading The SOP

Sometimes the need arises to view and/or modify the installed SOP file. This can be done by communications from the drive to an external PC, and is known as Uploading. This has two options - the serial communications port or the Ethernet port.

With the serial connection, a serial communications program is required - one that can capture and save the uploaded information in a file on the PC. The SOP Utilities provides this functionality. The procedure to upload and save the file is done in two parts, similar to the download process. Set the PC software up to receive and save a file, then initiate the transfer with parameter "System program upload" (ID 9130) in the "SOP & serial Functions" menu (ID 9110).

To upload using the Ethernet connection, use the Drive Tool and select the Upload System Program function from the Configuration menu, once the connection with the drive is established. See the *ToolSuite Manual* for more details.

8.17 Reverse Compilation

It sometimes becomes important to view the system program installed on the drive to troubleshoot or check functionality of the system. The reverse compiler function of the SOP Utilities allows the user to extract the text from the uploaded System Program file. Best results are achieved if the compiled hex file was created with embedded source code. This preserves the comments and any substituted variable names. However, a functional source file can be obtained even if this option were not used. The logic statements are recovered but comments are not.

The result is a text file with a ".dis" extension. This file should be edited or viewed to ensure that it can be recompiled. Warning and error messages must be removed before the compiler can be used on the file. The edited file should be renamed with a distinct name and the extension changed to ".sop," although the extension change is optional. See the SOP Utilities section of the *ToolSuite Manual* for more details.

8.18 Multiple Configuration Files

The NXG control allows for the use of up to 8 separate configuration files. These files contain most, but not all of the parameters of the drive. The purpose is to use the drive with up to 8 separate different motors. All motor parameters, and most loop tuning parameters, are contained in these files. They are stored on the flash card in a sub-folder (SubCfgs), under the configuration folder (CfgFiles), as a slave file with an ".sfg" extension.

To use the multiple configuration files, the menu parameter "Multiple config files" (ID 9185) in the "SOP & serial functions" menu must be enabled (the default is off). The means for creating and programming the slave files are detailed in Chapter 4. This is done via the "Setup SOP config flags" menu (ID 9186). The slave files can be created and assigned to the SOP variables via the menu items here.

Once the files are created and enabled, they are selected via the eight System program flags "SopConfigFile1_O" through "SopConfigFile8_O" in the logic of the SOP file. Ensure that only one valid flag is set true at a time within the System program. Also note that these cannot be switched while the drive is running. Doing so could cause instability and a trip.

Since the configuration files can also be changed via the menu, there is a potential conflict that could arise between whether the menu or the SOP selected file is to be used. If the menu is used to override the SOP selection, then the menu selection becomes the active configuration. This will remain in effect until the SOP changes the configuration file to be different from the menu selection.

8.19 Selecting the Active System Program

One additional feature is the ability to have multiple system programs stored on the Flash card. This is important for factory test or commissioning - to have a System program that allows the drive to be run with minimal external connections - to turn the motor, to check no-load voltage waveforms, etc.

To select a different active system program, the drive must not be running. The parameter "Select system program" (ID 9145) is used to select from a picklist from all available System programs. To determine which system program is currently selected, the "Display sys prog name" (ID 9140) function is used. Both are found under the "SOP & serial functions" menu (ID 9110).

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A   Glossary

This appendix contains definitions of terms and abbreviations used throughout the Perfect Harmony series manuals.

AND - AND is a logical Boolean function whose output is true if all of the inputs are true in SOP notation, AND is represented as "∗" (e.g., C=A∗B), although sometimes it may be omitted between operands with the AND operation being implied (e.g., C=AB).

ASCII - ASCII is an acronym for American Standard Code for Information Interchange, a set of 8-bit computer codes used for the representation of text.

Baud rate - Baud rate is a measure of the switching speed of a line, representing the number of changes of state of the line per second. The baud rate of the serial port of the Perfect Harmony is selected through the Baud Rate parameter in the Communications Menu [9].

Bit - Bit is an acronym for BInary digiT. Typically, bits are used to indicate either a true (1) or false (0) state within the drive's programming.

Boolean algebra - A form of mathematical rules developed by the mathematician George Boole used in the design of digital and logic systems.

Carrier frequency - Carrier frequency is the set switching frequency of the power devices (IGBTs) in the power section of each cell. The carrier frequency is measured in cycles per second (Hz).

"Catch a spinning load" feature - "Catch a spinning load" is a feature that can be used with high-inertia loads (e.g., fans), in which the drive may attempt to turn on while the motor is already turning. This feature can be enabled via the NXG menu system.

CLVC - An acronym for Closed Loop Vector Control - which is one of six control modes in the NXG drive. This is flux vector control for an induction machine (IM), utilizing an encoder for speed feedback.

CMP - Refer to the glossary term **SOP**.

Comparator - A comparator is a device that compares two quantities and determines their equality. The comparator submenus allow the programmer to specify two variables to be compared. The results of the custom comparison operations can be used in the system program.

Configuration Update - see ToolSuite definition.

Converter - The converter is the component of the drive that changes AC voltage to DC voltage.

Critical speed avoidance - Critical speed avoidance is a feature that allows the operator to program up to 3 mechanical system frequencies that the drive will "skip over" during its operation.

CSMC - An acronym for Closed Loop Synchronous Machine (SM) Control. One of six control modes of the NXG drive. This is a flux vector control for a synchronous machine, utilizing an encoder for speed feedback and providing a field excitation command for use by an external field exciter.

Debug Tool - see ToolSuite definition.

DC link - The DC link is a large capacitor bank between the converter and inverter section of the drive. The DC link, along with the converter, establishes the voltage source for the inverter.

De Morgan's Theorem - The duality principal of Boolean algebra used to convert system logic equations into sum-of-products notation.

Downloading - Downloading is a process by which information is transmitted from a remote device (such as a PC) to the drive. The term "downloading" implies the transmission of an entire file of information (e.g., the system program)

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rather than continued interactive communications between the two devices. The use of a PC for downloading requires special serial communications software to be available on the PC, which may link to the drive via RS232 or through the Host Simulator via an ethernet connection.

DRCTRY - Directory file for system tokens and flags used in the compilation of system programs. It provides a direct lookup table of ASCII names to internal ID numbers. It also identifies whether the flag is a word or bit-field, and also whether it can be used as an input or output only, or can be used for both.

Drive - The term "drive" refers to the power conversion equipment that converts utility power into power for a motor in a controlled manner.

ELV - ELV is an acronym for extra low voltage, and represents any voltage not exceeding a limit that is generally accepted to be 50 VAC and 120 VDC (ripple free).

EMC - EMC is an acronym for electromagnetic compatibility–the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

ESD - ESD is an acronym for electrostatic discharge. ESD is an undesirable electrical side effect that occurs when static charges build up on a surface and are discharged to another. When printed circuit boards are involved, impaired operation and component damage are possible side effects due to the static-sensitive nature of the PC board components. These side effects may manifest themselves as intermittent problems or total component failures. It is important to recognize that these effects are cumulative and may not be obvious.

Fault log - Fault messages are saved to memory so that the operator may view them at a later time. This memory location is called the fault log. The fault log lists both fault and alarm messages, the date and time that they occurred, and the time and date that they are reset.

Faults - Faults are error conditions that have occurred in the Perfect Harmony system. The severity of faults vary. Likewise, the *treatment* or corrective action for a fault may vary from changing a parameter value to replacing a hardware component such as a fuse.

Flash Card - Non-volatile memory storage device for the NXG control. It stores the drive program, system program, logs, parameters, and other related drive files.

FPGA - Field Programmable Gate Array. An FPGA is an integrated circuit that contains thousands of logic gates.

Function - A function is one of four components found in the Perfect Harmony menu system. Functions are built-in programs that perform specific tasks. Examples of functions include System Program Upload/Download and Display System Program Name.

Harmonics - Harmonics are undesirable AC currents or voltages at integer multiples of the fundamental frequency. The fundamental frequency is the lowest frequency in the wave form (generally the repetition frequency). Harmonics are present in any non-sinusoidal wave form and cannot transfer power on average.

Harmonics arise from non-linear loads in which current is not strictly proportional to voltage. Linear loads like resistors, capacitors, and inductors do not produce harmonics. However, non-linear devices such as diodes and silicon controlled rectifiers (SCRs) do generate harmonic currents. Harmonics are also found in uninterruptable power supplies (UPSs), rectifiers, transformers, ballasts, welders, arc furnaces, and personal computers.

Hexadecimal digits - Hexadecimal (or "hex") digits are the "numerals" used to represent numbers in the base 16 (hex) number system. Unlike the more familiar decimal system, which uses the numerals 0 through 9 to make numbers in powers of 10, the base 16 number system uses the numerals 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F to make numbers in powers of 16.

Historic log - The historic log is a troubleshooting/diagnostic tool of the Perfect Harmony NXG control. The historic log continuously logs drive status, including the drive state, internal fault words, and multiple user-selectable variables. This information is sampled every slow loop cycle of the NXG control (typically 450 to 900 times per second). If a fault occurs, the log is frozen a predefined number of samples after the fault event, and data samples prior to and after the fault condition are recorded to allow post-fault analysis. The number of samples recorded are user-selectable via the NXG control, as well as the option to record the historic log within the VFD event log.

Host Simulator - see ToolSuite definition.

I/O - I/O is an acronym for input/output. I/O refers to any and all inputs and outputs connected to a computer system. Both inputs and outputs can be classified as analog (e.g., input power, drive output, meter outputs, etc.) or digital (e.g., contact closures or switch inputs, relay outputs, etc.).

IGBT - IGBT is an acronym for Insulated Gate Bipolar Transistors. IGBTs are semiconductors that are used in the Perfect Harmony drives to provide reliable, high-speed switching, high-power capabilities, improved control accuracy, and reduced motor noise.

Induction motor - An induction motor is an AC motor that produces torque by the reaction between a varying magnetic field (generated in the stator) and the current induced in the coils of the rotor.

Intel hex - Intel hex refers to a file format in which records consist of ASCII format hexadecimal (base 16) numbers with load address information and error checking embedded.

Inverter - The inverter is a portion of the drive that changes DC voltage into AC voltage. The term "inverter" is sometimes used mistakenly to refer to the entire drive (the converter, DC link, and inverter sections).

Jog mode - Jog mode is an operational mode that uses a pre-programmed jog speed when a digital input (programmed as the jog mode input) is closed.

Jumpers - Jumper blocks are groups of pins that can control functions of the system, based on the state of the jumpers. Jumpers (small, removable connectors) are either installed (on) or not installed (off) to provide a hardware switch.

Ladder logic - (Also Ladder Diagram) A graphical representation of logic in which two vertical lines, representing power, flow from the source on the left and the sink on the right, with logic branches running between, resembling rungs of a ladder. Each branch consists of various labeled contacts placed in series and connected to a single relay coil (or function block) on the right.

Loss of signal feature - The loss of signal feature is a control scheme that gives the operator the ability to select one of three possible actions in the event that the signal from an external sensor, configured to specify the speed demand, is lost. Under this condition, the operator may program the drive (through the system program) to (1) revert to a fixed, pre-programmed speed, (2) maintain the current speed, or (3) perform a controlled (ramped) stop of the drive. By default, current speed is maintained.

LVD - LVD is an acronym for Low Voltage Directive, a safety directive in the EU.

Lvl RH - This term refers the two security fields associated with each parameter of the system. These fields allow the operator to individually customize specific security features for each menu option (submenu, parameter, pick list, and function). These fields are shown in parameter dumps and have the following meanings. Lvl is the term for the security level. Setting R=1 blocks parameter change, and setting H=1 hides the menu option from view until the appropriate access level has been activated.

Memory - Memory is the working storage area for the Perfect Harmony drive that is a collection of RAM chips.

Microprocessor - A microprocessor is a central processing unit (CPU) that exists on a single silicon chip. The microprocessor board is the printed circuit board on which the microprocessor is mounted. The NXG drive employs a single-board computer with a Pentium® microprocessor.

NEMA 1 and **NEMA 12** - NEMA 1 is an enclosure rating in which no openings allow penetration of a 0.25-inch diameter rod. NEMA 1 enclosures are intended for indoor use only. NEMA 12 is a more stringent NEMA rating in which the cabinet is said to be "dust tight" (although it is still not advisable to use NEMA 12 in conductive dust atmospheres). The approximate equivalent IEC rating is IP52.

Normally closed (NC) - Normally closed refers to the contact of a relay that is closed when the coil is de-energized.

Normally open (NO) - Normally open refers to the contact of a relay that is open when the coil is de-energized.

OLTM - An acronym for Open Loop Test Mode - One of six control modes of the NXG drive.

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OLVC - An acronym for Open Loop Vector Control, also known as Encoderless Vector Control. OLVC is a flux vector control that is one of six control modes of the NXG drive. The drive computes the rotational speed of the rotor and uses it for speed feedback.

OOS - OOS is an abbreviation for out of saturation - a type of fault condition in which a voltage drop is detected across one of the IGBTs during conduction. This can indicate that the motor is drawing current too rapidly or in excess.

OR - OR is a logical Boolean function whose output is true if any of the inputs is true. In SOP notation, OR is represented as "+".

Parameter - A parameter is one of four items found in the Perfect Harmony menu system. Parameters are system attributes that have corresponding values that can be monitored or, in some cases, changed by the user.

PED - PED is an acronym for pressure equipment directive, a directive of the EU relating to pressure vessels.

Pick list - A pick list is one of four items found in the Perfect Harmony menu system. Pick lists are parameters that have a finite list of pre-defined "values" from which to choose, rather than a value range used by parameters.

PID - PID is an acronym for proportional + integral + derivative, a control scheme used to control modulating equipment in such a way that the control output is based on (1) a proportional amount of the error between the desired setpoint and the actual feedback value, (2) the summation of this error over time, and (3) the change in error over time. Output contributions from each of these three components are combined to create a single output response. The amount of contribution from each component is programmable through gain parameters. By optimizing these gain parameters, the operator can "tune" the PID control loop for maximum efficiency, minimal overshoot, quick response time, and minimal cycling.

Qualified user - A qualified user is a properly trained individual who is familiar with the construction and operation of the equipment and the hazards involved.

Quick menu - Quick menu is a feature of the menu system that allows the operator to directly access any of the menus or parameters, rather than scrolling through menus to the appropriate item. This feature uses the [Shift] button in conjunction with the right arrow. The user is prompted to enter the four digit ID number associated with the desired menu or parameter.

RAM - RAM is an acronym for Random Access Memory, a temporary storage area for drive information. The information in RAM is lost when power is no longer supplied to it. Therefore, it is referred to as volatile memory.

Regeneration - Regeneration is the characteristic of an AC motor to act as a generator when the rotor's mechanical frequency is greater than the applied electrical frequency.

Relay - A relay is an electrically controlled device that causes electrical contacts to change their status. Open contacts will close and closed contacts will open when rated voltage is applied to the coil of a relay.

RS232C - RS232C is a serial communications standard of the Electronics Industries Association (EIA).

Setpoint - Setpoint is the desired or optimal speed of the VFD to maintain process levels (speed command).

Slip - Slip is the difference between the stator electrical frequency of the motor and the rotor mechanical frequency of the motor, normalized to the stator frequency as shown in the following equation.:

$$\text{Slip} = \frac{\omega_S - \omega_R}{\omega_S}$$

Slip is the force that produces torque in an induction motor. Slip can also be defined as the shaft power of the motor divided by the stator input power.

Slip compensation - Slip compensation is a method of increasing the speed reference to the speed regulator circuit (based on the motor torque) to maintain motor speed as the load on the motor changes. The slip compensation circuit increases the frequency at which the inverter section is controlled to compensate for decreased speed due to load droop. For example, a motor with a full load speed of 1760 rpm has a slip of 40 rpm. The no load rpm would be 1800 rpm. If the motor nameplate current is 100 A, the drive is sending a 60 Hz wave form to the motor (fully loaded); then

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the slip compensation circuit would cause the inverter to run 1.33 Hz faster to allow the motor to operate at 1800 rpm, which is the synchronous speed of the motor.

SMC - Is an acronym for Synchronous Motor Control - which is one of six control modes in the NXG drive.This mode computes the rotational speed similarly to open-loop vector control, and controls the field reference or the synchronous motor as in closed-loop synchronous motor control.

SOP - **(1)** SOP is an acronym for Sum Of Products. The term "sum-of-products" comes from the application of Boolean algebraic rules to produce a set of terms or conditions that are grouped in a fashion that represents parallel paths (ORing) of required conditions that all must be met (ANDing). This would be equivalent to branches of connected contacts on a relay logic ladder that connect to a common relay coil. In fact, the notation can be used as a shortcut to describe the ladder logic. **(2)** SOP, when used as a filename extension, refers to System Operating Program.

SOP Utilities - The program within the Siemens LD A ToolSuite used for converting between text and machine loadable code. It can also be used for uploading and downloading files over the RS232 connection.

Stop mode - Stop mode is used to shut down the drive in a controlled manner, regardless of its current state.

Submenus - A submenu is one of four components found in the Perfect Harmony menu system. Submenus are nested menus (i.e., menus within other menus). Submenus are used to logically group menu items based on similar functionality or use.

Synchronous speed - Synchronous speed refers to the speed of an AC induction motor's rotating magnetic field. It is determined by the frequency applied to the stator and the number of magnetic poles present in each phase of the stator windings. Synchronous Speed equals 120 times the applied Frequency (in Hz) divided by the number of poles per phase.

System Operating Program - The functions of the programmable inputs and outputs are determined by the default *system program.* These functions can be changed by modifying the appropriate setup menus from the front keypad and display. I/O assignments can also be changed by editing the system program (an ASCII text file with the extension .SOP), compiling it using the compiler program, and then downloading it to the controller through its serial port, all by utilizing the SOP Utility Program with the Siemens LD A ToolSuite.

SOP Utilities - see ToolSuite definition.

ToolSuite - Is the suite of programs developed by Siemens that allows easier access to the NXG drive for programming and monitoring. It is comprised of the following components:

- **ToolSuite Launcher** - also referred to as ToolSuite; used for coordinating other tools.

- **SOP Utilities** - used to launch an editor that compiles or reverse compiles a System Program. It also allows for serial connection to the drive for uploading and downloading System Programs.

- **Configuration Update** - allows for backing-up, updating, and cloning drives via direct access to the Flash Disk.

- **Host Simulator** - used for monitoring, programming, and controlling a drive remotely from a PC over the built-in ethernet port of the drive. Parameter changes, status display, and graphing of internal variables are its main functions.

- **Debug Tool** - this tool is used to display the diagnostic screens of the drive for diagnosing drive problems or improving performance via the built-in ethernet port of the drive.

ToolSuite Launcher - see ToolSuite definition.

Torque - The force that produces (or attempts to produce) rotation, as in the case of a motor.

Uploading - Uploading is a process by which information is transmitted from the drive to a remote device such as a PC. The term uploading implies the transmission of an entire file of information (e.g., the system program) rather than continued interactive communications between the two devices. The use of a PC for uploading requires communications software to be available on the PC.

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Variable frequency drive (VFD) - A VFD is a device that takes a fixed voltage and fixed frequency AC input source and converts it to a variable voltage, variable frequency output that can control the speed of an AC motor.

VHZ - Is an acronym for Volts per Hertz control, one of six control modes in the NXG drive. This mode is intended for multiple motors connected in parallel. Therefore, it disables spinning load and fast bypass. This is essentially open-loop vector control with de-tuned (smaller bandwidth obtained by reducing the gain) current regulators.

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B   Abbreviations

This appendix contains a list of symbols and abbreviations commonly used throughout this manual group.

Commonly Used Abbreviations

Abbreviation	Meaning
•	Boolean AND function
+	Addition or Boolean OR
Σ	Summation
µ	Microsecond
A	Amp, Ampere
AC	Alternating Current
accel	Acceleration
A/D	Analog to Digital Converter
ADC	Analog to Digital Converter
AI	Analog Input
alg	Analog
avail	Available
BIL	Basic Impulse Level
BTU	British thermal units
C	Centigrade or Capacitor
cap	Capacitor
CCB	Cell Control Board
ccw	Counter clockwise
CE	Formerly European Conformity, now true definition
CFM	Cubic feet per minute
CLVC	Closed Loop Vector Control
cmd	Command
com	Common
conn	Connector
CPS	Control Power Supply
CPU	Central Processing Unit
CSMC	Closed Loop Synchronous Motor Control
CT	Current Transformer
cu	Cubic
curr, I	Current
cw	Clockwise
D	Derivative (PID), depth

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Abbreviation	Meaning
D/A	Digital-to-analog (converter)
db	Decibel
DC	Direct Current
DCR	Digital Control Rack
DCS	Distributed Control System
decel	Deceleration
deg, °	Degrees
DHMS	Down hole monitoring system
div	Division
dmd	Demand
e	Error
EC	Electrically Commutated
ELV	Extra Low Voltage
EMC	Electromagnetic Compatibility
EMF	Electromotive Force
EMI	Electromagnetic Interference
EPS	Encoder Power Supply
ESD	Electrostatic Discharge
ESP	Electrical Submersible Pump
ESTOP, e-stop	Emergency Stop
fb, fdbk	Feedback
ffwd	Feed Forward
FLC	Full Load Current
freq	Frequency
ft, '	Feet
fwd	Forward
GenIIIe	Generation IIIe
GenIV	Generation IV
gnd	Ground
GUI	Graphical User Interface
H	Height
H_2O	Water
hex	Hexadecimal
hist	Historic
hp	Horsepower
hr	Hour
HV	High Voltage
HVAC	Heating, Ventilation, Air Conditioning
HVF	Harmonic Voltage Factor

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Abbreviation	Meaning
Hz	Hertz
I	Integral (PID)
ID	Identification
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IGBT	Insulated Gate Bipolar Transistor
in	Input
in, "	Inches
INH	Inhibit
I/O	Input(s)/Output(s)
IOB	I/O Breakout Board
IOC	Instantaneous Overcurrent
IP	Input Protection
k	1,000 (e.g., Kohm)
kHz	KiloHertz
kV	Kilo Volts
kVA	One Thousand Volt Amps
kW	Kilowatt
L	Inductor
LAN	Local Area Network
lbs	Pounds (weight)
LCD	Liquid Crystal Display
ld	Load
LED	Light-emitting Diode
LFR	Latch Fault Relay
lim	Limit
LOS	Loss Of Signal
lps	Liters Per Second
mA	Milliamperes
mag	Magnetizing
max	Maximum
MCC	Motor Control Center
mg	Milligram
min	Minimum, Minute
msec	Millisecond(S)
msl	Mean Sea Level
MV	Medium Voltage
mvlt	Motor Voltage
MW	Megawatt

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B

Abbreviation	Meaning
NC	Normally Closed
NEMA	National Electrical Manufacturer's Association
NMI	Non-Maskable Interrupt
No	Normally Open
NVRAM	Non-Volatile Random Access Memory
NXG	Next Generation Control
NXG II	Next Generation Control II
oamp	Output Current
OLVC	Open Loop Vector Control
O-M	Overmodulation
OOS	Out of Saturation (IGBT)
overld	Overload
P	Proportional (PID)
Pa	Pascals
pb	Push Button
PC	Personal Computer or Printed Circuit
PCB	Printed Circuit Board
PID	Proportional Integral Derivative
PLC	Programmable Logic Controller
PLL	Phase Locked Loop
pot	Potentiometer
pp	Peak-to-peak
ppm	Parts per Million
PPR	Pulses per Revolution
PQM	Power Quality Meter
ProToPS™	Process Tolerant Protection Strategy
PSDBP	Power Spectral Density Break Point
psi	Pounds Per Square Inch
pt	Point
PT	Potential Transformer
PWM	Pulse Width Modulation
Q1,Q2,Q3,Q4	Output Transistor Designations
rad	Radians
RAM	Random Access Memory
ref	Reference
rev	Reverse, Revolution(S)
RFI	Radio Frequency Interference
RLBK	Rollback
rms	Root-mean-squared

B

Abbreviation	Meaning
RPM	Revolutions Per Minute
RTD	Resistance Temperature Detector
RTU	Remote Terminal Unit
RX	Receive (RS232 Communications)
s	Second(s)
SCB	Signal Conditioning Board
SCR	Silicon Controlled Rectifier
sec	Second(s)
ser	Serial
SMC	Synchronous Motor Control
SOP	Sum of Products; System Operating Program
spd	Speed
stab	Stability
std	Standard
sw	Switch
T1, T2	Output Terminals TI and T2
TB	Terminal Block
TBD	To Be Determined
TCP/IP	Transmission Control Protocol/Internet Protocol
THD	Total Harmonic Distortion
TOL	Thermal Overload
TP	Test Point
trq, τ	Torque
TX	Transmit (RS232 Communications)
UPS	Uninterruptable Power Supply
V	Voltage, Volts
VA	Volt-Amperes
VAC	Volts AC
var	Variable
VDC	Volts DC
vel	Velocity
VFD	Variable Frequency Drive
V/Hz	Volts per Hertz
vlts	Voltage(s), Volts
VSI	Voltage Source Inverter
W	Width, Watts
WAGO	Expansion I/O System
WCIII	Water Cooled III
xfmr, xformer	Transformer

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C   System Control Drawings

C

This appendix contains the system control diagrams for a Perfect Harmony drive with Next Gen Control.

- • Perfect Harmony Control Diagram drawing number 459712

- • Command Generator Diagram drawing number A5E01219450A

- • Input/Output Process Diagram drawing number A5E01219451A

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OUTPUT PROCESS DIAGRAM — 459717

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