NXG
CONTROL MANUAL

Manual Number: A1A19001588
Version 4.0
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Siemens Energy & Automation, Inc.

Large Drives A

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This manual applies to all Perfect Harmony adjustable-speed AC motor drives, with the exception of LNG and HA drives.

This manual applies to NXG software from version 5.0 and later.

For technical assistance and Field Service emergency support in the area nearest to you, please call the SIEMENS 1.800.333.7421 toll-free number.

Version History

Version 1.0 (original)	January 2007
Version 2.0 (12288)	June 2007
Version 3.0 (13494)	May 2009
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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.

Warning!

- **Always** comply with local codes and requirements if disposal of failed components is necessary (for example, CPU battery, capacitors, etc.).
- **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.
- **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: A1A19001588)
- *NXG Communications Manual* (Manual Number: A1A902399)
- *NXG ToolSuite User Manual* (Manual Number: A1A902291)

The *NXG Control Manual* describes the NXG Control interface, applications, troubleshooting, maintenance, and system programming.

The *NXG Communications Manual* describes the Communications 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 Communications board alone. All others require optional controller cards, called UCS modules or AnyBus modules, which plug into the Communications 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 Drive Host tool, the operator can navigate through a drive's features using a PC and a mouse or touch screen, which makes the Drive Host tool more convenient to use than a keypad. The NXG Drive Host tool is a high-level GUI that runs on a PC equipped with the Microsoft Windows operating system.

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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CHAPTER

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 was the second generation of control for these drives, adding a variety of new features not found on the original control. The NXGII Control, covered in this manual, replaces NXG and adds additional features and capabilities. Software versions including 4.0 and beyond, require NXGII hardware. References to NXG hardware throughout this manual now refer to NXGII, unless otherwise stated.

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 User Manual* (A5E01454341)
- *WCIII Product User Manual* (A5E02118669A)
- *HV Product User Manual* (A5E01593078A)
- *NXG Communications Manual* (A1A902399)
- *NXG ToolSuite Manual* (A1A902291)

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.

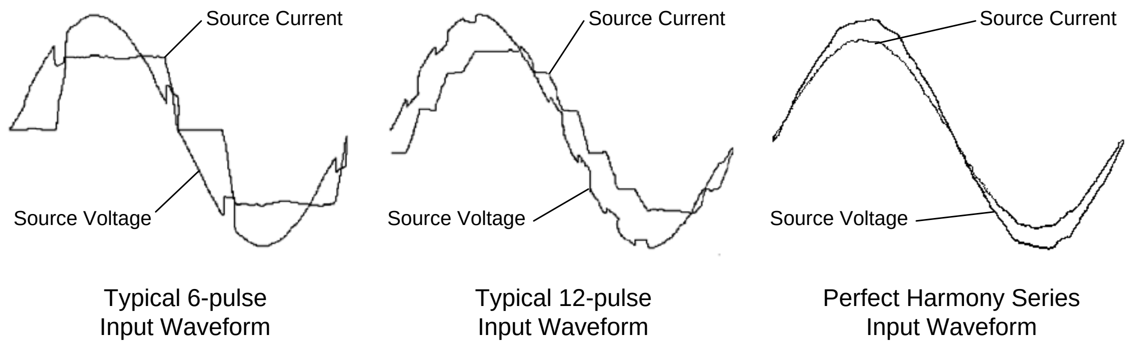

Figure 1-1: Harmonic Distortion Waveform Comparisons (6-pulse, 12-pulse and Perfect Harmony)

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 made 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 shows a comparison of Power Factor versus Percent Speed for the Perfect Harmony series and a typical phase-controlled SCR drive.

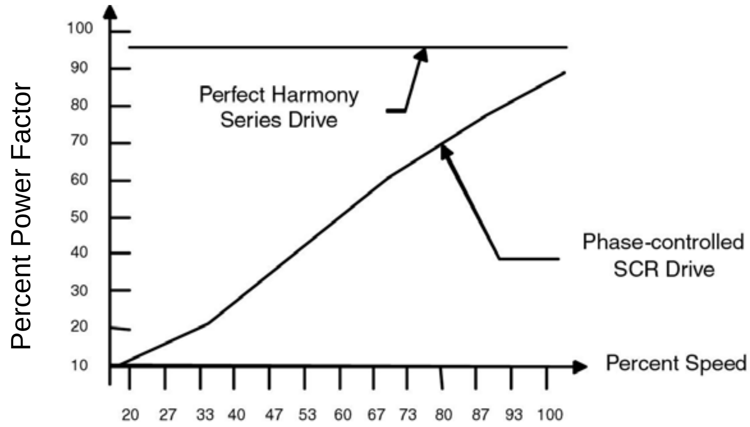

Figure 1-2: Comparison of Perfect Harmony and a Typical Phase-controlled SCR Drive

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.

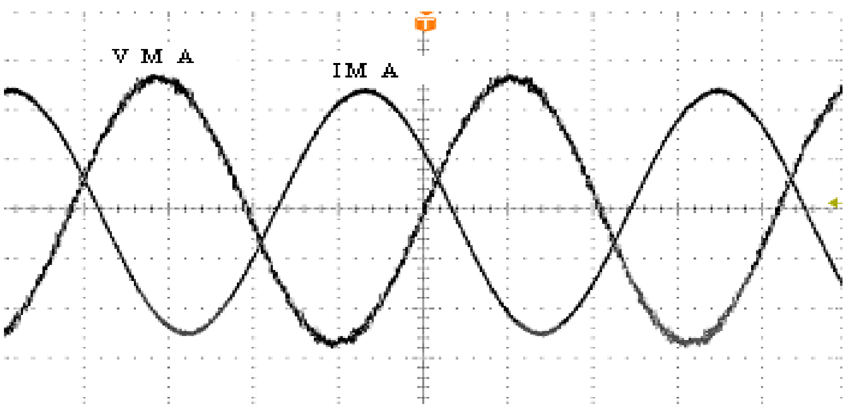

Figure 1-3: Nearly Sinusoidal Wave Form of the Output Voltage and Current from a Perfect Harmony Drive

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 “wire-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 a 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).

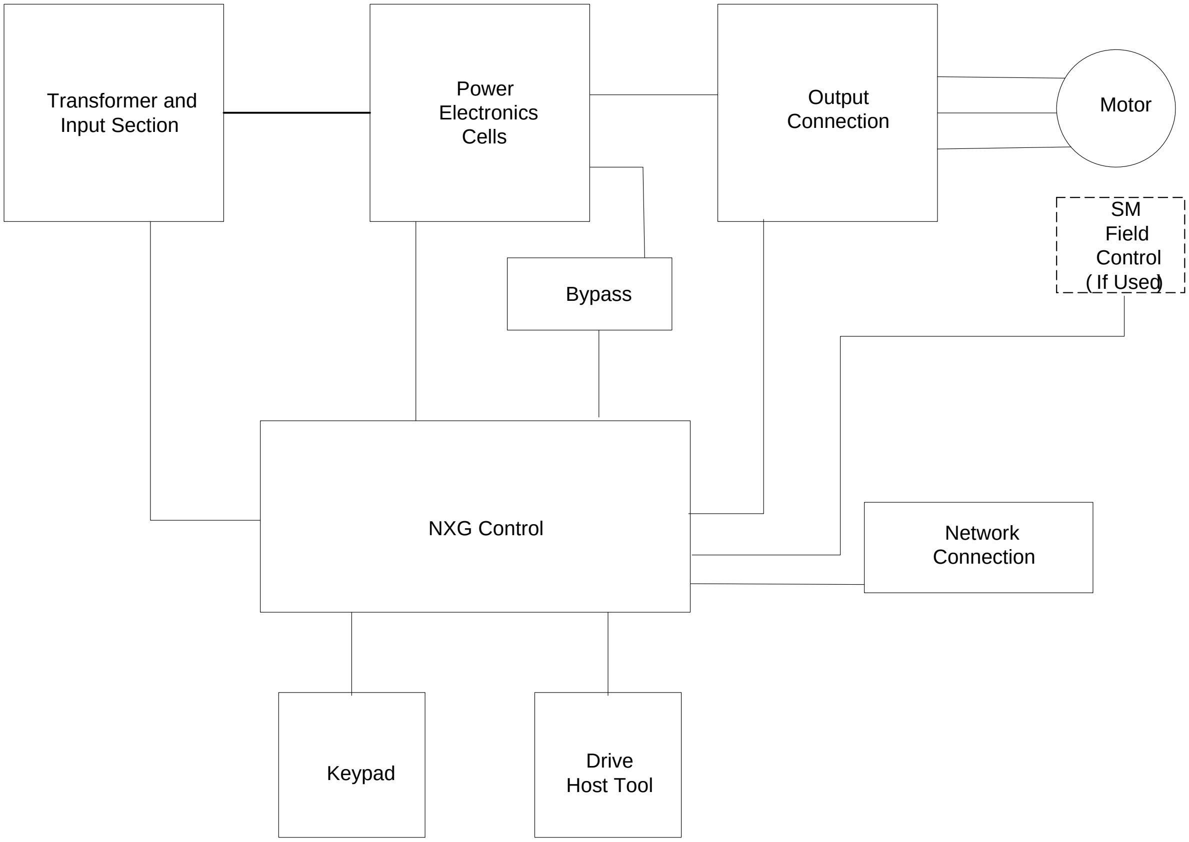

Figure 2-1: NXG Control In A Typical Drive System

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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. Figures 2-2 and 2-3 show the comparison of the NXG and NXGII Control platforms. The NXGII Control is needed to take full advantage of all the new features in the latest software.

The NXG Control System, located within the control cabinet, consists of a chassis and several control boards as shown in Figure 2-2. The NXGII Control System, located within the control cabinet, also consists of a chassis and several control boards as shown in Figure 2-3.

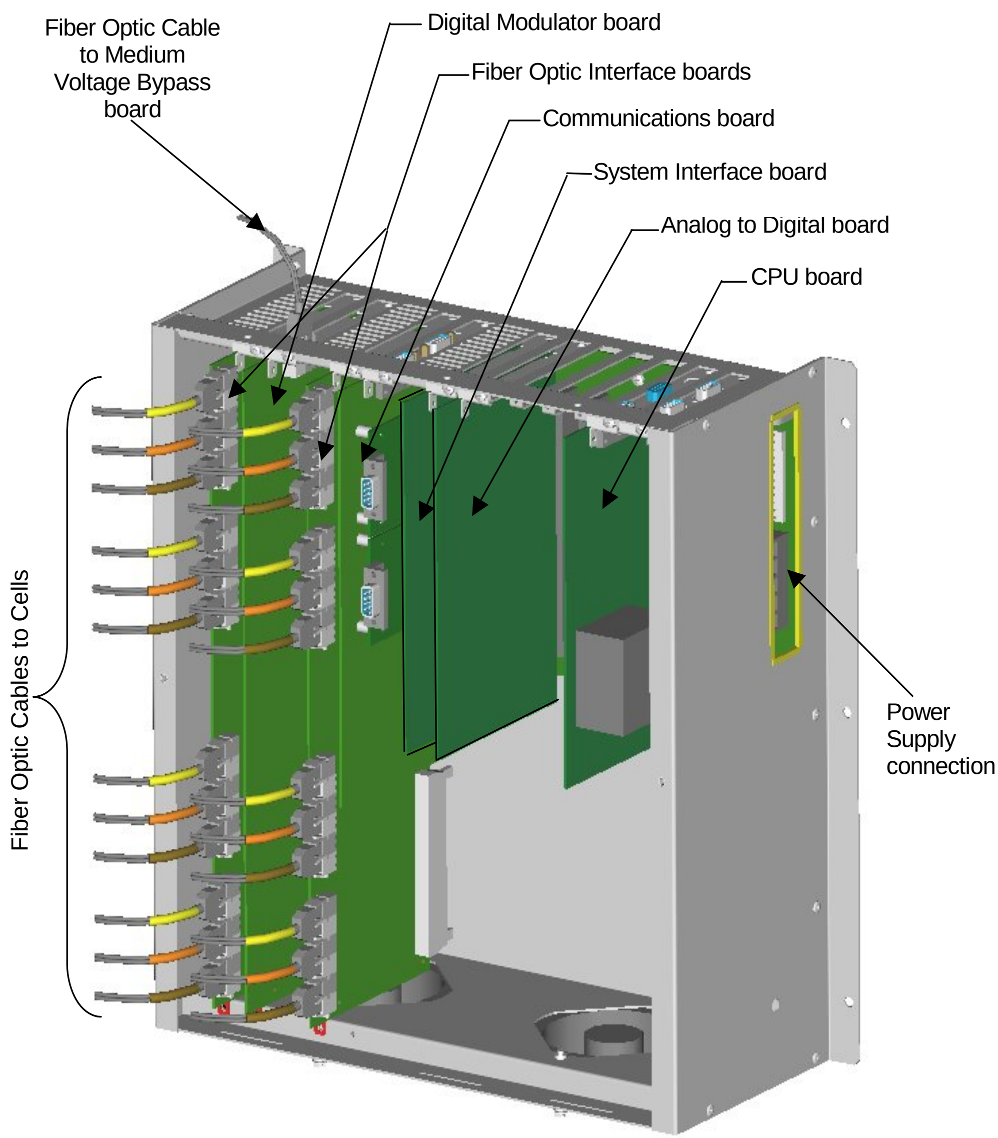

Figure 2-2: NXG Master Control Chassis

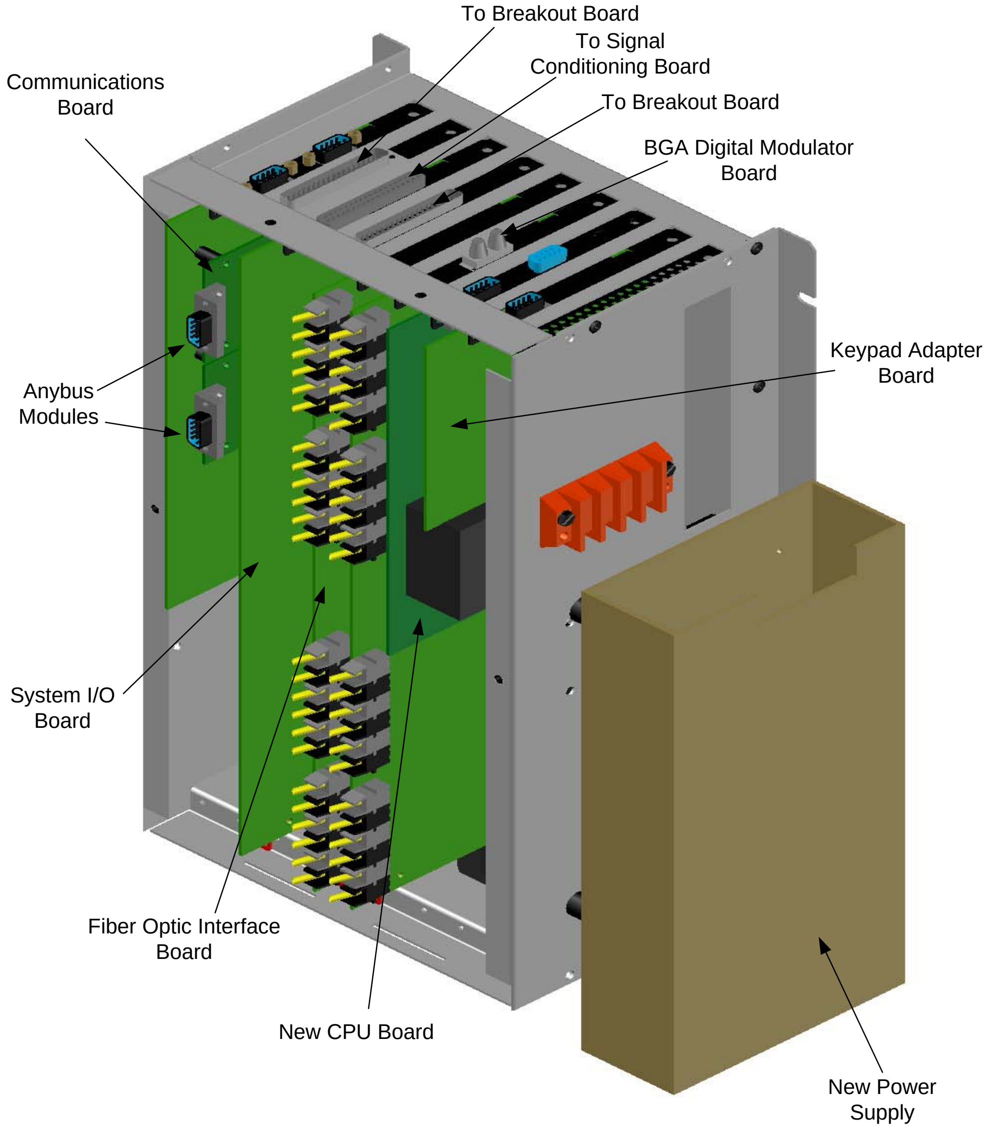

Figure 2-3: NXGII Master Control Chassis

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 NXGII 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 NXGII Control.

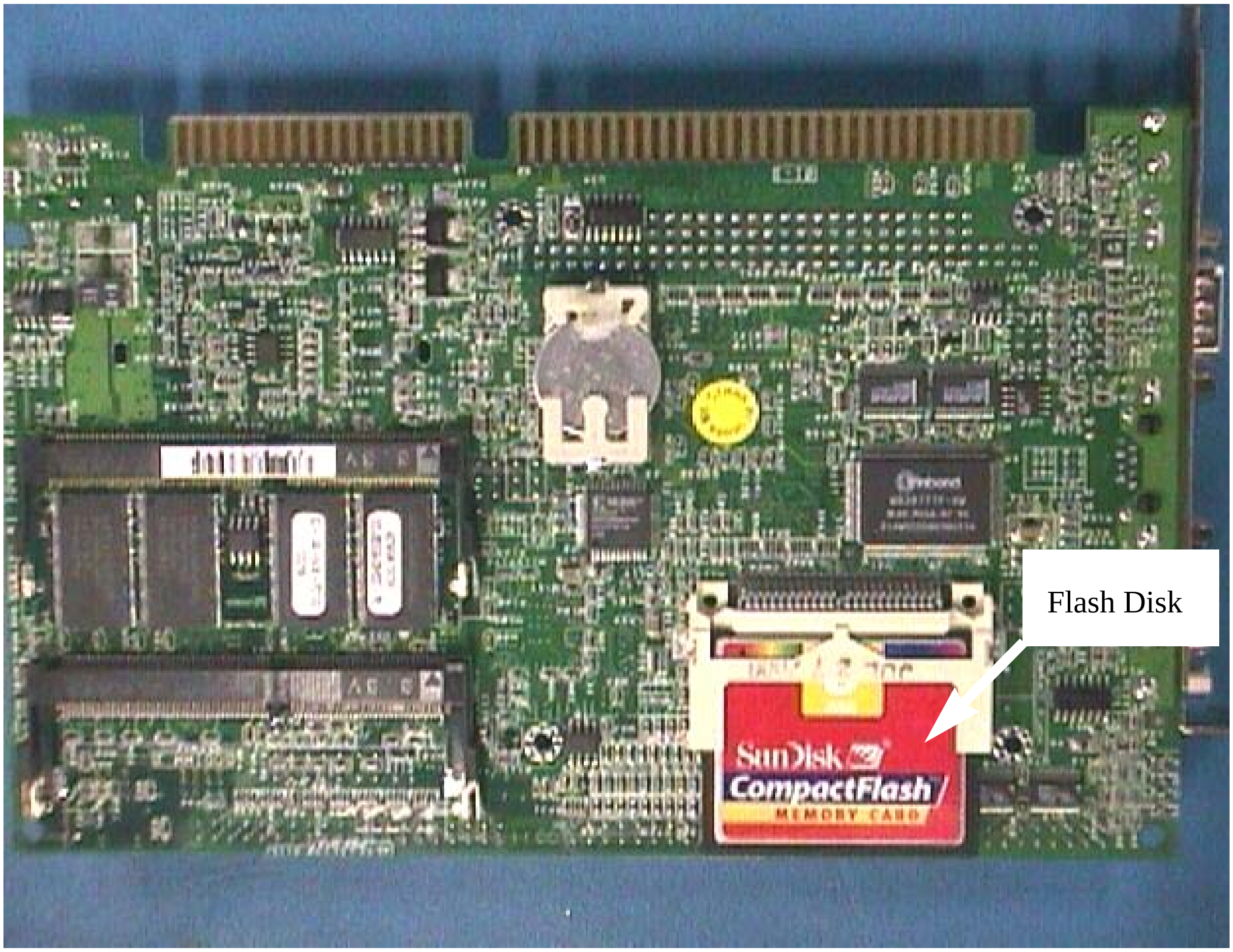

Figure 2-4: Location of Flash Disk on the NXG Microprocessor Board

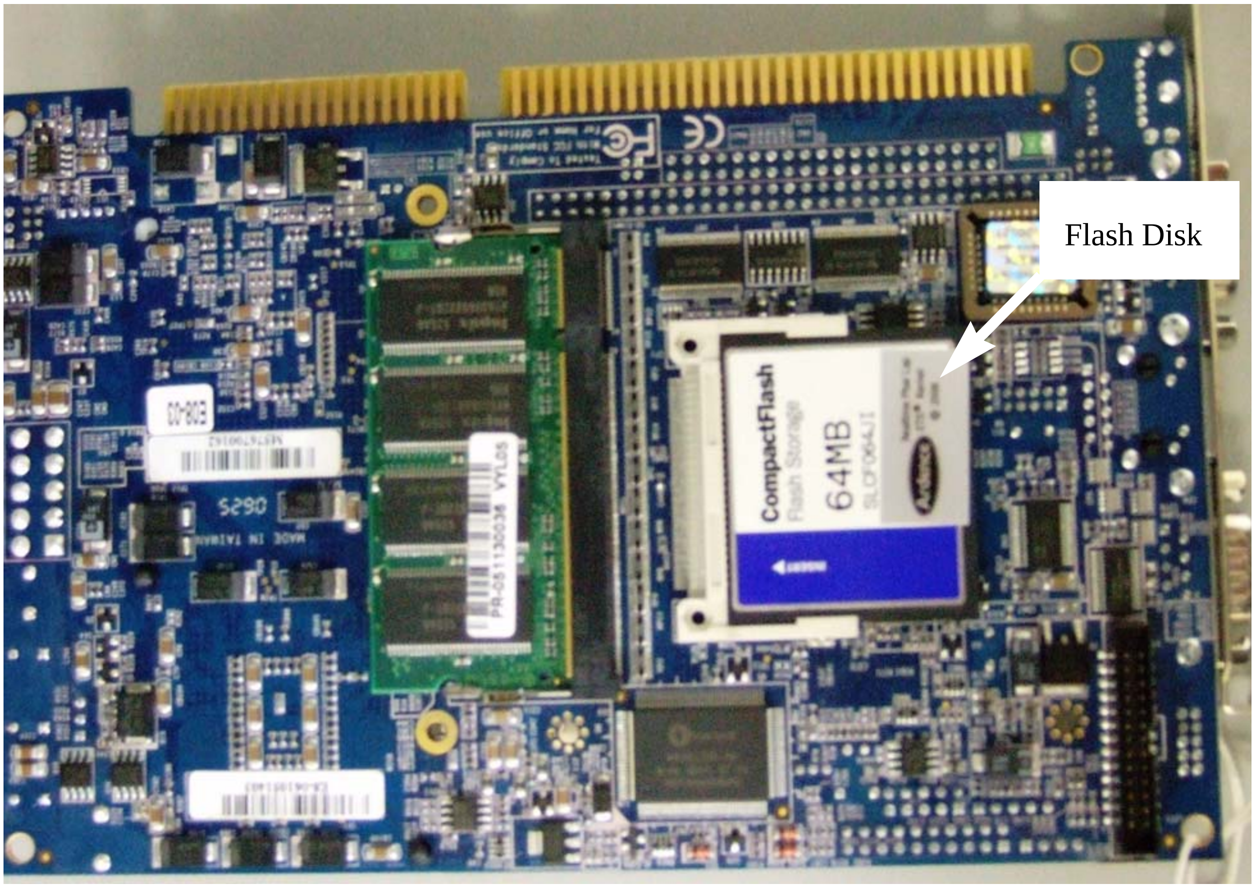

Figure 2-5: Location of Flash Disk on the NXGII Microprocessor Board

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 NXGII 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: The number of fiber optic interface boards and the number of fiber optic channels vary 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 the old version of the Operating Interface Keypad for the Perfect Harmony series VFD.

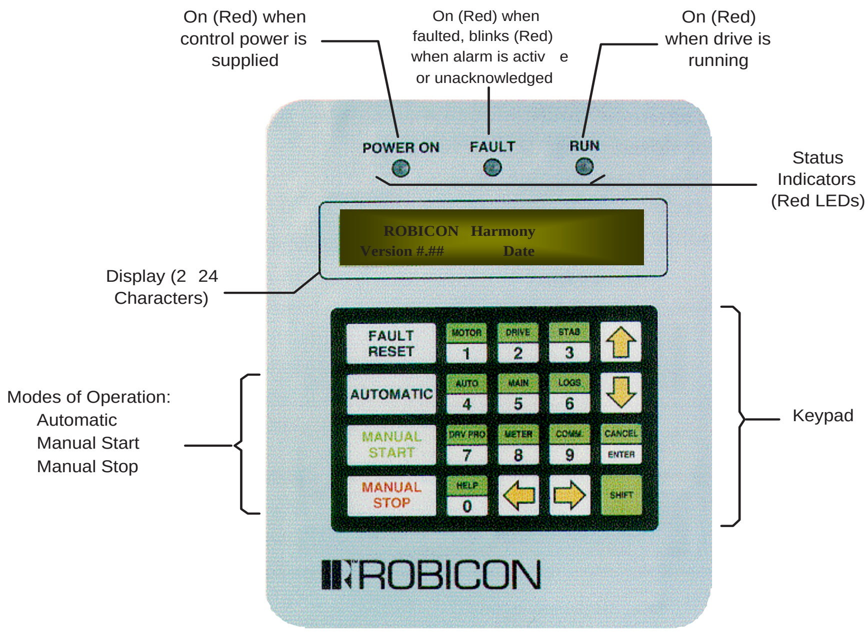

Figure 2-6: Typical Operating Interface Keypad

A detailed description of the Operating Interface Keypad along with all of its functions and modes of operation are described in Chapter 4.

Figure 2-7 shows the new Multi-Language Operating Interface Keypad for the Perfect Harmony series VFD.

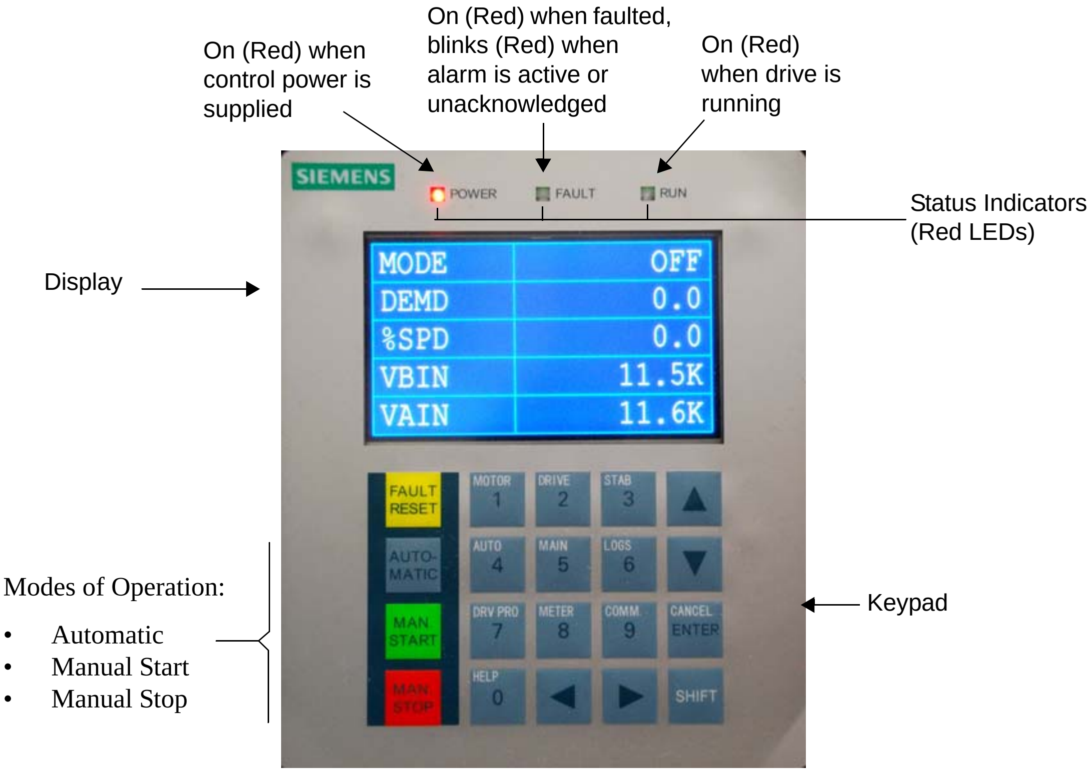

Figure 2-7: Multi-Language Operating Interface Keypad

A detailed description of the Multi-Language Operating Interface Keypad along with all of its functions and modes of operation are described in Chapter 4.

2.4 Software Version Requirements and Limitations

Since versions of NXG code of 4.x and above require NXGII hardware, no software limitations remain.

Do not attempt to load this software on old NXG hardware without upgrading the boards to NXGII levels.

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CHAPTER

3 Hardware Interface

3.1 Introduction

The NXG and the NXGII 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 & I/O Breakout Boards

With the NXGII Control, the System I/O board, through the I/O Breakout board, provides additional digital and analog I/O (see Figure 3-1), often adequate to eliminate the need for the Wago System.

3.3.1 I/O Specifications

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The System I/O - I/O Breakout board combination provides the following capability to the system:

- 20 digital inputs arranged in 5 groups. They accept either 24 VDC or 120 VAC logic depending on the I/O Breakout board used. 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.
- Isolated Encoder interface for a typical quadrature, optical encoder, interface type HTL.
- The 'begin analog conversion' signal comes from Modulator board and triggers the coordinated acquisition of the analog feedback. Then the 'end of conversion' signal goes out to the CPU board as an interrupt for the control fast loop.
- The following functions by the System I/O board provide a signal directly to the modulator to shut down all cells immediately:
    - Hall Effect Power Supply fail signal to Modulator
    - IOC level to Modulator (0-10VDC)
    - Control Power Supply Fail signal to Modulator
    - Inhibit or CR3 signal to Modulator

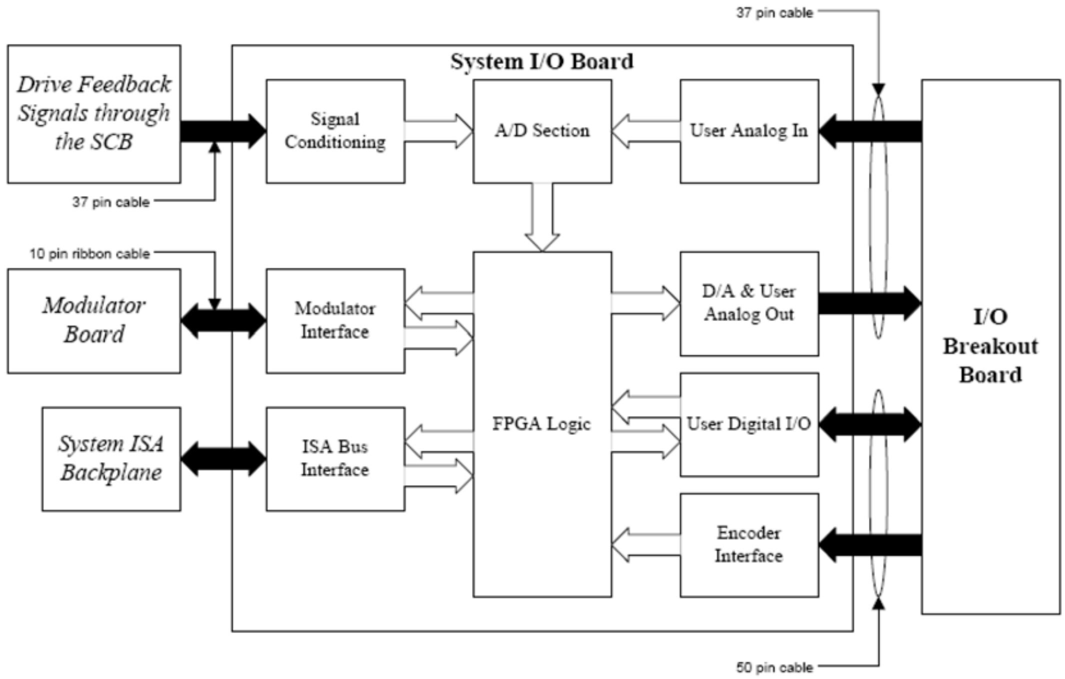

Figure 3-1: System I/O - I/O Breakout Board Block Diagram

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Table 3-1: I/O Specification

I/O Breakout Board P/N	I/O Point Type	Nominal Voltage	Maximum Voltage	Minimum Voltage	Threshold	Loading
A5E01648776	Digital Input	120Vac	135 Vac	85 Vac	~51 V	500mW
A5E01649341	Digital Input	24Vdc	135 Vac	18 Vdc	~9.1 V	500mW

I/O Breakout Board P/N	I/O Point Type	Type	Voltage	Current		
Both	Digital Output	Relay, form “C”	250Vac, 30Vdc	1A, derated		

I/O Breakout Board P/N	I/O Point Type	Type	Load	Accuracy	Software Correction	
Both	Analog Input	0-20 mA, 4-20 mA	25 Ohm	10 bits	range, offset	
Both	Analog Input	0-10Vdc	10K Ohm	10 bits	range, offset	
Both	Analog Output	4-20 mA	(4) 250 Ohm loads	10 bits	range, offset	

I/O Breakout Board P/N	I/O Point Type	Nominal Voltage	Maximum Voltage	Minimum Voltage	Threshold	Loading
Both	Encoder	15 V	18 V	9 V	~4.5 V	20 mA

Notes:

- ac given in rms
- While the 24V digital input circuit can operate at 120Vac, it is not recommended due to the low threshold voltage.

Since this I/O resource is consistent with every system that uses this board set, and to improve consistency of usage, some of the I/O have been given standard assignments that are used by the Drive core code. This improves response time, and prevents changes in the SOP from affecting the drive protection measures assigned to the specific I/O.

3.3.2 Encoder Interface

Vector control requires closed-loop feedback signals. These inputs come from a *tachometer* or *encoder* that is directly sensing the shaft speed of the motor being driven. The Perfect Harmony requires four square wave signals (channel A, channel B, channel $\overline{A}$, channel $\overline{B}$) from the tachometer / encoder.

The channel A and channel B signals are directly proportional to the motor shaft speed. The signals are 90° out of phase with each other and are 180° out of phase with their respective complements. This is illustrated in Figure 3-3.

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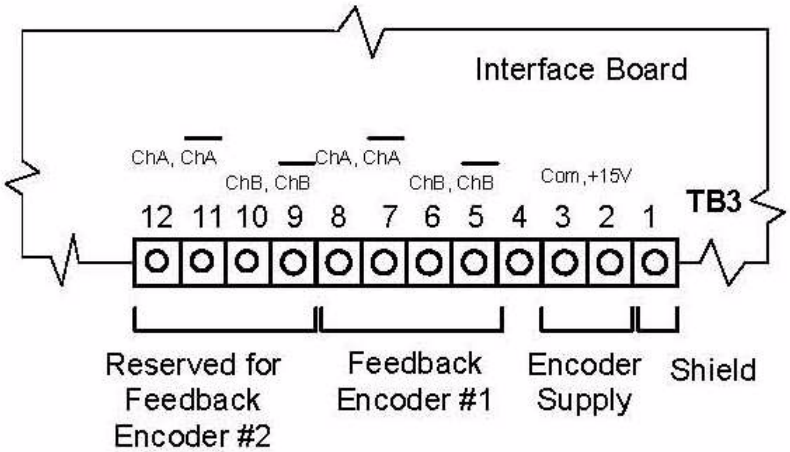

Figure 3-2: Encoder Connections on TB3 of the Harmony Interface Board

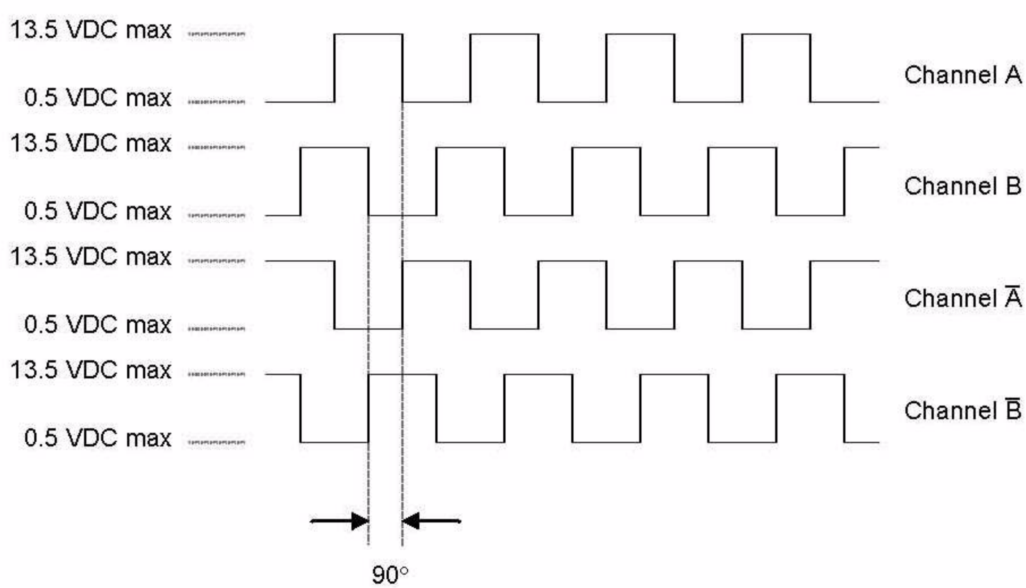

Figure 3-3: Wave Forms of Encoder / Tachometer Feedback Signals

The maximum signal level at the input to the drive is 0.5 VDC_{max} for the low signal and 13.5 VDC_{max} for the high signal. Siemens recommends a minimum pulse rate of 1024 pulses per revolution to ensure good speed regulation.

Note: The Perfect Harmony requires all four feedback signals to function properly.

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 to the card rack via the System Break-out board. This is mounted on the same panel as the Control Rack and connects 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

Table 3-2: Dedicated Inputs

Input	Function	Description	
6	InSyncRelayACK	Precharge Sync OK	DI-2B (InternalDigitalInput2b_I)
14	PrechargeRequest	Request to start precharge	DI-2D (InternalDigitalInput2d_I)
15	M2CloseACK	feedback of M2 contact	DI-3D (InternalDigitalInput3d_I)
16	M3CloseACK	feedback of M3 contact	DI-0E (InternalDigitalInput0e_I)
17	M4CloseACK	feedback of M4 contact	DI-1E (InternalDigitalInput1e_I)
18	M1CloseACK	feedback of M1 contact	DI-2E (InternalDigitalInput2e_I)
19	LFRInputProtectACK	Latch Fault Relay (LFR) status	DI-3E (InternalDigitalInput3e_I)

Table 3-3: Dedicated Outputs

Output	Function	Description	
9	PrechgCompleteM1Close	Command to close M1	DO-9 (InternalDigitalOutput9_O)
10	M2Close	Command to close M2	DO-10 (InternalDigitalOutput10_O)
11	M3Close	Command to close M3	DO-11 (InternalDigitalOutput11_O)
12	M4Close	Command to close M4	DO-12 (InternalDigitalOutput12_O)
13	BreakerTrip	Command to open (trip) precharge supply breaker	DO-13 (InternalDigitalOutput13_O)
14	M1ClosePermit	M1 close permissive	DO-14 (InternalDigitalOutput14_O)
15	LFRInputProtect	Command to set LFR (1 sec pulse)	DO-15 (InternalDigitalOutput15_O)

For GenIV type cells

Table 3-4: Dedicated Inputs

Input	Function	Description	
19	LFRInputProtectACK	Latch Fault Relay (LFR) status	DI-3E (InternalDigitalInput3e_I)

Table 3-5: Dedicated Outputs:

Output	Function	Description	
14	M1ClosePermit	M1 close permissive	DO-14 (InternalDigitalOutput14_O)
15	LFRInputProtect	Command to set LFR (1 sec pulse)	DO-15 (InternalDigitalOutput15_O)

All other cell types or precharge modes

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
10	InternalDigitalOutput10_O
11	InternalDigitalOutput11_O
12	InternalDigitalOutput12_O
13	InternalDigitalOutput13_O
14	InternalDigitalOutput14_O
15	InternalDigitalOutput15_O

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.

3.7 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, *User 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* (A1A902291).

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 NXGII 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 Section 4.5, *Menu Descriptions* in Chapter 4 for setup and usage.

3

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 Figure 3-4 below). The Configuration of the I/O is handled through the External I/O Menu (2800) (Section 3.10.3).

Note: Like modules must be grouped together. Refer to the Wago literature for specifics on limitations and power equipment.

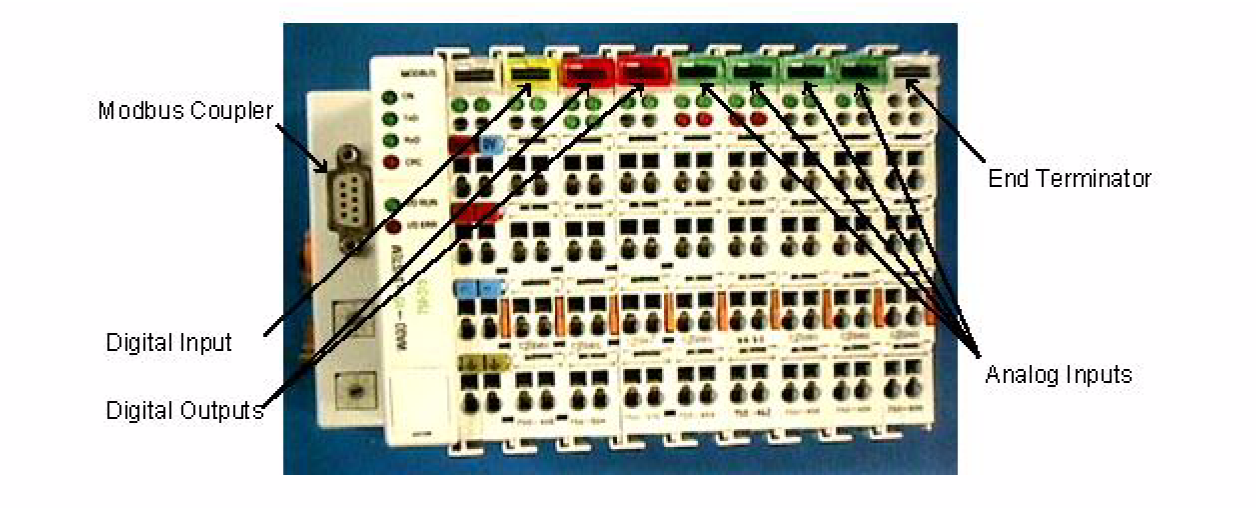

Figure 3-4: Wago I/O System Photo

Table 3-6: 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 3-5 shows the bottom of the WAGO Fieldbus coupler case. To access the DIP switches, remove the cover. To do so, pry the bottom of the unit with just a little pressure, where there is a small “bump” on either side. Then, start to apply pressure from the top where the DB9 connector is, pushing down.

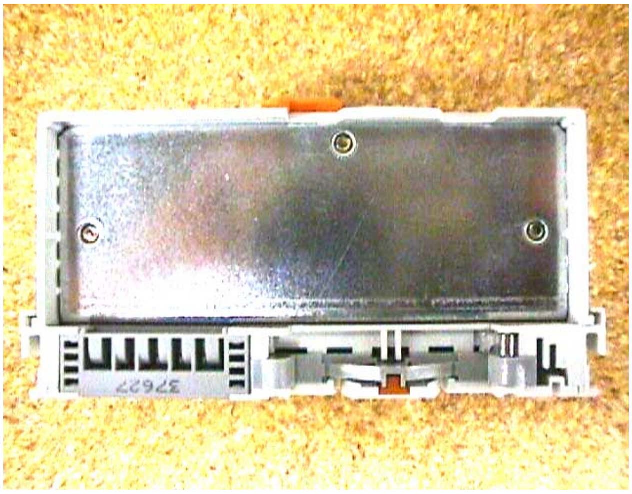

Figure 3-5: Wago MODBUS Coupler Bottom

Figure 3-6 shows how the cover should lift off of the WAGO Fieldbus Coupler to give access to the DIP switches.

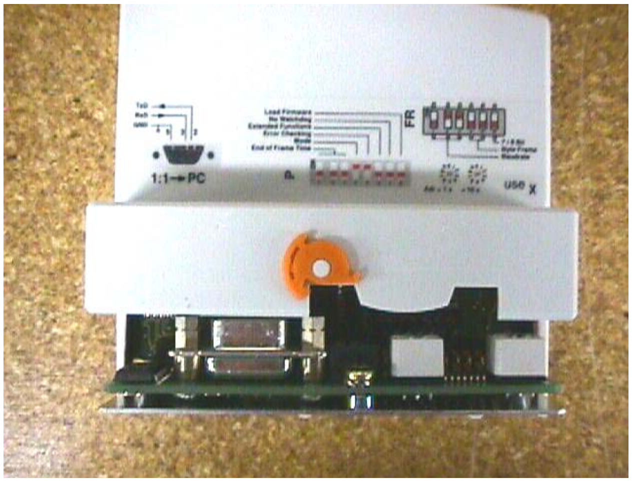

Figure 3-6: Wago MODBUS Coupler with Cover lifted

Figure 3-7 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 (Figure 3-7) and differ from the picture displayed on the outside cover that is removed to access the DIP switches (Figure 3-8).

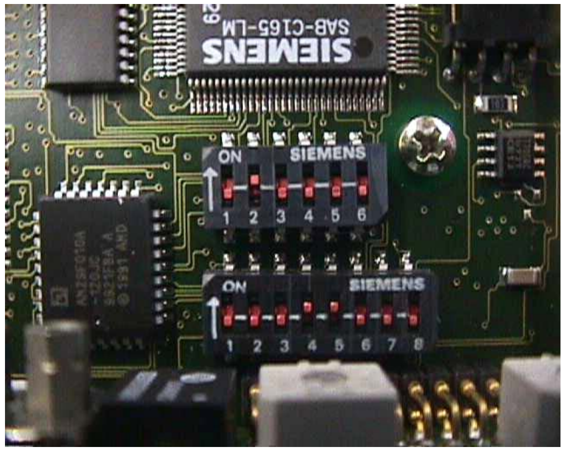

Figure 3-7: Wago MODBUS Coupler DIP switch settings

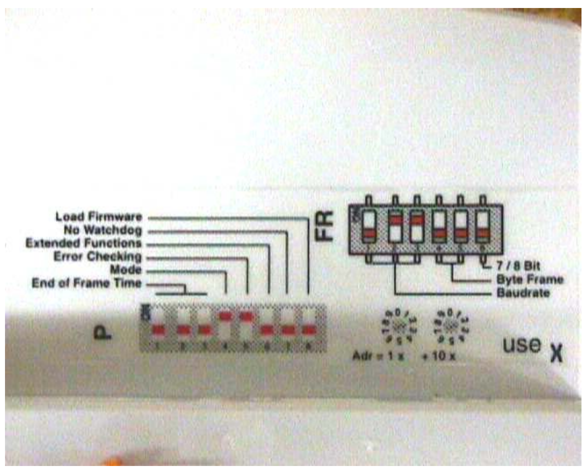

Figure 3-8: Wago MODBUS Coupler DIP switch settings label

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/O per Table 3-7 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 3-7: 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 3-8: 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 4-66).

Table 3-9: 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 following calculations 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.

Figure 3-9 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).

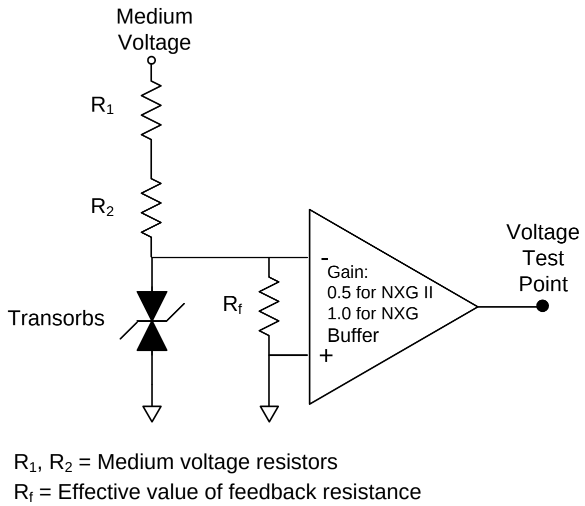

Figure 3-9: Attenuator Circuit

Calculate the resistor values as follows (see Note):

$\mathbf{R_1 + R_2 = (722.3 * V_{mv}) - 4765}$

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) * (√2 / √3)
- 5.3864 is the nominal NXG voltage at the test point for 1 PU.
  2.6932 is the nominal NXGII voltage at the test point for 1 PU.
- √2 is used to convert from L-L to L-N voltage
- √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.

Danger - Electrical Hazards!

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.

Note: When NXGII or System I/O board is used, the nominal test point voltage is ½ the nominal test voltage specified above. However, the attenuator selection method is unchanged and the nominal test point voltage specified above must be used.

3.11.2 Software Supported Voltages

Although the voltage ranges for the input (200 to 125,000V) and the output (200 to 23,000V) allow for much flexibility, the usable voltages must be supported by the appropriate set of attenuator resistors. The values input to the drive determine the rated input and output voltages respectively. If not set to the values represented by the actual hardware devices, the drive may not operate properly.

Examples of valid voltages for which an attenuator resistor kit is available are:

2400, 3000, 3300, 3400, 4160, 4800, 6000, 6600, 7200, 8400, 10000, 11000, 12000, 12500, 13200, 13800, 22000 and 33000.

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* (A1A902291).

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 Communications board also allows the addition of two network adapters to cover all the other supported protocols. See the *NXG Communications Manual* (A1A902399) for use and configuration of these features.

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CHAPTER

4 User Interface

4.1 Introduction

All Control Systems provide a means to change and tune the controls. There are four basic ways to change parameters in the drive. Three of these are the standard keypad, the Multi-Language keypad and the PC-based Drive Tool, which are introduced here. The fourth method involves changing the parameters by means of the networks, but is too complex to describe here, and is less commonly used. Since the latter method 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* (A1A902399).

This chapter discusses, in detail, the navigation of the standard keypad, the Multi-Language keypad, and will introduce a more advanced external interface in the PC-based Drive Tool.

4.2 Standard Keypad

This section pertains to the standard keypad hardware and operation. The actual contents of the parameter menu system are discussed in detail in Chapter 5: *Applications and Advanced Features*.

The menu system of this interface is secured with multiple programmable password levels, but for security and 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 in Tables 4-3 and 4-4.

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

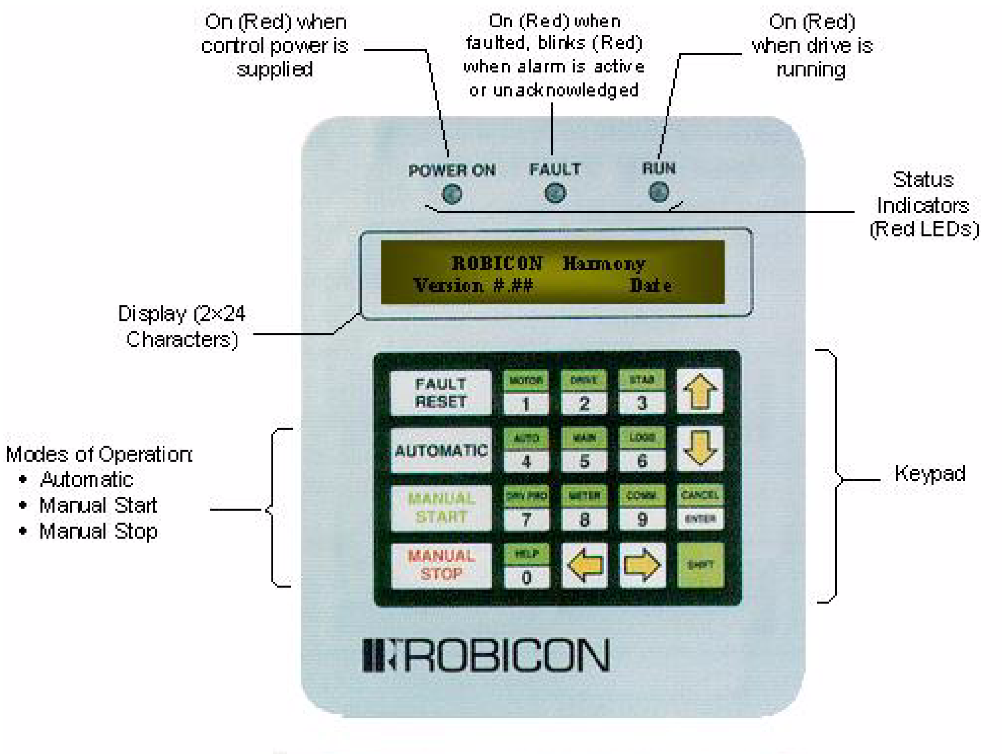

Figure 4-1: The Keypad and Display Interface of the Perfect Harmony Series

The Perfect Harmony keypad contains 20 keys. Each of these keys has at 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 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.

Note: When the fault log is full of unacknowledged faults or alarms (greater than 256), the display shows this message: “Fault/Alarm log” “overflow”. The cause may be an alarm or several that occur and are not manually reset to “acknowledge” the alarm. An alarm sets and resets itself with no external intervention. However, an alarm is never acknowledged until the fault reset button (or remote fault reset) is true - with no fault to reset.

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.

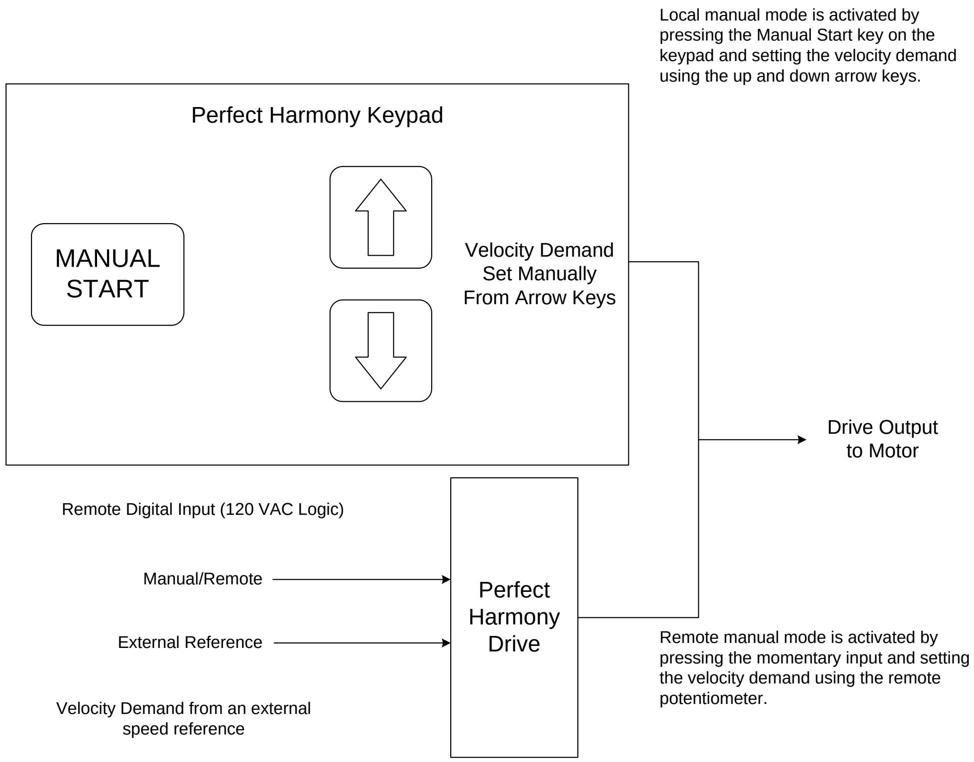

Figure 4-2: Example of Two Programmed Control Modes

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

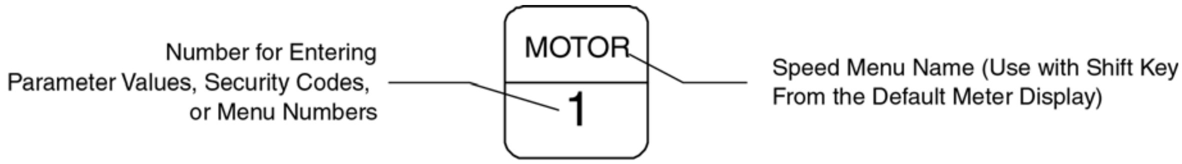

Figure 4-3: Anatomy of a Numeric Keypad Key

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.

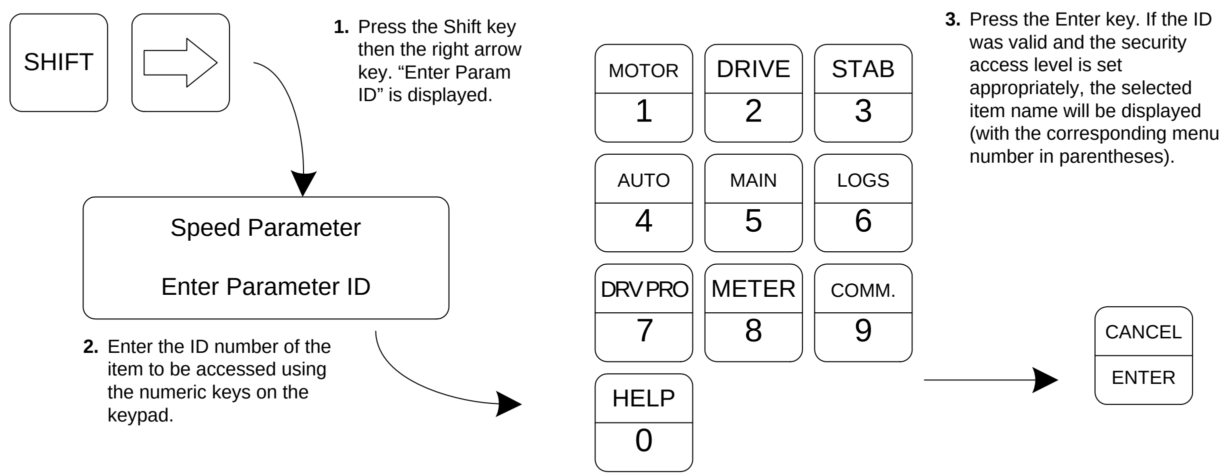

Figure 4-4: Accessing Items Using ID Numbers

> **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/decrementing 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 4.3.4). 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 PR 7	Speed menu to the Drive Protect menu (from the default meter display).
SHIFT, METER 8	Speed menu to the Meter menu (from the default meter display).

Key Combination	Description
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.
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.

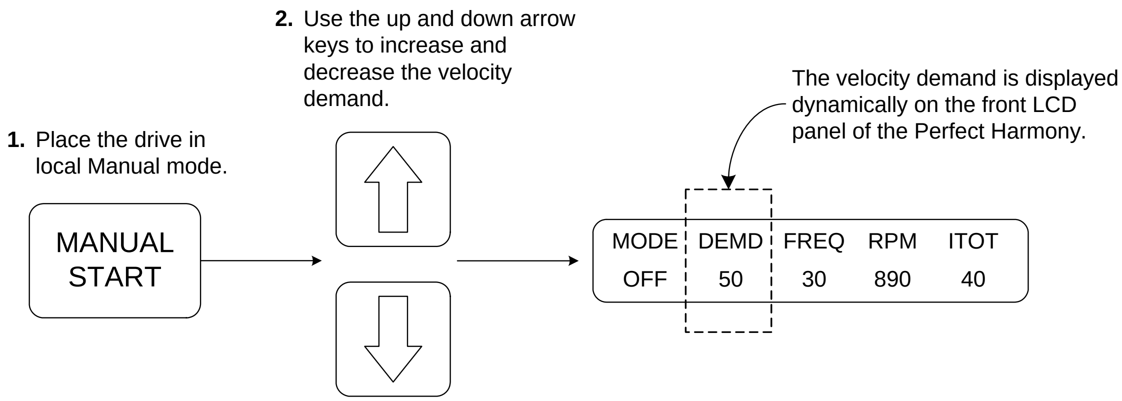

Figure 4-6: Using the Up and Down Arrow Keys to Control Velocity Demand

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 finished (for security reasons), the control can be reset by toggling power to the control 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.

Figure 4-7: Security Level Cleared Message on the Perfect Harmony Display

Notes:

- 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.
[SHIFT] [⇦]	When editing a value that has been changed from its factory default, this key sequence will return the value to its factory default.

4.2.9 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).

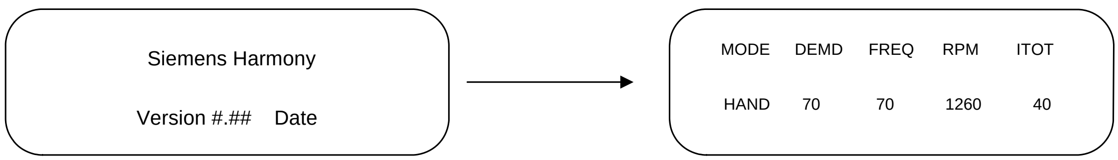

Figure 4-8: The Identification/Version Screen and Meter Displays

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.

Refer to Chapter 7: *Troubleshooting and Maintenance*, Tables 7-6 and 7-7, which list the mode displays for the first and second lines of the fixed display field, respectively.

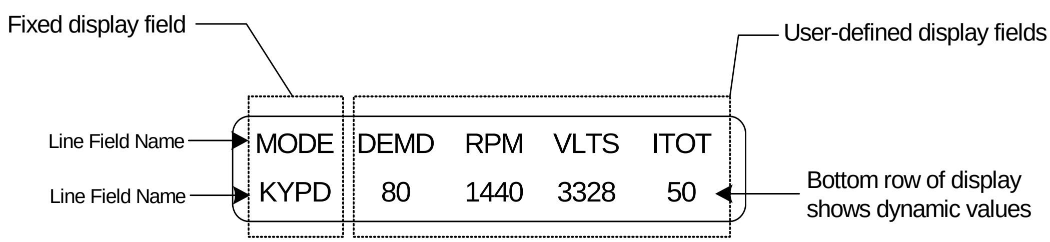

Figure 4-9: Dynamic Programmable Meter Display

The MODE field displays the current operational mode of the Harmony system. This field can have any one of the displays summarized in Table 7-6, 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).

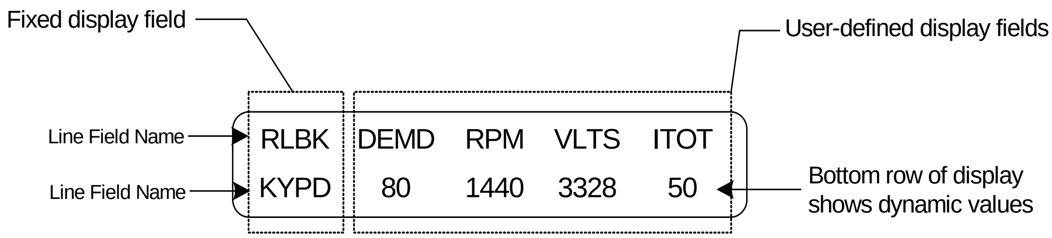

Figure 4-10: Dynamic Programmable Meter Display in Rollback Mode

The KYPD field displays the current operational mode of the Harmony system. This field can have any one of the displays summarized in Table 7-7, depending on the current operational mode or the current state of the drive. Figure 4-11 depicts the display in regeneration mode.

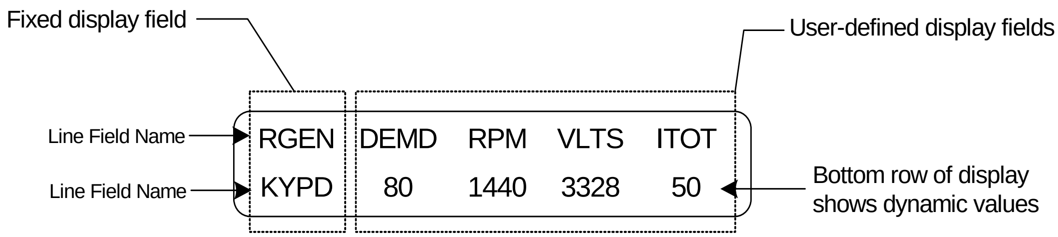

Figure 4-11: Dynamic Programmable Display in Regeneration Mode

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 4-9 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.

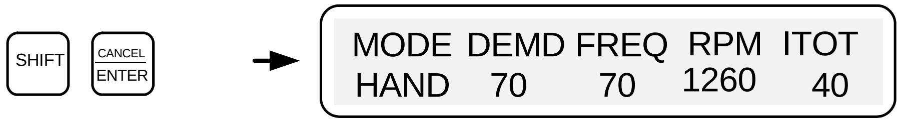

Figure 4-12: Status Display In Metering Mode

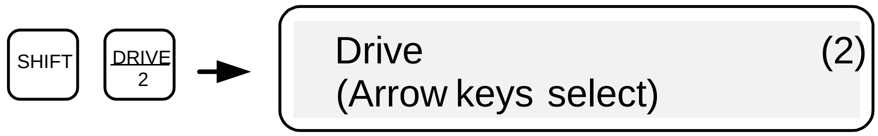

Figure 4-13: Status Display After [SHIFT] + [2] Sequence

Figure 4-14: Status Display After [⇩] [⇩] Key Sequence

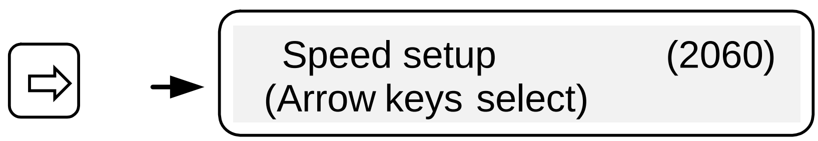

Figure 4-15: Status Display After [⇨] Key Sequence

Figure 4-16: Status Display After [⇩] Key Sequence

Figure 4-17: Status Display After [ENTER] Key to Change a Parameter

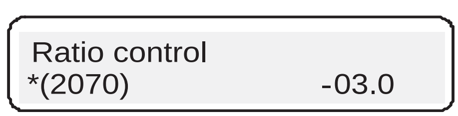

Figure 4-18: Status Display Upon Entering a Value In the Range of the System

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 4-20). 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.

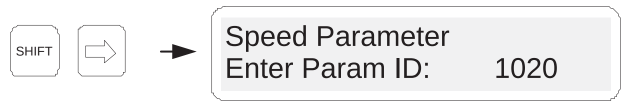

Figure 4-19: Status Display After [SHIFT] [⇨] and the Parameter ID 1020 is Entered

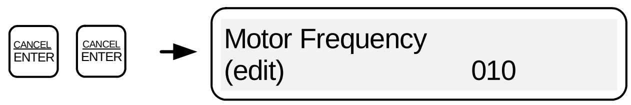

Figure 4-20: Status Display After [ENTER] [ENTER]

Figure 4-21: Status Display Upon Entering a Value Beyond the range of the System

4.3 Multi-Language Keypad

The Multi-Language keypad is intended to be a direct replacement for the existing standard keypad. This section pertains to the Multi-Language keypad hardware and operation. The actual contents of the parameter menu system are 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 and 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 (Figure 4-22). This keypad/display interface is located on the front of the Perfect Harmony Drive Control Cabinet. The ML keypad architecture consists of five parts:

1. Key buttons for human input
2. Display for visual output
3. Support electronics
4. Mechanical mounting
5. Software

The electrical connection and mechanical fit/mounting are the same between the ML Keypad and the existing standard keypad.

> ☝ **Note:** Eagle version 5.0 software for the NXG type VFD control is required to fully utilize the language display capabilities of the Multi-Language keypad.
>
> Prior versions of Eagle control software before version 5.0 will also be compatible with the ML keypad, but will have reduced capabilities.

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 in Tables 4-7 and 4-8.

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.

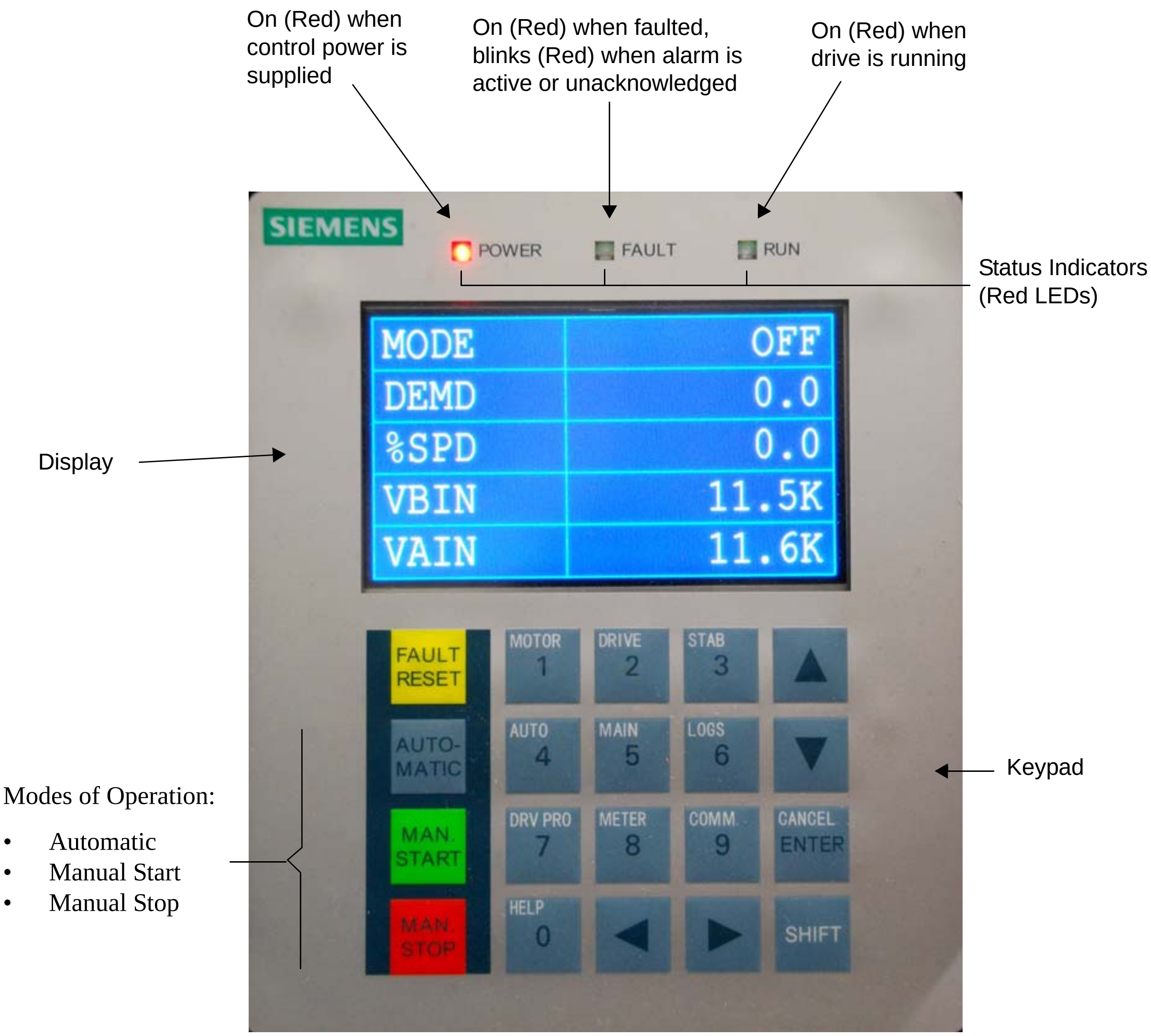

Figure 4-22: The Multi-Language Keypad and Display Interface of the Perfect Harmony Series

The Perfect Harmony Multi-Language Keypad contains 20 keys. Each of these keys has at 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.

4.3.1 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 4-5 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 a generic fault reset, but can also be changed to incorporate system logic specific to an application.

4

Table 4-5: Fault LED Conditions

Fault LED Condition[1]	Display	Fault Condition	Alarm Condition	Alarm Acknowledged or Fault Reset?
Flashing	Status display will be reduced in height and alarm name will be shown in yellow box at bottom of display.	N/A	Active (not acknowledged)	No
Flashing*	Status display will be reduced in height and alarm name will be shown in yellow box at bottom of display.	N/A	Cleared (not acknowledged)	No
Flashing	None	N/A	Active (acknowledged)	Yes
Flashing **Note:** See Figure 4-23 below	Status display will be reduced in height and alarm names will be shown in rotation in yellow box at bottom of display.	N/A	Multiple unacknowledged Alarms	No
On Continuously***	Fault name **Note:** Background is red for fault display.	Active	N/A	No
On Continuously***	Fault name within display** **Note:** Background is red for fault display.	Multiple Faults	N/A	No

[1] *Up to three faults can be displayed simultaneously on the display.*

* *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.*

****Assumes the "Fault Display Override" (ID 8200) is "Off".*

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.

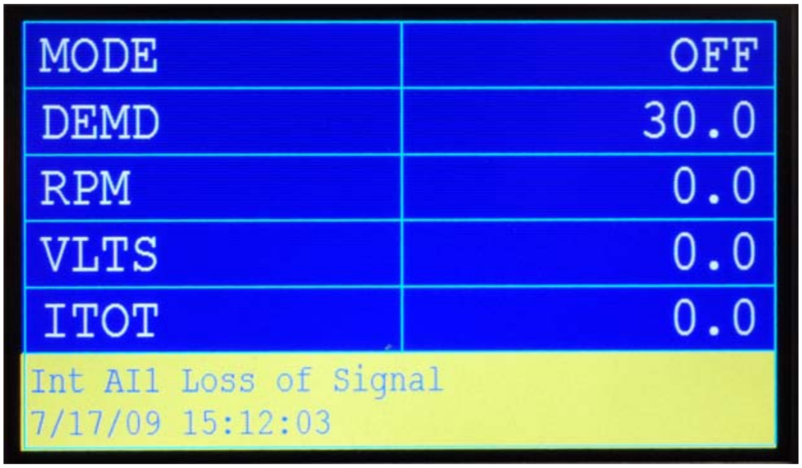

Figure 4-23: Multiple Alarms Active

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.

> **Note:** When the fault log is full of unacknowledged faults or alarms (greater than 256), the display shows this message: “Fault/Alarm log” “overflow”. The cause may be an alarm or several that occur and are not manually reset to “acknowledge” the alarm. An alarm sets and resets itself with no external intervention. However, an alarm is never acknowledged until the fault reset button (or remote fault reset) is true - with no fault to reset.

4.3.2 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.

4.3.3 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.

4.3.4 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 4-24.

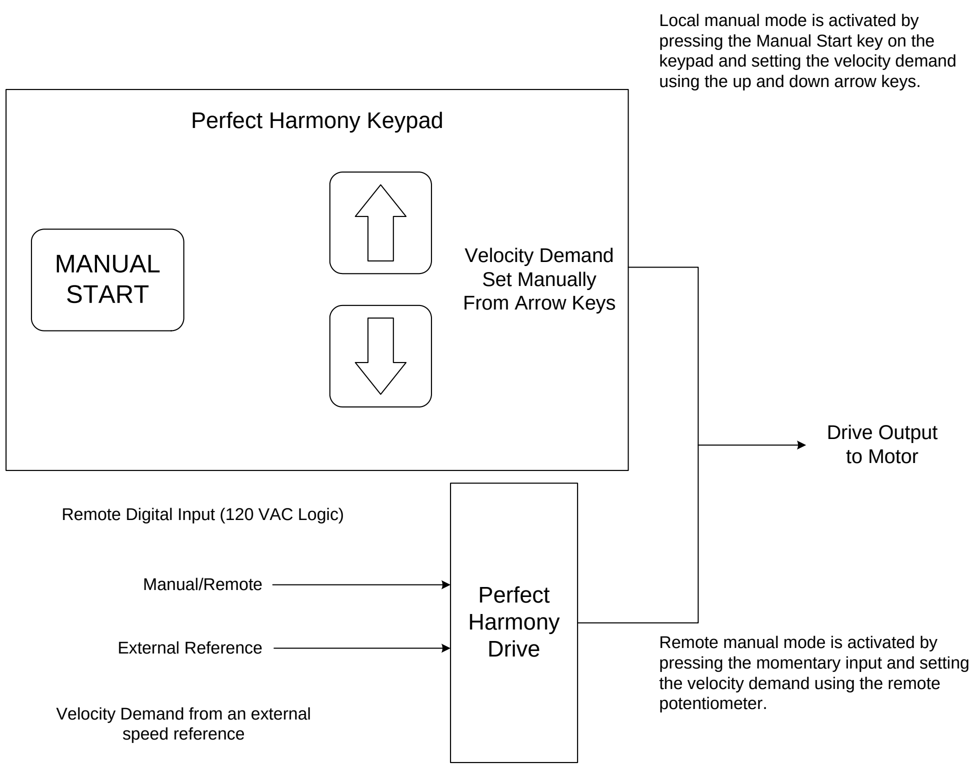

Figure 4-24: Example of Two Programmed Control Modes

4.3.5 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 4-6. 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 4-6 and Figure 4-25 for clarification.

Table 4-6: 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

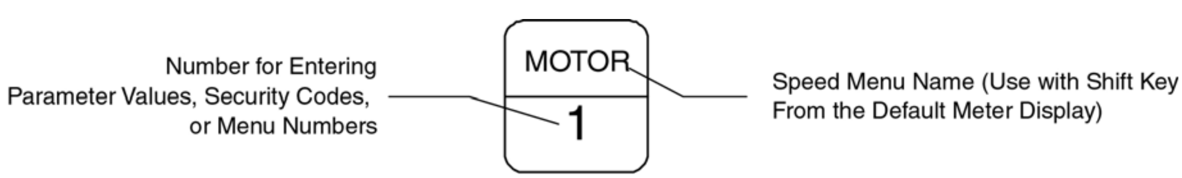

Figure 4-25: Anatomy of a Numeric Keypad Key

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 4-26.

☝ **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.

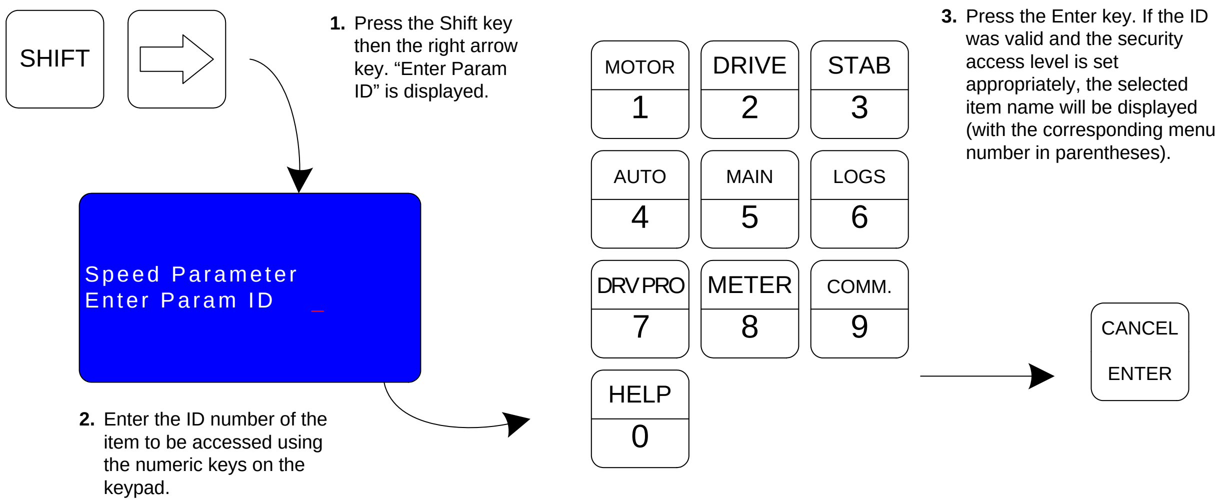

Figure 4-26: Accessing Items Using ID Numbers

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.

4.3.6 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

4.3.7 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 4-6 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 4-27. This Shift Function is a toggle, pressing [SHIFT] again before pressing any other key removes the pending SHIFT and clears the indicator.

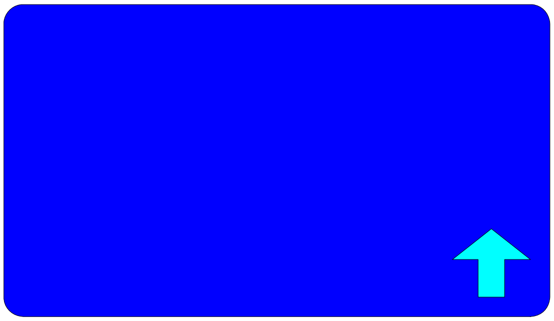

Figure 4-27: Location of Shift Mode Indicator on the Perfect Harmony Display

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 4-7.

4.3.8 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/decrementing 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 4.3.4). 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 4-28.

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 4-7: 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 PR 7	Speed menu to the Drive Protect menu (from the default meter display).
SHIFT + METER 8	Speed menu to the Meter menu (from the default meter display).

Key Combination	Description
[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.
[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.

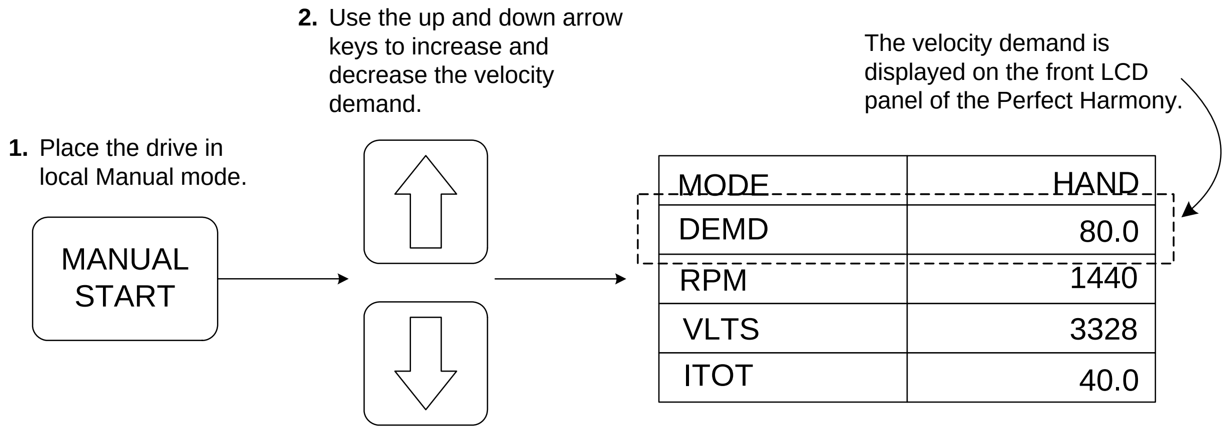

Figure 4-28: Using the Up and Down Arrow Keys to Control Velocity Demand

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 finished (for security reasons), the control can be reset by toggling power to the control 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 4-29.

Figure 4-29: Security Level Cleared Message on the Perfect Harmony Display

Notes:

- 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 4-29. Some common arrow key sequences are listed in Table 4-8. 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 4-8: 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.
[SHIFT] [←]	When editing a value that has been changed from its factory default, this key sequence will return the value to its factory default.

4.3.9 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 4-22 for the location of the 3 diagnostic indicators.

4.3.10 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 4-30).

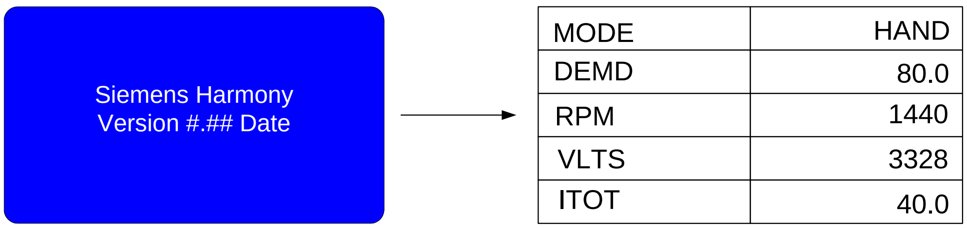

Figure 4-30: The Identification/Version Screen and Meter Displays

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 4-31. The MODE field is fixed. The last 4 fields on the display contain parameter values that can be defined by the operator.

Refer to Chapter 7: *Troubleshooting and Maintenance*, Tables 7-6 and 7-7, which list the mode displays for the first and second lines of the fixed display field, respectively.

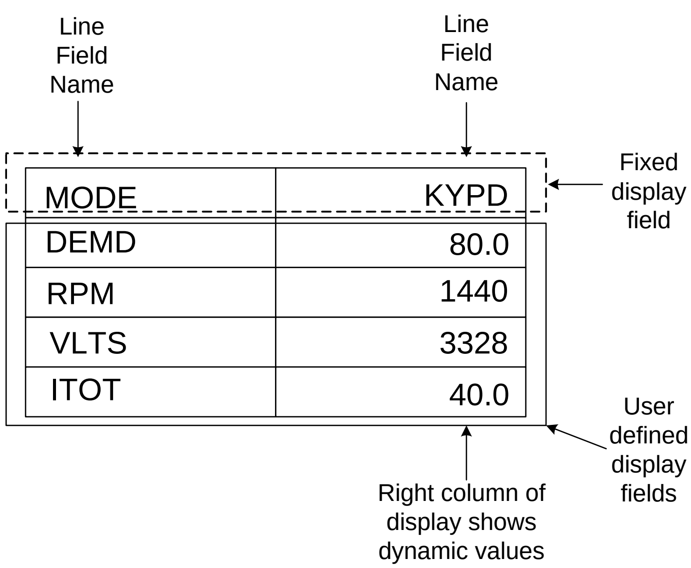

Figure 4-31: Dynamic Programmable Meter Display

The MODE field displays the current operational mode of the Harmony system. This field can have any one of the displays summarized in Table 7-6, depending on the current operational mode or the current state of the drive. Figure 4-32 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).

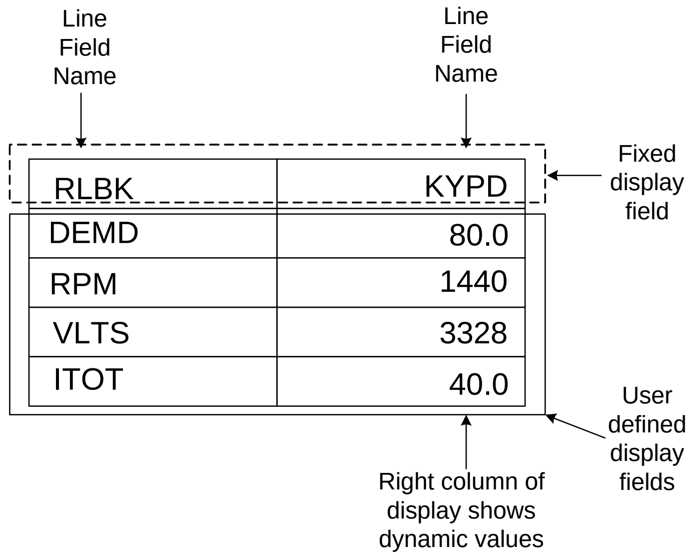

Figure 4-32: Dynamic Programmable Meter Display in Rollback Mode

The KYPD field displays the current operational mode of the Harmony system. This field can have any one of the displays summarized in Table 7-7, depending on the current operational mode or the current state of the drive. Figure 4-33 depicts the display in regeneration mode.

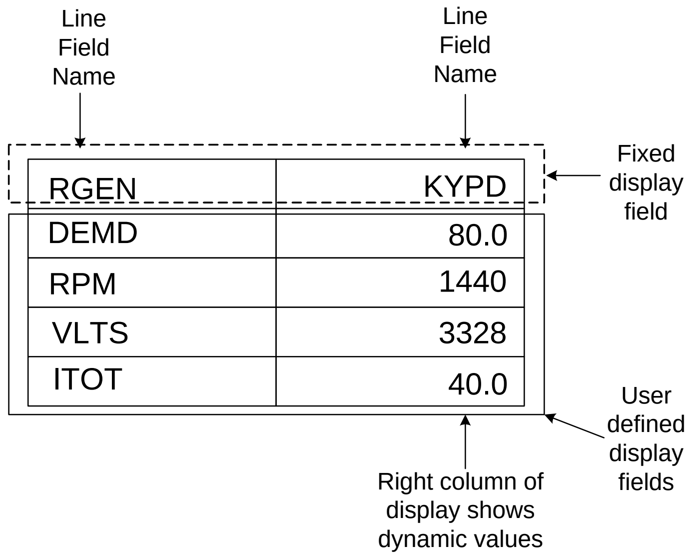

Figure 4-33: Dynamic Programmable Display in Regeneration Mode

The following illustrations depict the multi-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 4-34) shows the “commanded speed reference” in percent. Figure 4-35 depicts the display following a [SHIFT]+[2] ([DRIVE]) key combination. From this point, the nine standard menus listed in Table 4-9 can then be selected using the up / down arrow keys ([⇧] and [⇩]). Figure 4-36 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 4-38 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 4-39 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 4-40 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.

MODE	HAND
DEMD	80.0
RPM	1440
VLTS	3328
ITOT	40.0

Figure 4-34: Display In Status/Metering Mode

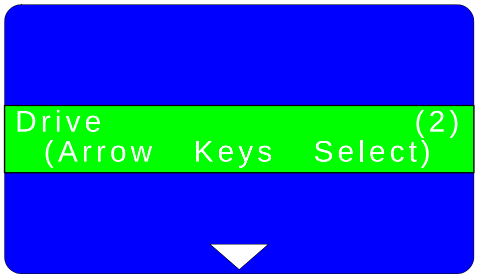

Figure 4-35: Display After [SHIFT] + [2] Sequence

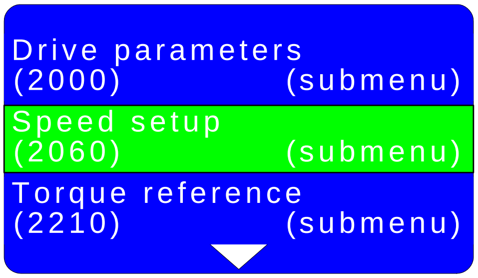

Figure 4-36: Display After [⇩] [⇩] Key Sequence

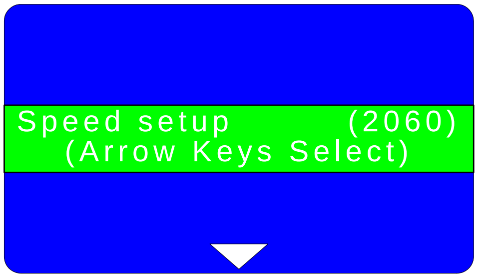

Figure 4-37: Display After [⇨] Key Sequence

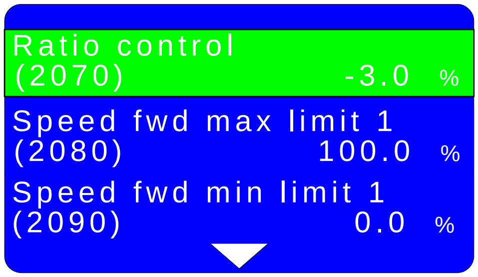

Figure 4-38: Display After [⇩] Key Sequence

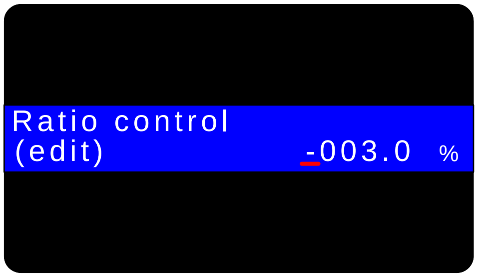

Figure 4-39: Display After [ENTER] Key to Change a Parameter

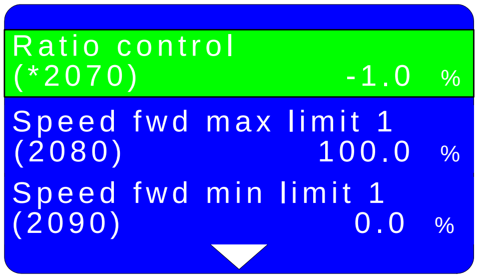

Figure 4-40: Display Upon Entering a Value In the Range of the System

In the following example, press [SHIFT] [⇨] to get to the Parameter ID display. The parameter ID for Motor Frequency (1020) is entered. See Figure 4-41. The [ENTER] key is pressed once to show the Motor Frequency display, and then [ENTER] is pressed again to edit its value (Figure 4-42). Figure 4-43 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.

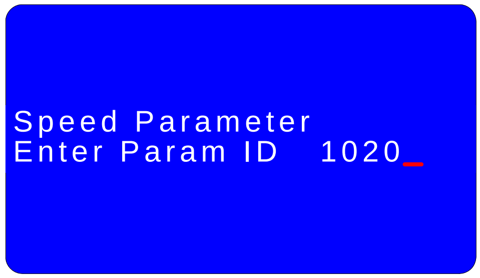

Figure 4-41: Display After [SHIFT] [⇨] and the Parameter ID 1020 is Entered

Figure 4-42: Display After [ENTER] [ENTER]

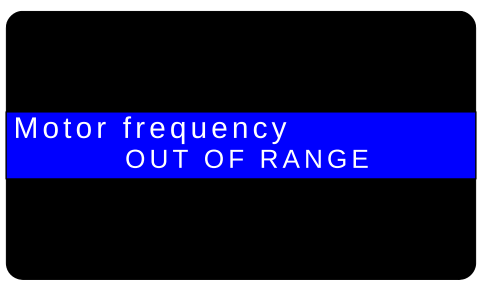

Figure 4-43: Display Upon Entering a Value Beyond the range of the System

4.4 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* (A1A902291).

The ToolSuite contains the following:

- Drive Tool
- Debug Tool
- SOP Utilities
- Configuration Update Utility

4.4.1 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:

- Drive Configuration
- Drive Variable Graphing
- Drive Status
- Drive Control

4.4.2 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.

4.4.3 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.

4.4.4 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.

4.5 Menu Descriptions

The following sections contain a condensed description of all parameter items available in the Perfect Harmony menu structure. Table 4-9 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.

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☝ **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.

☝ **Note:** 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.

☝ **Note:** Table 4-9 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 4-9 to quickly locate the table in the chapter that explains all of the associated items.

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.

Table 4-9: Perfect Harmony Menu and Submenu Summary

Menu	ID	Submenu Names	ID	Table	Description
Motor Menu	1	Motor Parameter	1000	Table 4-10	Used to enter motor-specific data. These parameters provide PU ratings for most of the output variables.
		Limits	1120	Table 4-11	
		Autotune (Keypad only)	1250	Table 4-13	
		Encoder	1280	Table 4-14	
Drive Menu	2	Drive Parameter	2000	Table 4-15	Used to configure the VFD for various load conditions and drive applications.
		Speed Setup	2060	Table 4-16	
		Torque Reference	2210	Table 4-17	
		Speed Ramp Setup	2260	Table 4-18	
		Critical Frequency	2340	Table 4-19	
		Spinning Load	2420	Table 4-20	
		Conditional Time Setup	2490	Table 4-21	
		Cells	2520	Table 4-22	
		Sync Transfer	2700	Table 4-24	
		External I/O	2800	Table 4-25	
		Internal I/O	2805	Table 4-26	
		Output Connection	2900	Table 4-38	
		High Starting Torque	2960	Table 4-39	
		Watchdog	2970	Table 4-40	
Stability Menu	3	Input Processing	3000	Table 4-42	Used to adjust the VFD's various control loop gains, including current and speed regulator gains.
		Output Processing	3050	Table 4-44	
		Control Loop Test	3460	Table 4-51	
Auto Menu	4	Speed Profile	4000	Table 4-52	Used to configure various speed setpoint, profile, and critical speed avoidance and comparator parameters.
		Analog Inputs	4090	Table 4-53	
		Analog Outputs	4660	Table 4-61	
		Speed Setpoints	4240	Table 4-63	
		Incremental Speed Setup	4970	Table 4-64	
		PID Select	4350	Table 4-65	PID Select Menu contains PID setup parameters.
		Comparator Setup	4800	Table 4-66	Used to configure the analog comparators controlled through the SOP.

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 4-41	
		Auto	4	see Auto Menu, above	
		Logs	6	see Logs Menu, below	
		Drive Protect	7	Table 4-77	
		Meter	8	Table 4-80	
		Communications	9	Table 4-85	
		Security Edit Functions	5000	Table 4-70	Configures security features.
Logs Menu	6	Event Log	6180	Table 4-73	Used to configure and inspect the event, alarm / fault, and historic logs of the VFD.
		Alarm/Fault Log	6210	Table 4-74	
		Historic Log	6250	Table 4-75	
Drive Protect Menu	7	Input Protection	7000	Table 4-78	Adjusts setpoint limits for critical VFD variables.
Meter Menu	8	Display Parameters	8000	Table 4-81	Set up Variables for display to LCD.
		Hour Meter Setup (Keypad only - not in menu tree with Drive Host tool, in Status menu at top)	8010	Table 4-83	
		Input Harmonics	8140	Table 4-84	
		Fault display override (Keypad only - does not show in Drive Host tool)	8200	Table 4-80	

Menu	ID	Submenu Names	ID	Table	Description
Communications Menu	9	Serial Port Setup	9010	Table 4-86	Used for configuring the various Communications features of the VFD.
		Network Control	9943	Please refer to *NXG Communications Manual* (A1A902399)	
		Network 1 Configure	9900		
		Network 2 Configure	9914		
		Display Network Monitor (Keypad only - does not show in Drive Host tool)	9950	Table 4-85	
		Serial echo back test (Keypad only - does not show in Drive Host tool)	9180	Please refer to *NXG Communications Manual* (A1A902399)	
		Sop & serial functions	9110	Table 4-87	
		TCP/IP Setup	9300	Table 4-88	

4.5.1 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 4-10: Motor Parameter Menu (1000)

Parameter	ID	Units	Default	Min	Max	Description
Motor frequency	1020	Hz	60	15	400	Enter the rated or base frequency of the motor from the nameplate.
Full load speed	1030	RPM	1780	1	31500	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	100000.0	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 4-11: Limits Menu (1120)

Parameter	ID	Units	Default	Min	Max	Description
Overload select	1130		Inverse time with speed derating			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	%	105.0	10.0	210.0	Sets the overload level at which a warning is issued (constant mode).
Overload	1140	%	110.0	20.0	210.0	Sets the overload trip level at which the timeout counter is started (constant mode).
Overload timeout	1150	sec	5.0	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 4-12.
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. Torque limit 1 (1190 & 1200) are used as default when no other torque limits are selected via the System Program (SOP). The magnitude of this torque limit is the maximum effective magnitude for the remaining torque limits (1200, 1210, 1220, 1230 & 1240).

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Parameter	ID	Units	Default	Min	Max	Description
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. Selected via System Program (SOP).
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. Selected via System Program (SOP).
Motor torque limit 3	1230	%	100.0	0.0	300.0	Sets the motoring torque limit as a function of the available motor current. Selected via System Program (SOP).
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. Selected via System Program (SOP).
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.
Peak Reduction Enable	1248		VFD volt rating			Selects the Peak reduction (third harmonic injection point) based on VFD or Motor Voltage rating and neutral connection. VFD volt rating (default) Mot volt rating
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.

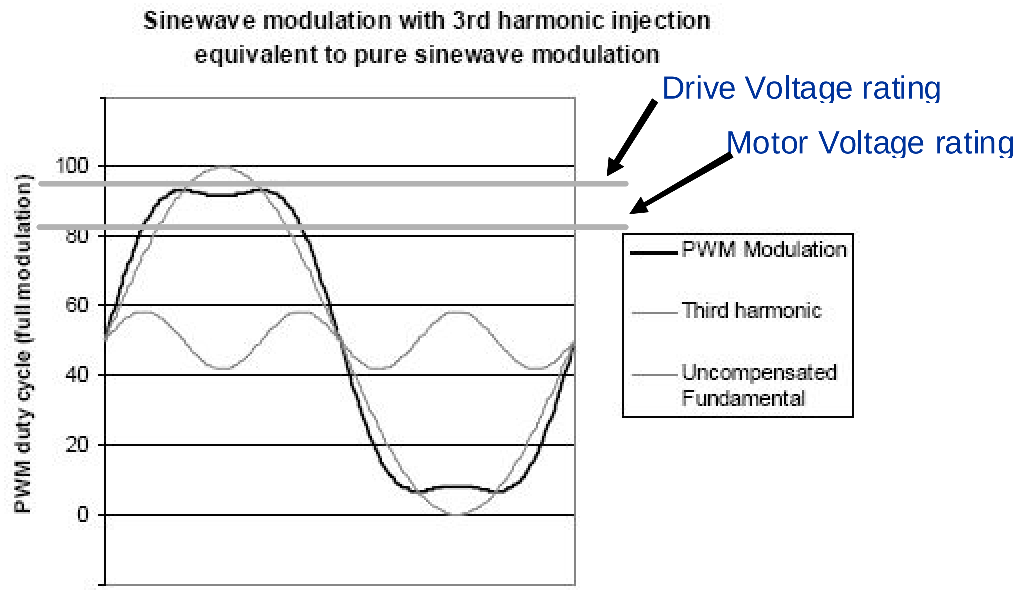

Figure 4-44: Peak Reduction (3rd Harmonic Injection)

The purpose of the “Peak Reduction Enable” (1248) parameter is to set the starting point of third harmonic injection (peak reduction) based on either the VFD Voltage rating (default) or the Motor Voltage rating. This is used in motor test stand applications where the VFD voltage rating may be considerably higher than the motor voltage rating. This is used to reduce voltage stress on the insulation of a smaller motor.

Table 4-12: 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 4-13: 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 4-13). The process is performed in two stages.

Table 4-14: 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		0.75	0.1	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	%	5.0	1.0	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)

4.5.2 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 4-15: 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.

Parameter	ID	Units	Default	Min	Max	Description
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	(% of rated input transformer VA)
Rated Lagging Vars	2043	%	50	0	75	(% of rated input transformer VA)
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.
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)] ÷ [(√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 4-16: 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).

Table 4-17: 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 4-18: 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 4-19: 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.
Frequency avoid accel time	2410	sec	5.0	0	18	The acceleration rate used to pass through critical speed bands.

The critical frequency feature (sometimes called resonance avoidance) is accomplished using skip frequencies and skip bands as defined in Table 4-19. This is illustrated in Figure 4-45.

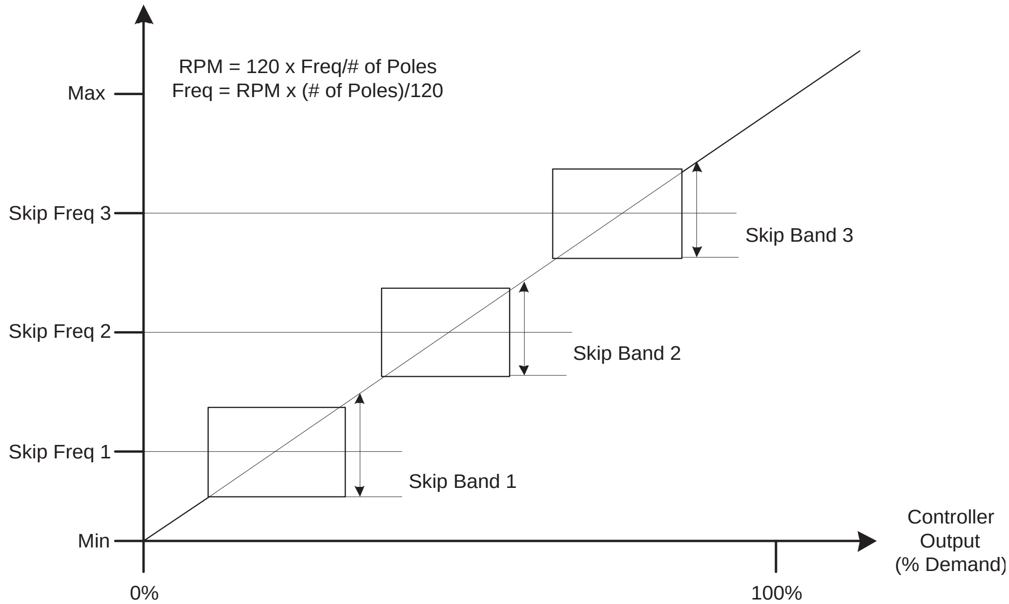

Figure 4-45: . Critical Speed (Resonance Avoidance) Parameters

Table 4-20: 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 4-21: 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 4-22: Cell Menu (2520)

Parameter	ID	Units	Default	Min	Max	Description
Installed cells/ phase	2530		4	1	8	Installed cells per phase in the drive.
Regen cells/ phase	2531		0	0	8	Regen cells per phase (regen drives only)
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 750 Gen IV 1375 HV 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.

Parameter	ID	Units	Default	Min	Max	Description
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
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 (Keypad only)	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.

Parameter	ID	Units	Default	Min	Max	Description
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 HV - 3CB (Resonant Precharge) • Type 2 HV - 2CB (Resonant Precharge) • Type 3 Parallel Drv • Type 4 (Not used) • Type 5 Open (750V AP and 750V AP 4Q) • Type 6 Closed (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
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’ or ‘Type 6 Closed’. Parameter 2550, ‘Cell Voltage’ must be set to either ‘750V AP’ or ‘750V AP 4Q.’ Refer to the *WCIII Product User Manual* (A5E02118669A) for more information on the 750 V AP cell.

Warning!

The drive Precharge will not work properly if relevant parameters are not set correctly.

Table 4-23: 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	200	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		25th			This parameter selects the AFE cell PWM frequency as a multiple of the fundamental frequency. Possible selections are 13th, 15th, 17, 19, 21, 23, 25, 27, 29. 29 is not a valid selection for 60 Hz applications.
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.

Parameter	ID	Units	Default	Min	Max	Description
AP diff temp fault lvl	2596	deg	24	10	30	Sets the AFE cell maximum temperature differential before fault.
AP Mplx Data Select	2597		Air Temp			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.
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.

Parameter	ID	Units	Default	Min	Max	Description
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*

Table 4-24: 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	0.0	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 4-25: 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	10	0	600	Sets the Wago watchdog timeout period. Setting to zero disables this function.

Note: For proper functioning of the Wago timeout, the Enable (CPU) Watchdog parameter (ID 2971) must also be enabled. The Wago Fieldbus coupler DIP switches must also be set correctly (see section 3.10.2 *Wago Modbus Coupler Settings*).

4.5.3 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.

Table 4-26: 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 4-27
Internal Analog Input #2 Setup Menu	2825	Submenu				Contains the Setup menu for Internal Analog Input #2. See Table 4-28
Internal Analog Input #3 Setup Menu	2835	Submenu				Contains the Setup menu for Internal Analog Input #3. See Table 4-29
Internal Analog Output #1 Menu	2845	Submenu				Contains the Setup menu for Internal Analog Output #1. See Table 4-30
Internal Analog Output #2 Menu	2855	Submenu				Contains the Setup menu for Internal Analog Output #2. See Table 4-31
Internal Test Point #28 Setup Menu	2860	Submenu				Contains the Setup menu for Internal Test Point #28. See Table 4-32
Internal Test Point #29 Setup Menu	2865	Submenu				Contains the Setup menu for Internal Test Point #29. See Table 4-33
Internal Test Point #31 Setup Menu	2870	Submenu				Contains the Setup menu for Internal Test Point #31. See Table 4-34
Internal Test Point #24 Setup Menu	2875	Submenu				Contains the Setup menu for Internal Test Point #24. See Table 4-35
Internal Test Point #25 Setup Menu	2880	Submenu				Contains the Setup menu for Internal Test Point #25. See Table 4-36
Internal Test Point #26 Setup Menu	2885	Submenu				Contains the Setup menu for Internal Test Point #26. See Table 4-37

Table 4-27: 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 4-28: 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 4-29: 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 4-30: 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 4-31: 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 4-32: 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		0.00	0.00	10.00	Scales output range of selected variable

Table 4-33: 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		0.00	0.00	10.00	Scales output range of selected variable

Table 4-34: 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		0.00	0.00	10.00	Scales output range of selected variable

Table 4-35: 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		0.00	0.00	10.00	Scales output range of selected variable

Table 4-36: 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		0.00	0.00	10.00	Scales output range of selected variable

Table 4-37: 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		0.00	0.00	10.00	Scales output range of selected variable

Table 4-38: 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.

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Table 4-39: 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 4-40: Watchdog Menu (2970)

Parameter	ID	Units	Default	Min	Max	Description
Enable watchdog	2971		Enable			Enables or disables the CPU watchdog which watches the various threads. If a thread stops running, the watchdog will timeout, tripping the drive by allowing the modulator watchdog to timeout. No fault is recorded (see section 5.26).

Note: It is highly recommended that this parameter be set true. If the Wago System is being used, then this parameter must be enabled for proper operation of the Wago Timeout (ID 2850).

4.5.4 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 the tables that follow.

Table 4-41: 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 4-42.
Output Processing Menu	3050	Submenu				Contains all of the sub menus related to drive motor side processing. See Table 4-44.
Control Loop Test Menu	3460	Submenu				Contains all of the sub menus related to speed and torque loop testing. See Table 4-51.
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.
Sampling Delay comp	3570	%	0	0	150	Compensates flux vector angle for Sampling delay on high speed motor operation.
Carrier frequency	3580	Hz	400.0	100.0	1550.0	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).

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Table 4-42: 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	1	32767	Sets scaling for input nominal value. This is the sum of the two input resistors per phase.

Table 4-43: 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	12000	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	0.1	3	Weight applied to Var error depending upon how many AFE cells are in saturation.

Table 4-44: 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 4-45.
Flux control	3100	Submenu				This menu contains the flux control parameters. See Table 4-46.
Speed loop	3200	Submenu				This menu contains the speed loop parameters. See Table 4-47.
Current loop	3250	Submenu				This menu contains the current loop parameters. See Table 4-48.
Stator resistance	3300	Submenu				This menu contains the stator resistance estimator parameters. See Table 4-49.
Braking	3350	Submenu				This menu contains the dual frequency braking parameters. See Table 4-50.
PLL prop gain	3420		188	1	500	Flux vector PLL prop gain - should not be changed from default.
PLL integral gain	3430		2760	0	12000	Flux vector PLL integral gain - should not be changed from default.
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	32767	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 4-45: 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. The NXGII Standard I/O board must be set the same as the -00 board using the default 12.566 value. There is no -02 System I/O board.
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.

Table 4-46: 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	0.16	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.
Flux droop	3195	%	0	0	200	Flux droop for parallel drives.

Table 4-47: 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 4-48: 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.*

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Table 4-49: 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 4-50: 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 or six step regeneration are enabled, Dual Frequency Braking is disabled.

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Table 4-51: 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.

4.5.5 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 4-52: 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 4-46 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.

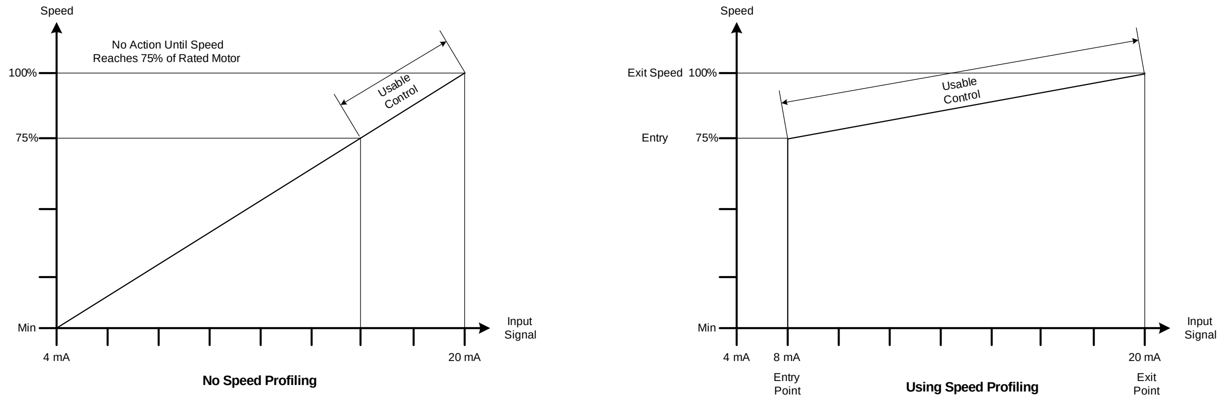

Figure 4-46: Advantages of Using Speed Profiling Control

Table 4-53: Analog Input Menu (4090)

Parameter	ID	Type	Description
Analog input #1	4100	Submenu	Menu for Analog input #1. See Table 4-54.
Analog input #2	4170	Submenu	Menu for Analog input #2. See Table 4-55.
Analog input #3	4232	Submenu	Menu for Analog input #3. See Table 4-56.
Analog input #4	4332	Submenu	Menu for Analog input #4. See Table 4-57.
Analog input #5	4341	Submenu	Menu for Analog input #5 See Table 4-58.
Auxiliary input #1	4500	Submenu	Menu for Auxiliary input #1. See Table 4-59.
Auxiliary input #2	4580	Submenu	Menu for Auxiliary input #2. See Table 4-60.

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 4-54 and 4-55 for scaling information.

Table 4-54: 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 4-55: 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 4-54 and 4-55 for scaling information.

Table 4-56: Analog Input #3 Menu (4232)

Parameter	ID	Units	Default	Min	Max	Description
Source	4233		Off			This parameter sets the input source for analog input #3. Off Ext 1-24
Type	4234		4 – 20mA			This parameter sets the operational mode for analog input #3. 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.

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Table 4-57: Analog Input #4 Menu (4332)

Parameter	ID	Units	Default	Min	Max	Description
Source	4333		Off			This parameter sets the input source for analog input #4. Off Ext 1-24
Type	4334		4 – 20mA			This parameter sets the operational mode for analog input #4. 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.

Table 4-58: Analog Input #5 Menu (4341)

Parameter	ID	Units	Default	Min	Max	Description
Source	4342		Off			This parameter sets the input source for analog input #5. Off Ext 1-24 **Note** - Analog input number is redundant since the menu (and in this case the table text) has the input number displayed.
Type	4343		4 – 20mA			This parameter sets the operational mode for analog input #5. 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.

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Table 4-59: Auxiliary Input #1 Menu (4500)

Parameter	ID	Units	Default	Min	Max	Description
Source	4510		Off			Auxiliary input #1 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).
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.

Table 4-60: Auxiliary Input #2 Menu (4580)

Parameter	ID	Units	Default	Min	Max	Description
Source	4590		Off			Auxiliary input #2 source Off Ext 1-3
Type	4600		4 – 20mA			This parameter sets the operational mode for analog input #2. 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.

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Table 4-61: 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 4-62.
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 4-62: Pick list for Analog Variable parameters (all units are %)

Motor Voltage	Input Power Avg	Analog Input #1
Total Current	Input Pwr Factor	Analog Input #2
Average Power	Ah Harmonic	Analog Input #3
Motor Speed	Bh Harmonic	Analog Input #4
Speed Demand	Total Harmonics	Analog Input #5
Speed Reference	Xfmr Therm Level	Analog Input #6
Raw Flux Demand	1 Cycle Protect	Analog Input #7
Flux Reference	Single Phase Cur	Analog Input #8
Current (RMS)	Under Volt Limit	Input KVAR
Zero Sequence Av	Out Neutral Volts	Drive Losses
Neg Sequence D	Synch Motor Field	Excess React I
Neg Sequence Q	Motor Torque	Spd Droop %
Input Frequency	Encoder Speed	

Table 4-63: 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 4-64: 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 4-65: 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 4-54 and 4-55 for scaling information.

Attention!

The user is responsible for providing correct inputs for PID command and feedback.

Table 4-66: 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 4-67.

Table 4-67: 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 4-68.
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)

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Table 4-68: Variable Pick List for Comparator Setup Submenus

Manual Value	Analog Input 13	Motor current
Analog Input 1	Analog Input 14	Enter Manual Value
Analog Input 2	Analog Input 15	Max Avail Out Vlt
Analog Input 3	Analog Input 16	Magnetizing Current Ref (Ids Ref)
Analog Input 4	Analog Input 17	Magnetizing Current (Ids)
Analog Input 5	Analog Input 18	Torque Current Ref (Iqs Ref)
Analog Input 6	Analog Input 19	Torque Current (Iqs)
Analog Input 7	Analog Input 20	Input frequency
Analog Input 8	Analog Input 21	Manual ID Number*
Analog Input 9	Analog Input 22	Internal Analog input 1
Analog Input 10	Analog Input 23	Internal Analog input 2
Analog Input 11	Analog Input 24	Internal Analog input 3
Analog Input 12	Motor speed	

**Reference Appendix D 'Manual ID's for Comparators' for further listings.*

4.5.6 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 4-47 depicts a typical menu selection from the Main Menu level.

Figure 4-47: : Example of Main Menu

Main Menu (**5**) functions and submenus are explained in the tables that follow.

Table 4-69: 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 4-72.
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 are as follows:

Table 4-70: 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 4-71.
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 4-71.

Table 4-71: 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 **completely** 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 4-72: 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: 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 4-72.

4.5.7 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.

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.

Table 4-73: Event Log Menu (6180)

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 4-74: 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.

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).

Table 4-75: Historic Log Menu (6250)

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 4-76 for pick list variables.
Historic log variable 2	6270	Trq I Cmd	Select the 2nd variable for the historic log. See Table 4-76 for pick list variables.
Historic log variable 3	6280	Mtr Flux	Select the 3rd variable for the historic log. See Table 4-76 for pick list variables.
Historic log variable 4	6290	Pwr Out	Select the 4th variable for the historic log. See Table 4-76 for pick list variables.
Historic log variable 5	6300	I Total Out	Select the 5th variable for the historic log. See Table 4-76 for pick list variables.
Historic log variable 6	6310	Mag I Fdbk	Select the 6th variable for the historic log. See Table 4-76 for pick list variables.
Historic log variable 7	6320	Mtr Flux	Select the 7th variable for the historic log. See Table 4-76 for pick list variables.
Historic log upload	6330		Upload Historic log to serial port.

Table 4-76: 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

4.5.8 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 the tables that follow.

Table 4-77: Drive Protect Menu (7) Parameters

Parameter	ID	Units	Default	Min	Max	Description
Input Protection	7000		Submenu			Input protection parameters. See Table 4-78.
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.

Reference Appendix E ‘Auto Resettable Faults’ for a listing of these faults.

Table 4-78: Input Protect Menu (7000)

Parameter	ID	Units	Default	Min	Max	Description
Single phasing	7010	Submenu				Single phasing protection parameters. See Table 4-79.
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.
UV Flux Reduction gain	7075		0.05	0.0	0.5	Undervoltage Flux Reduction Integrator regulator gain term. Rolls back flux demand on induction motors when up against the modulation index clamp limit.
UV Flux Recovery gain	7076		0.01	0.0	0.5	Undervoltage Flux Recovery Integrator regulator gain term.
MI Lim Reduce gain	7077		0.01	0.0	0.5	Overmodulation Speed Reduction Integrator regulator gain term.Rolls back speed demand on PMM motors when up against the modulation index clamp limit
MI Lim Recover gain	7078		0.01	0.0	0.5	Overmodulation Speed Recovery Integrator regulator 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.

Parameter	ID	Units	Default	Min	Max	Description
1 Cycle Max React Curr	7082	%	5.0	3.5	8.0	Sets the maximum level of allowable Reactive Current at idle.
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, +10%} 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.

Table 4-79: 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

4.5.9 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 the tables that follow.

Table 4-80: Meter Menu (8)

Parameter	ID	Units	Default	Min	Max	Description
Display Parameters	8000	Submenu				This menu contains display parameters. See Table 4-81.
Hour Meter Setup	8010	Submenu				This menu contains hour meter setup. See Table 4-83.
Input Harmonics	8140	Submenu				This menu contains input harmonics. See Table 4-84.
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 digits). This has been obsoleted by 8101 on 4.1.0 code.
Customer order	8101		0	0	9999999999	Customer order number (10 digits). Replaces ID 8100 on version 4.1.0 and later.
Customer drive	8110		1	0	20	Customer drive number.

Table 4-81: 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 4-82.
Status variable 2	8002	%SPD	Select variable 2 to be displayed on the LCD display. Pick List - See Table 4-82.
Status variable 3	8003	VLTS	Select variable 3 to be displayed on the LCD display. Pick List - See Table 4-82.
Status variable 4	8004	ITOT	Select variable 4 to be displayed on the LCD display. Pick List - See Table 4-82.
Status variable 5	8005	IMRF	Select variable 5 to be displayed on the Tool* display. Pick List - See Table 4-82.
Status variable 6	8006	IMRF	Select variable 6 to be displayed on the Tool* display. Pick List - See Table 4-82.
Status variable 7	8007	IMRF	Select variable 7 to be displayed on the Tool* display. Pick List - See Table 4-82.
Status variable 8	8008	IMRF	Select variable 8 to be displayed on the Tool* display. Pick List - See Table 4-82.
Status variable 9	8009	IMRF	Select variable 9 to be displayed on the Tool* display. Pick List - See Table 4-82.

This menu contains the pick lists to select the variables to be displayed on the front panel default display.

**Available for Drive Host tool (only).*

Note: Table 4-82 contains symbol, text and comments columns of standard pick list variables (used in the Historic Log Menu, the Display Variable Menu, etc.). The symbol column contains an abbreviated form of the variable name. This abbreviation (between 2 and 5 characters in length) is what the Perfect Harmony displays on the front panel of the drive.The text 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 comments column gives a description of the variable.

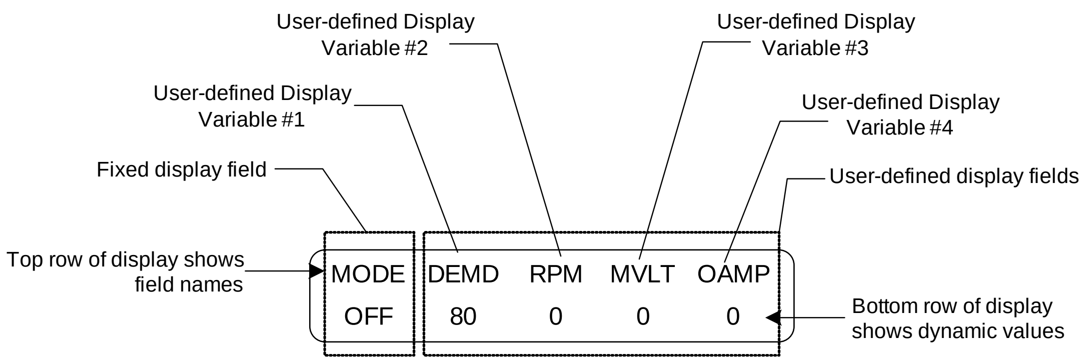

Figure 4-48: Standard Keypad Dynamic Programmable Meter Display

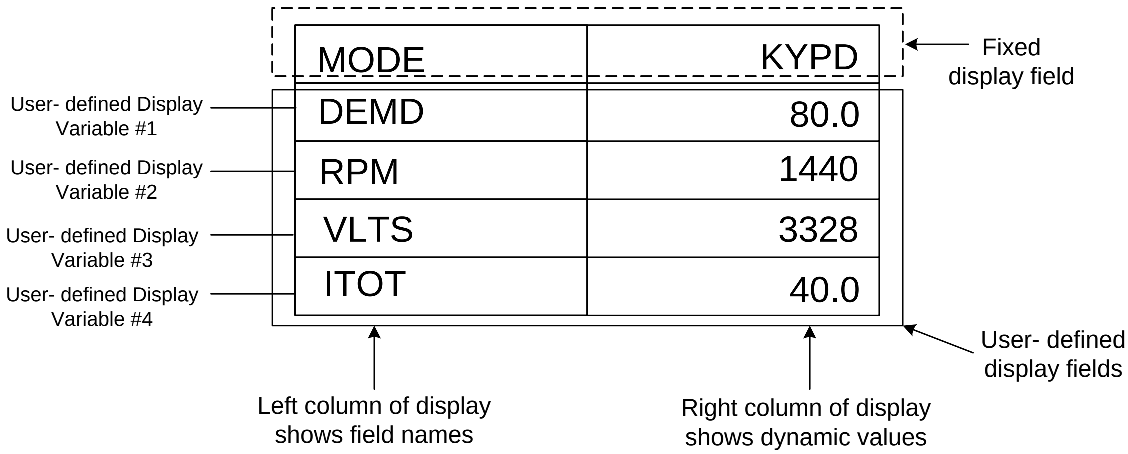

Figure 4-49: Multi-Language Keypad Dynamic Programmable Meter Display

Table 4-82: Pick List Variables for the Front Display

Symbol	Text	Comments
IMRF	Mag current ref (A)	Output Ids reference (amps)
ITRF	Trq current ref (A)	Output Iqs reference (amps)
FLDS	Flux DS (%)	Motor Flux DS - Main flux component - magnitude of flux vector
FLQS	Flux QS (%)	Motor Flux QS - Quadrature component (should be close to or at zero)
VDRF	Vds reference (%)	Motor Vds (direct component) reference
VQRF	Vqs reference (%)	Motor Vqs (quadrature component) reference
SLIP	Slip frequency (%)	Motor slip frequency (%)
%SPD	Motor speed (%)	Motor speed (%)
FREQ	Output Frequency (Hz)	Output Frequency (Hz)
RPM	Motor speed (RPM)	Motor speed - slip (RPM) Motor speed with slip correction
VLTS	Motor voltage (V)	Motor voltage (volts)
IMAG	Mag current filtered (A)	Motor Ids filtered (amps) Motor voltage producing current
ITRQ	Trq current filtered (A)	Motor Iqs filtered (amps) Torque producing current
ITOT	Motor current (A)	Motor Total motor current (amps)
%TRQ	Torque out (%)	Motor Torque (%) Percent of rated torque
KWO	Output power (KW)	Output power (KW) Real output power component
RESS	Stator resistance	Motor stator resistance
DEMD	Speed demand (%)	Motor speed demand - before the ramp (%)
SREF	Speed reference (%)	Motor speed reference - input to speed regulator (ramp output) (%)
FDMD	Raw flux demand (%)	Motor raw flux demand
FXRF	Flux reference (%)	Motor flux reference
IDIN	Id input current (A)	input real current (Amps)
IQIN	Iq input current (A)	input reactive current (Amps)

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Symbol	Text	Comments
IAIN	Phase A input current (A)	phase A input current (Amps RMS)
IBIN	Phase B input current (A)	phase B input current (Amps RMS)
ICIN	Phase C input current (A)	phase C input current (Amps RMS)
IAVI	Total input current (A)	three phase input current (Amps RMS)
VAIN	Phase A input voltage (V)	phase A input voltage (Volts RMS)
VBIN	Phase B input voltage (V)	phase B input voltage (Volts RMS)
VCIN	Phase C input voltage (V)	phase C input voltage (Volts RMS)
VZSQ	Zero sequence voltage (V)	Input Zero sequence average (Volts)
VNSD	Negative sequence D voltage (V)	Input negative sequence D voltage (Volts) - direct component of the negative sequence input voltage - responsible for input losses & heating
VNSQ	Negative sequence Q voltage (V)	Input negative sequence Q voltage (Volts) - quadrature component of the negative sequence input voltage - responsible for input losses & heating
VDIN	Input D voltage (V)	Input voltage Magnitude (Volts RMS)
VQIN	Input Q voltage (V)	Input quadrature voltage - drives the input PLL - too high of a value implies the PLL is not locked onto the input voltage
VAVI	Input voltage (V)	input voltage - three phase, L-L RMS voltage
FRIN	Input frequency (Hz)	input frequency (Hz)
KWIN	Input power average (KW)	input power average (KW)
PFIN	Input power factor (%)	input power factor
HRCA	Ah harmonic coefficient (%)	Input ah harmonic (%)
HRCB	Bh harmonic coefficient (%)	Input bh harmonic (%)
HARM	Total A, B harmonics (%)	Input total harmonics (%)
XTHL	Transformer thermal level (%)	Input transformer thermal level (%)
1CRI	One cycle reactive current level (%)	Input one cycle reactive current level (%)
SPHI	Single phasing current level (%)	Input single phasing current level (%)

Symbol	Text	Comments
UNVL	Under Voltage level (%)	Input Under Voltage level (%)
EFF	Efficiency (%)	Input Drive Efficiency (%)
THD	Total Harmonic Distortion (%)	Input Total Harmonic Distortion (%)
VNGV	Output Neutral Voltage (V)	Output Neutral to ground voltage (volts)
%VNG	Output Neutral Voltage (%)	Output Neutral to ground voltage (%)
SMFC	Synch Motor Field Current (A)	Motor Synch Motor Field Current command
%ESP	Encoder Speed (%)	Motor Encoder Speed in percent
ERPM	Encoder Speed (RPM)	Motor Encoder Speed in RPM
IAF	Phase A filter current (A)	Output Filter Current Ia
IBF	Phase B filter current (A)	Output Filter Current Ia
ICF	Phase C filter current (A)	Output Filter Current Ia
MVAO	Motor Phase A volts (V)	Voltage Phase A (Va) at Drive Output
MVBO	Motor Phase B volts (V)	Voltage Phase B (Vb) at Drive Output
MVCO	Motor Phase C volts (V)	Voltage Phase C (Vc) at Drive Output
MVNG	Measured Output Neutral Voltage (V)	Output Drive Neutral voltage
%MAV	Max Avail Output Volts (%)	Output Maximum Available Output Voltage
KVAR	Input Avg Reactive Power (KVAR)	Input Drive average reactive power
LOSS	Excessive Drive Losses (KW)	Drive internal power losses (input - output)
XRCA	Excessive Reactive current (A)	Input reactive current over max allowed
UXFR	Up Transfer State value	Up Transfer State Machine state variable
DXFR	Down Transfer State value	Down Transfer State Machine state variable
%DRP	Speed Droop (%)	Motor Speed Droop (speed slow-down proportional to torque current) in percent

Table 4-83: 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 4-84: Input Harmonics Menu (8140)

Parameter	ID	Units	Default	Min	Max	Description
Selection for HA (Harmonic Analysis)	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

4.5.10 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 the tables that follow.

Table 4-85: 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 4-86.
Network Control	9943	Submenu				Please refer to *NXG Communications Manual* (A1A902399).
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 4-87.
TCP/IP Setup	9300	Submenu				This menu contains functions which set the parameters for TCP/IP. See Table 4-88.

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Table 4-86: 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 A1A10000096.

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Table 4-87: 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.
Delete system program	9148	Function				Used to delete a System Program file.
Select system program	9145		None			Displays the list of System Program files. (Replaced by 9146 on 4.1.0 and later).
Select system program	9146		nowago.hex			Displays the list of System Program files on the flash disk to allow selecting the active one. (This replaces the parameter 9145 which did the same thing but stored the result as an offset into an array. This function stores the selected file by file name).
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	

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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 4-88: 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 drive IP address in dotted decimal.
Subnet mask	9320		255.255.0.0	0.0.0.0	255.255.255.255	Used to enter the drive subnet mask in dotted decimal.(Keypad only).
Gateway address	9330		172.16.1.1	0.0.0.0	255.255.255.255	Used to enter the drive gateway address in dotted decimal.(Keypad only).

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. (xxxxxxxx.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 4-89).

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).

Table 4-89: 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 4-90: 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
Speed rev max limit 1	2410	Current ramp	2460

Parameter	ID	Parameter	ID
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
Prop gain during brake	3280		

Parameter	ID	Parameter	ID
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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CHAPTER

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 5-2.

Figure 5-2 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:

$$\alpha = \frac{T}{J} \qquad \omega = \int \alpha dt$$

where:

α =	acceleration	T =	torque
J =	inertia (an unsigned magnitude)	ω =	rotational speed.

Figure 5-1: Motor Equations for Speed and Acceleration

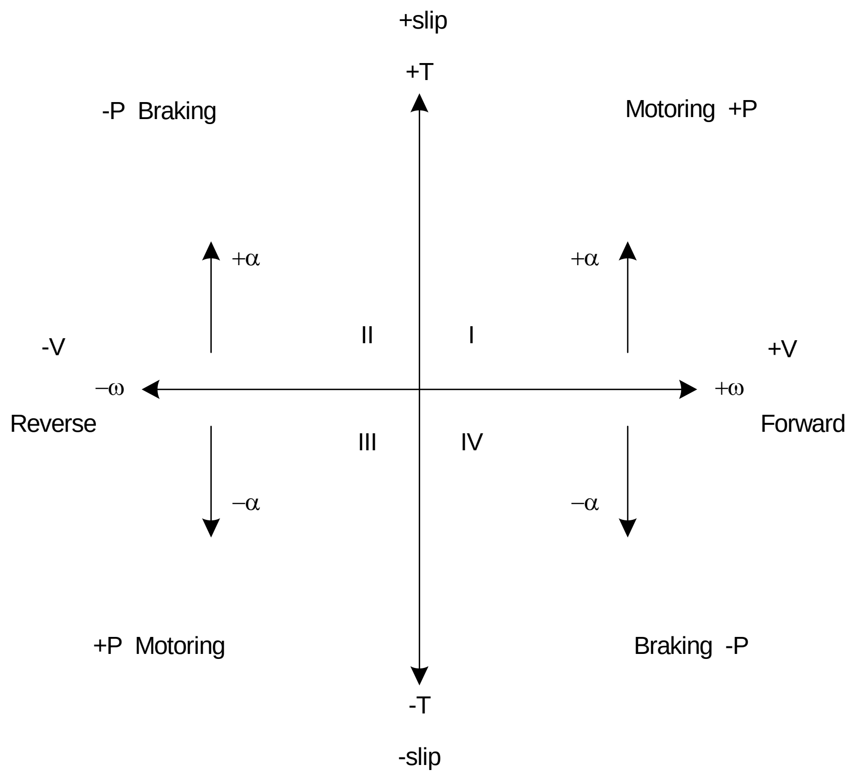

Figure 5-2: Four Quadrant Operation of a Motor

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 between slip and torque.

5

5

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 5-3. 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.

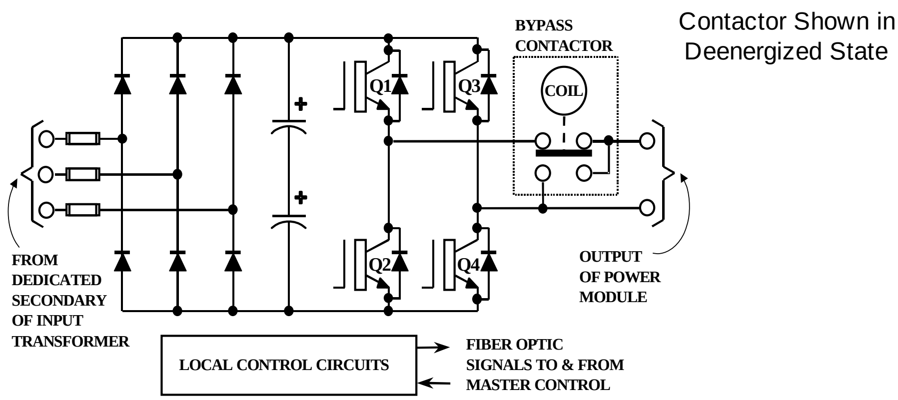

Figure 5-3: Typical Cell with Bypass Contactor

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.

Note: A cell fault is always a drive fault. The ***FatalFault_I*** SOP flag will go true, and the ***DriveRunning_I*** SOP flag will go false momentarily. This may or may not be seen in the SOP when Fast Bypass is enabled since the cell diagnostics thread runs at a higher priority during fast bypass. The run request must be maintained in order for the drive to continue running after the cell is bypassed. Fast Bypass issues an automatic reset to the drive after the cell has successfully bypassed.

5

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 5-4 through 5-9 illustrate the voltage available from a Perfect Harmony drive, where the cells, represented by circles, are shown as simple voltage sources. Figure 5-4 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°.

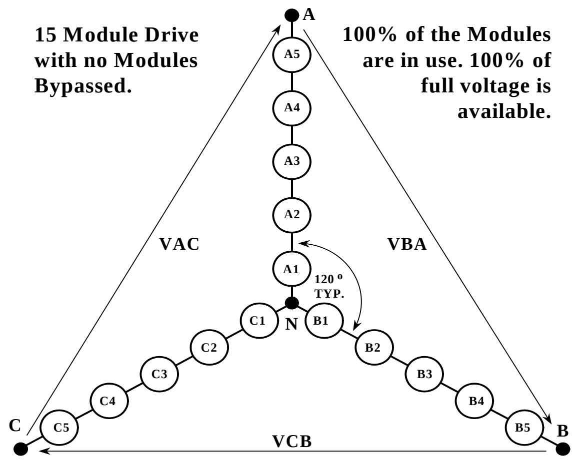

Figure 5-4: A Simplified diagram of a 15 Cell Drive

When cells are bypassed in one of the drive phases, the output voltage will tend to become unbalanced, as illustrated in Figure 5-5. One possible remedy is to bypass an equal number of cells in all three phases, even though some may not have failed. Figure 5-6 illustrates this approach. Obviously, this method prevents unbalance but sacrifices possible voltage capability. In Figure 5-6, 87% of the cells are functional, but only 60% are in use, and only 60% voltage is available.

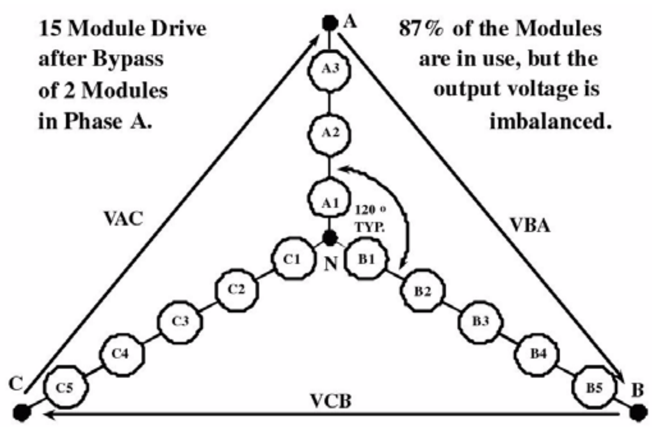

Figure 5-5: Drive output with 2 Cells Bypassed

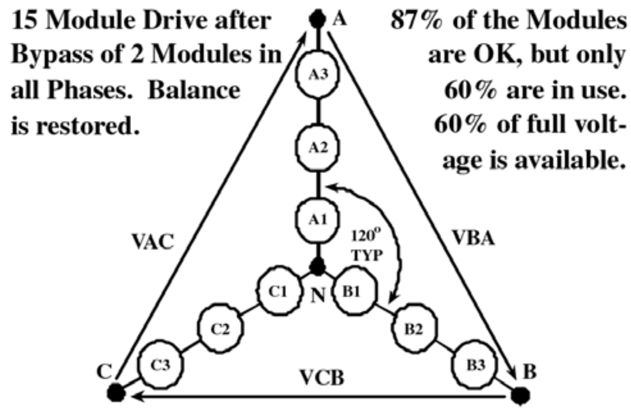

Figure 5-6: Drive output re-balanced by Bypassing Functional Cells

A better approach is illustrated in Figure 5-7. 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 5-7 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°.

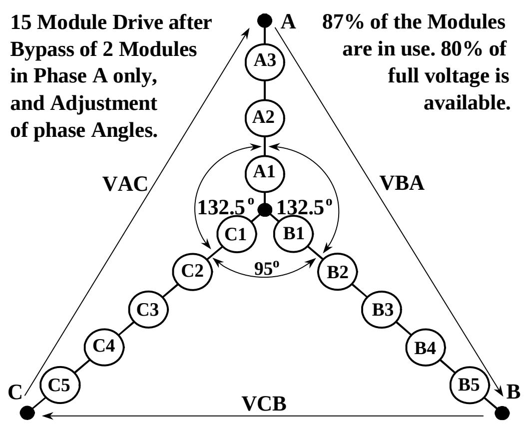

Figure 5-7: Drive output re-balanced by Adjusting Phase Angles (Neutral-Shift)

The same neutral-shift approach can be applied to more extreme situations, as is illustrated by Figures 5-8 and 5-9. Figure 5-8 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 5-8, 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 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.

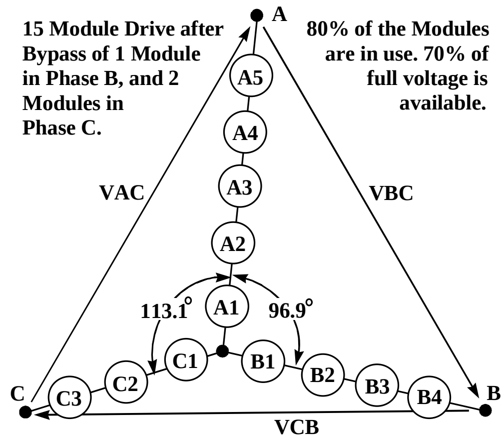

Figure 5-8: Drive output after loss of 3 Cells

As another example, Figure 5-9 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 5-9, 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.

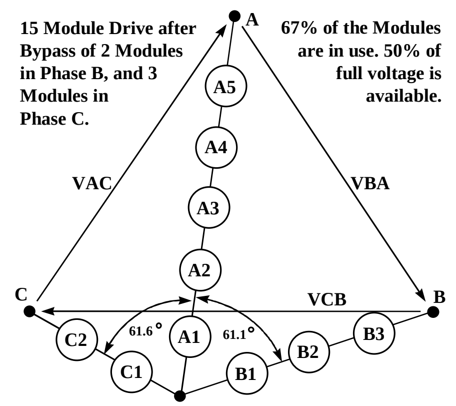

Figure 5-9: Drive output after loss of 5 Cells

Figure 5-10 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:

Vout_bypass = 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):

Vout = 1.78 * 6 * 690 = 7.37 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 = 7370 * (2 * 6 - 3) / (2 * 6) = 5.53 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.

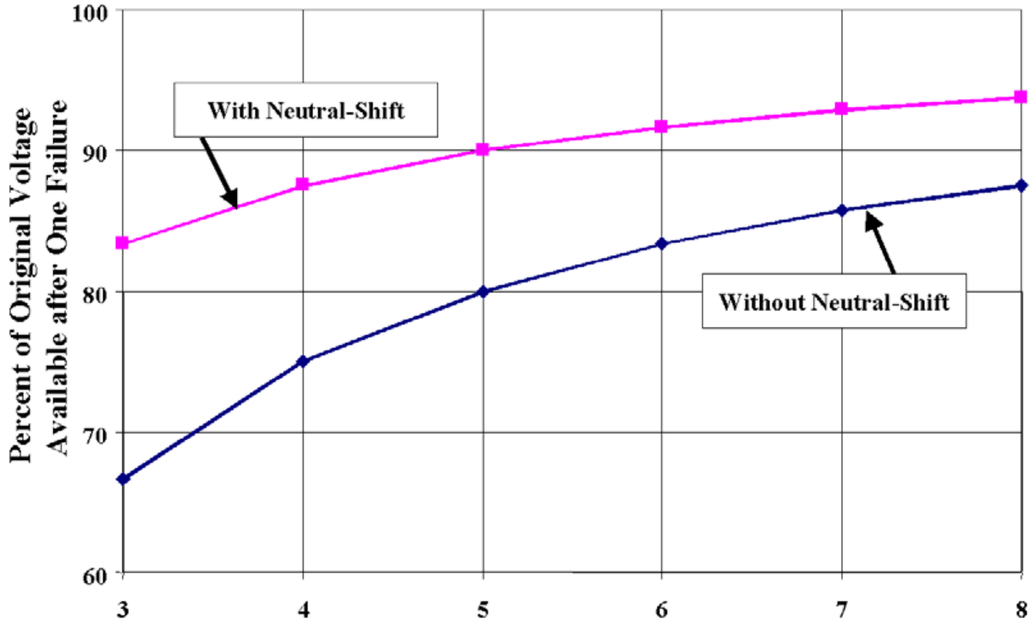

Figure 5-10: Available Voltage After First Failure

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.

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

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 5-11 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 5-12 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.

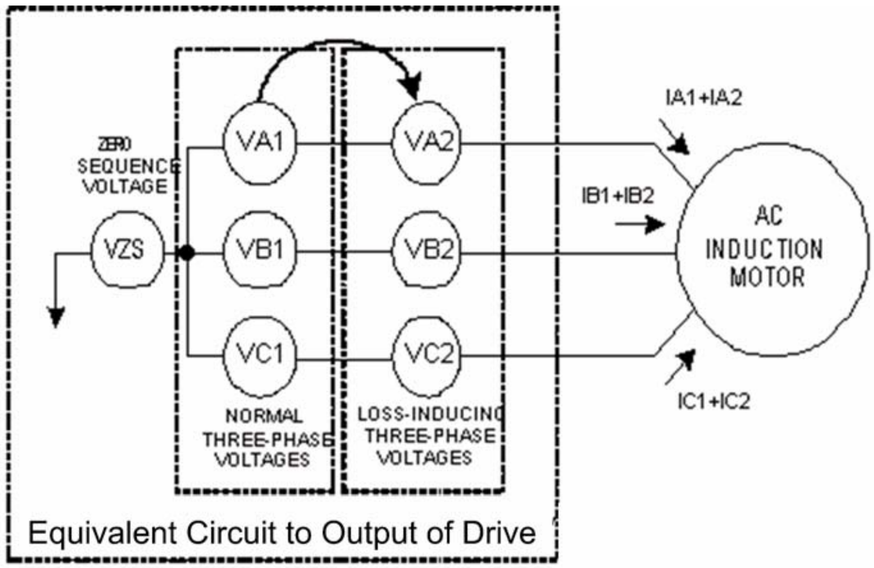

Figure 5-11: Dual Frequency Voltages Being Added Together With The Normal Three-phase Voltages

Note: Zero Sequence Voltage is the DC offset voltage.

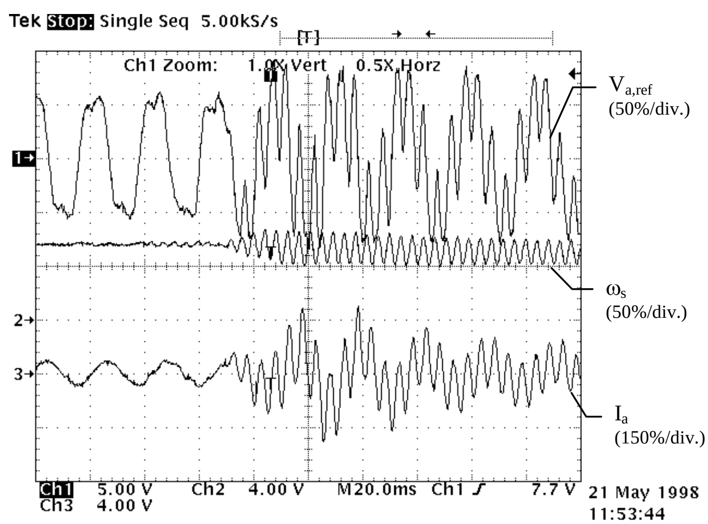

Figure 5-12: Scope Picture Showing Dual Frequency Braking Waveform

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 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.

5.7.3 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

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 5-13 shows the typical braking torque that can be expected with Dual Frequency Braking.

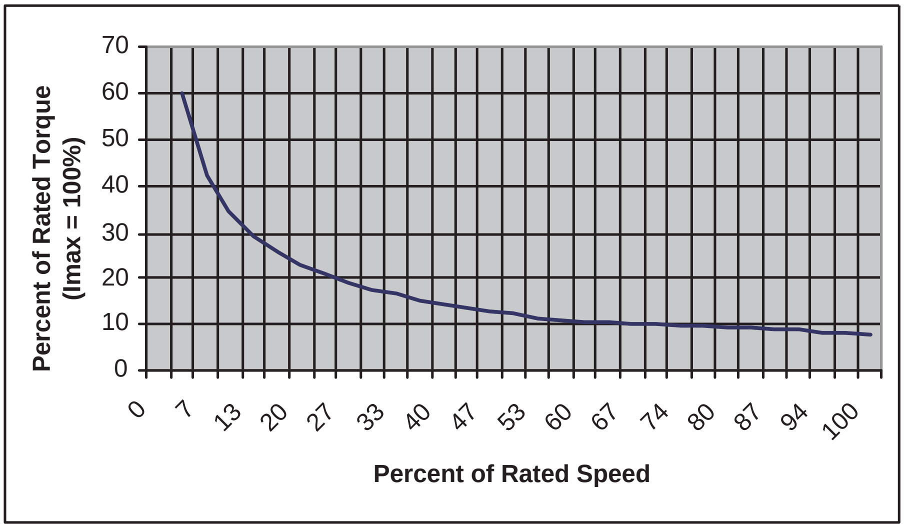

Figure 5-13: Best Case Braking Torque With Dual Frequency Braking For A Typical Motor

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 5-13. 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

NXG Perfect Harmony Control provides a Motor Thermal Overload Model (similar to a TOL) to protect the motor from being subjected to excessive temperatures.

> **Warning!**
>
> The user should understand that this software model does not measure the motor temperature directly; but only estimates it from available data. The estimate is no better that the available data, and no better than the accuracy of the parameters entered. In particular, the software model has no data about the ambient temperature at the location of the motor. For critical applications, a direct measurement method such as RTD's inside the motor should be used.

5

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)	Inv Time w/ derate
Overload pending	1139	Sets the thermal overload level at which a first level warning is issued. Constant mode - This is based on Motor Total Current as a percent of rating. Inverse modes - This is a percentage of Thermal Capacity based on the thermal model Motor heating.	105.0 for constant and inverse time settings
Overload	1140	Sets the motor thermal overload trip level and sets an impending trip warning. Once this level is reached, the timeout counter is started for the overload fault. Constant mode - This is based on Motor Total Current as a percent of rating. Inverse modes - This is a percentage of Thermal Capacity based on the thermal model Motor heating.	110.0 for constant and inverse time settings
Overload timeout	1150	Sets the time for the overload trip once the overload trip level has been reached. Since the inverse time algorithms estimate thermal heating of the motor, the overload timeout should be minimal for trip.	5.0 for inverse time modes 60.0 for constant mode
Speed Derate Curve	1151	This menu sets allowable motor load as a function of speed for tailoring the derating curve to the specific motor manufacturers data for best protection.	Sub-menus define a curve for a quadratic load. If the manufacturers data is available, this should be used instead.
Maximum Load Inertia	1159	Sets the maximum load inertia that the motor can line start without exceeding maximum temperature. This is used in determining the Thermal Capacity of the motor. Entering zero allows the software to estimate the thermal capacity of the motor as the default. If specific data is available, it should be used instead. **Note:** The internal calculation is only valid for HP and Sync Speed within the NEMA Table. (See Note and Table 5-7 at the end of this section for details and caveats.)	0.0 This value cannot be left zero for proper operation of the Inverse Time modes, if the motor parameters are outside the supported range. It is always best to use manufacturers data if available.

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.

Note: For all modes, the heating in the motor is increased by the square of the current above the motor ratings. Therefore a setting of 120% produces an increase of 44% more thermal energy into the motor - $[(1.2)^2 - (1.0)^2 = 0.44$ increase (PU)].

5.9.1 Constant Mode

The first model, which is called “constant,” is based on the total 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.

Note: Both the Alarms 1 and 2 have to be enabled through the SOP for the drive to display those conditions.

The Constant Mode might be appropriate for a motor having a separate blower, and operating in a constant ambient temperature, so that it has constant capability regardless of speed.

Note: Since this method uses a single threshold level, it cannot distinguish between a relatively minor overload condition and a major one. Therefore this method is not recommended as the default. For most applications, the best protection is from the mode - Inverse Time with Speed derating.

5.9.2 Inverse-time Modes

The second and third thermal models, which are called "straight inverse time" and "inverse time with thresholds," use a software motor thermal model to estimate motor heating. See Figure 5-14. For these options, the "overload pending" and "overload" settings represent the motor thermal mass limits (in percent of rated motor thermal mass allowance or capacity) at which the overload warning and trip are generated. This model is based on NEMA ratings as described below. A brief description of the thermal model follows.

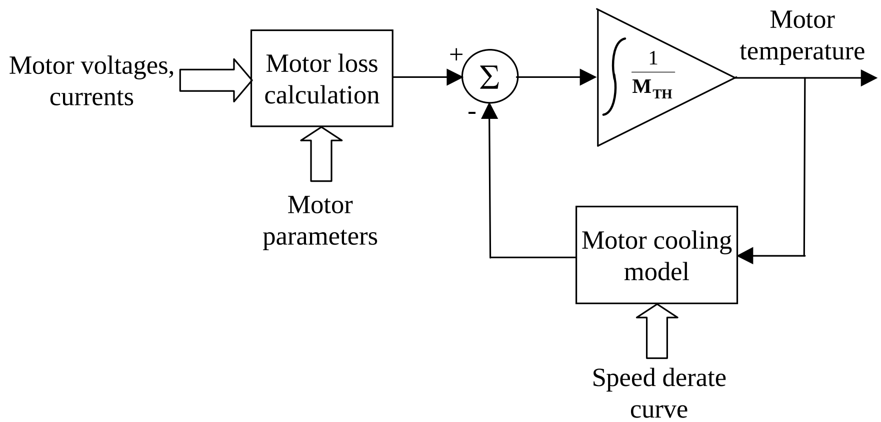

Figure 5-14: Block Diagram Of Motor Thermal Model

The motor model estimates motor temperature based on the net heat generated in the motor and its thermal mass - the amount of thermal energy input to the motor before overheating. This is generally a function of motor losses and how well a motor can cool itself, or be cooled through external means. A block diagram of the implementation is shown in Figure 5-14. The heat generated in the motor is estimated from the stator voltages, currents, and motor parameters, while an estimate of the heat dissipated by the motor due to motor cooling, is made from the allowable motor current. 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 (see Table 5-7). The user has the option of entering a known value of max load inertia as well (which can be obtained from the manufacturer).

The thermal level (or thermal capacity) begins at 1.0 when the control first powers up. The pre-bootup condition of the motor is unknown to the control algorithm, therefore the control uses the following conservative approach. When the motor reaches operating temperature, the level will stabilize at around 1.0 PU (rated thermal capacity) if set correctly. When off, the motor model will produce a "cooling" trend, with the level integrating below this optimal point. If overheating occurs, the value of the level will rise above 1.0 until the alarms and eventually, the trip level are reached.

The thermal level is not retained if control power is turned off, but will begin again at 1.0 PU. Therefore, the algorithm begins by assuming the motor has already reached the rated operating temperature.

The plot in Figure 5-15 shows results from an experimental evaluation of the software thermal model with the "straight inverse time" option (fixed 100% Motor Current rating) for various levels of drive current. This curve is plotted at constant rated speed, and the threshold is fixed for calculating thermal capacity. If the "speed curve" were plotted for this mode, it would appear as a straight line fixed at 100% over the entire speed range.

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.

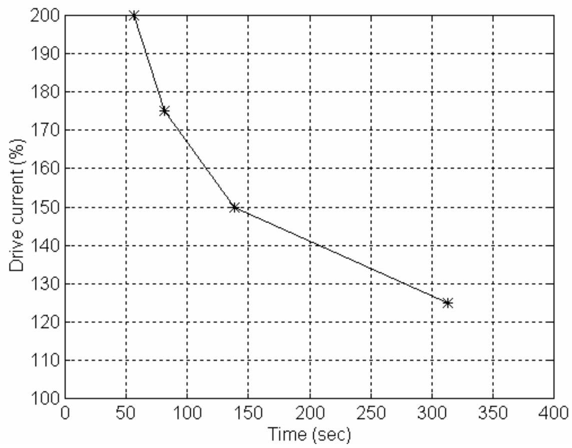

Figure 5-15: Drive Current (In Percent Of Motor Rated Current) Versus Time Taken For Motor Temperature
**The data was measured with the "straight inverse time" option with the motor operating at full speed*

If "straight inverse time" protection is chosen, the motor model thermal curve is based on the Full-load current rating of the motor throughout the entire speed range.

> **Note:** Since this mode uses no derating for reduced speed operation, this setting should only be used for quadratic loads (minimal torque requirements at low speed) or for when the motor is equipped with a constant-speed cooling fan. For constant loads (loading throughout the speed range), "inverse time with speed derating" should be used.

The thermal model is based on motor ratings to attempt to estimate the heating of the motor, where the main thermal input is due to motor losses in direct relationship to the total current (stator and rotor losses). The balance of heat storage (thermal input) and heat loss (cooling) determine the motor temperature, and is known as Thermal Capacity.

> **Note:** This algorithm attempts to estimate this heating, but is an estimate at best, and is not intended to replace external motor thermal monitoring to protect the motor in critical applications.

As the thermal input exceeds the thermal output, the temperature of the motor increases. If this continues unabated, the motor will overheat. Therefore two levels of thermal capacity are established: one to allow for early warning and corrective action, and another for when a fault trip is impending. The control software also follows the curve for cooling when the thermal input becomes lower than the thermal output, such that a lower thermal input produces faster cooling until a new equilibrium is established and the temperature is maintained.

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, thereby eliminating the speed derating and allowing a higher level of operation.

> **Note:** This is not recommended unless the motor has a higher service factor, and a constant speed separate blower.

5

5.9.3 Inverse time with speed derating

The inverse time curve with speed derating is a special case of inverse time protection. Since it derates the maximum motor rating with respect to speed, it provides the best motor protection of the three modes, especially at starting and for low speed operation. For motors without separate blowers, this is the recommended setting.

If Inverse time with speed derating is used, the allowable current level used in the model is determined from the speed-derating curve entered through the keypad. This curve requires the user to enter allowable motor loads for various speed breakpoints. The default-derating curve provides breakpoints for a quadratic cooling curve (and is shown in Figure 5-16). The motor manufacturer normally provides data for this curve.

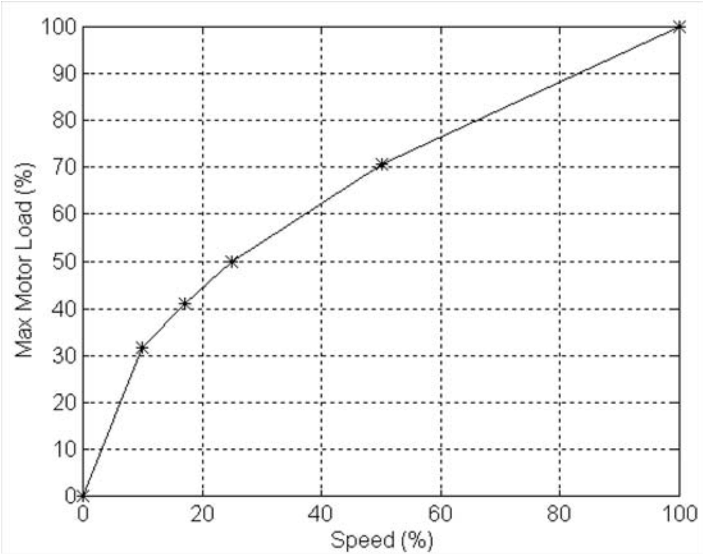

Figure 5-16: Default Speed-derating Curve Showing Maximum Motor Load As A Function Of Speed

This algorithm is complex in that it provides a family of curves similar to the straight inverse time mode, but with the maximum point of each curve at the operational speed, defined by the max motor load current at the speed taken from the Speed derating curve.

> **Note:** The Inverse time with speed derating is the recommended setting for most applications, especially when high starting torque is needed or low speed protection is required.

> **Note:** The inverse time algorithms will only work correctly if the proper Max Load Inertia is used. If this is known from the manufacturer, then this should be entered into parameter "Maximum Load Inertia" (ID 1159). If this value is zero, the NXG software will attempt to calculate the value based on the "Motor kW Rating" (1010) and the synchronous speed (based on Motor Frequency (1020) and Full Load Speed (1030)).
>
> If the values are outside of the range of the NEMA Table 20-1 from NEMA Standard MG-1 (See Table 5-7) in either HP or Synchronous Speed, then the maximum value for the synchronous speed column must be used, but must be converted from lb-ft² units to kg-m² units by multiplying the table number by 23.73. The result should then be entered into the Maximum Load Inertia parameter.

Note: To convert to HP to use this table, multiply the Motor kW rating by 0.746.

Table 5-7: NEMA Table 20-1 from NEMA Standard MG-1 1993 Part 20.42
Maximum Load Inertia for Polyphase Squirrel-Cage Induction Motors in lb-ft²

	<------------------------					Synchronous RPM					------------------------>
HP	**3600**	**1800**	**1200**	**900**	**720**	**600**	**514**	**450**	**400**	**360**	**327**	**300**
100								12670	16830	21700	27310	33690
125								15610	20750	26760	33680	41550
150							13410	18520	24610	31750	39960	49300
200						12060	17530	24220	32200	41540	52300	64500
250					9530	14830	21560	29800	39640	51200	64400	79500
300				6540	11270	17550	25530	35290	46960	60600	76400	94300
350				7530	12980	20230	29430	40710	54200	69900	88100	108800
400			4199	8500	14660	22870	33280	46050	61300	79200	99800	123200
450			4666	9460	16320	25470	37090	51300	68300	88300	111300	137400
500			5130	10400	17960	28050	40850	56600	75300	97300	122600	151500
600	443	2202	6030	12250	21190	33110	48260	66800	89100	115100	145100	179300
700	503	2514	6900	14060	24340	38070	55500	76900	102600	132600	167200	206700
800	560	2815	7760	15830	27440	42950	62700	86900	115900	149800	189000	233700
900	615	3108	8590	17560	30480	47740	69700	96700	129000	166900	210600	260300
1000	668	3393	9410	19260	33460	52500	76600	106400	141900	183700	231800	286700
1250	790	4073	11380	23390	40740	64000	93600	130000	173600	224800	283900	351300
1500	902	4712	13260	27350	47750	75100	110000	153000	204500	265000	334800	414400
1750	1004	5310	15050	31170	54500	85900	126000	175400	234600	304200	384600	476200
2000	1096	5880	16780	34860	61100	96500	141600	197300	264100	342600	433300	537000
2250	1180	6420	18430	38430	67600	106800	156900	218700	293000	380300	481200	596000
2500	1256	6930	20030	41900	73800	116800	171800	239700	321300	417300	528000	655000
3000	1387	7860	23040	48520	85800	136200	200700	280500	376500	489400	620000	769000

	<--- Synchronous RPM --->											
HP	**3600**	**1800**	**1200**	**900**	**720**	**600**	**514**	**450**	**400**	**360**	**327**	**300**
3500	1491	8700	25850	54800	97300	154800	228600	319900	429800	559000	709000	881000
4000	1570	9460	28460	60700	108200	172600	255400	358000	481600	627000	796000	989000
4500	1627	10120	30890	66300	118700	189800	281400	395000	532000	693000	881000	1095000
5000	1662	10720	33160	71700	128700	206400	306500	430800	581000	758000	963000	1198000
5500	1677	11240	35280	76700	138300	222300	330800	465600	628000	821000	1044000	1299000
6000		11690	37250	81500	147500	237800	354400	499500	675000	882000	1123000	1398000
7000		12400	40770	90500	164900	267100	399500	565000	764000	1001000	1275000	1590000
8000		12870	43790	98500	181000	294500	442100	626000	850000	1114000	1422000	1775000
9000		13120	46330	105700	195800	320200	482300	685000	931000	1223000	1563000	1953000
10000		13170	48430	112200	209400	344200	520000	741000	1009000	1327000	1699000	2125000
11000			50100	117900	221900	366700	556000	794000	1084000	1428000	1830000	2291000
12000			51400	123000	233500	387700	590000	845000	1155000	1524000	1956000	2452000
13000			52300	127500	244000	407400	622000	893000	1224000	1617000	2078000	2608000
14000			52900	131300	253600	425800	653000	939000	1289000	1707000	2195000	2758000
15000			53100	134500	262400	442900	681000	983000	1352000	1793000	2309000	2904000

Note: The gaps in Table 5-7 are present in the NEMA standard.

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

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. This loop runs external to the speed loop, with its output used as an alternative input speed demand to the drive command generator. The PID is depicted in Figure 5-17, and also in the *Command Generator Diagram*, drawing number A1A459713 rev. BI, 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, Table 4-55). 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 (Table 4-54). Refer to “PID Select Menu (4350)” in Chapter 4 (Table 4-65) for details regarding the PID parameters.

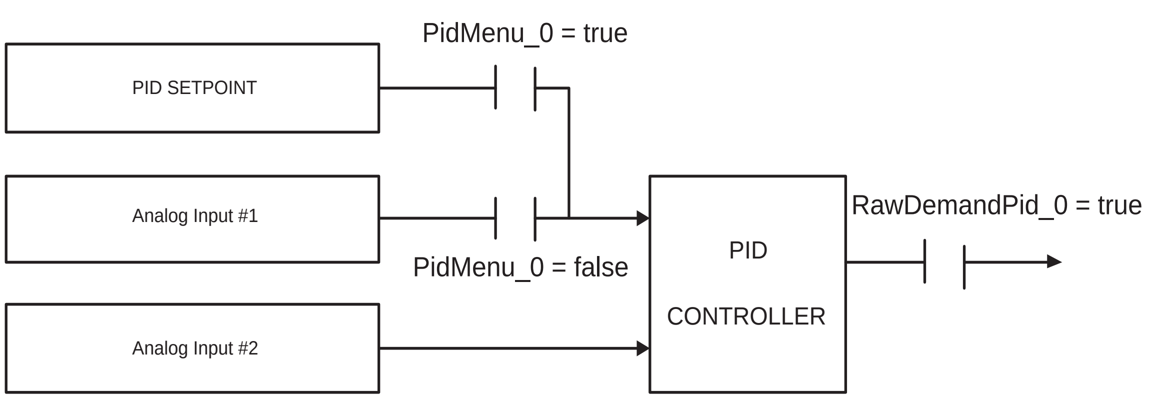

Figure 5-17: PID Controller

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.

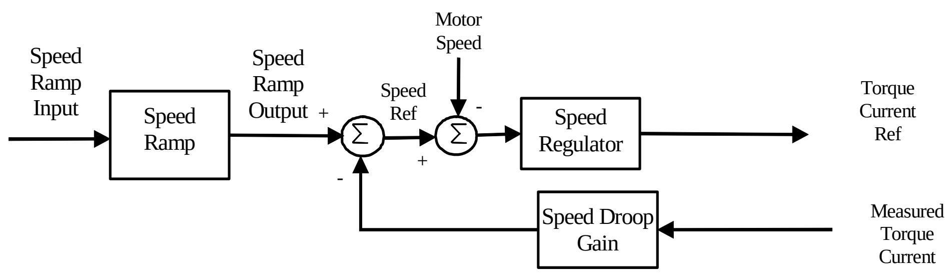

Figure 5-18: Speed Droop

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

Table 5-8: Parameters for Speed Droop

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 7.7.2 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. The parameter should be set to the default value of 12.566 rad/s for the Standard I/O board.
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 from 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 5-9 shows that the default value is good for power factors as low as 0.90, but may be marginal. See Chapter 7, Section 7.7 for details of the one cycle protection implementation.

Table 5-9: 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:

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

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. 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. $S_{MOT} = f_{OUT} – (Slip * T_{PU})$

4. $S_{ERR} = S_{DMD} – S_{MOT}$

5

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. 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.

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 5-19 and Table 5-10):

Table 5-10: 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.*

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).

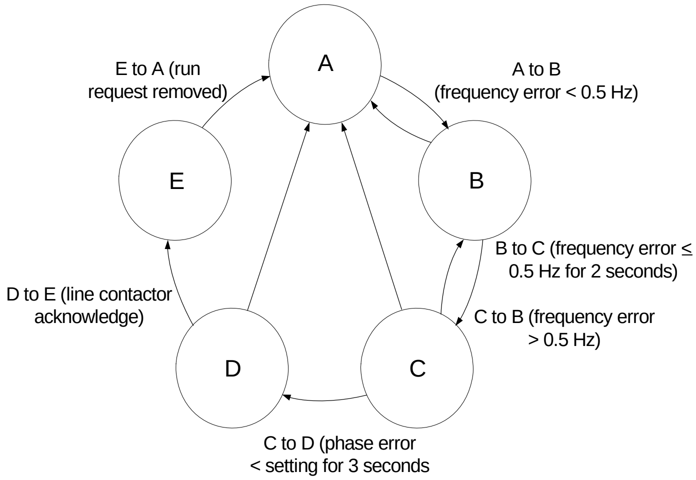

Figure 5-19: Synchronous Transfer State Diagram for "Up Transfer"

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. Once the run request is removed, the drive will exit the Up Transfer drive state. The ***UpTransferComplete_I*** flag is set false when the ***UpTransferRequest_O*** is set false.
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 "IDLE" state.

A transfer fault without a corresponding drive fault or inhibit prior to transfer completion, will cause the drive to return to the run state awaiting a transfer reset and new transfer request.

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:

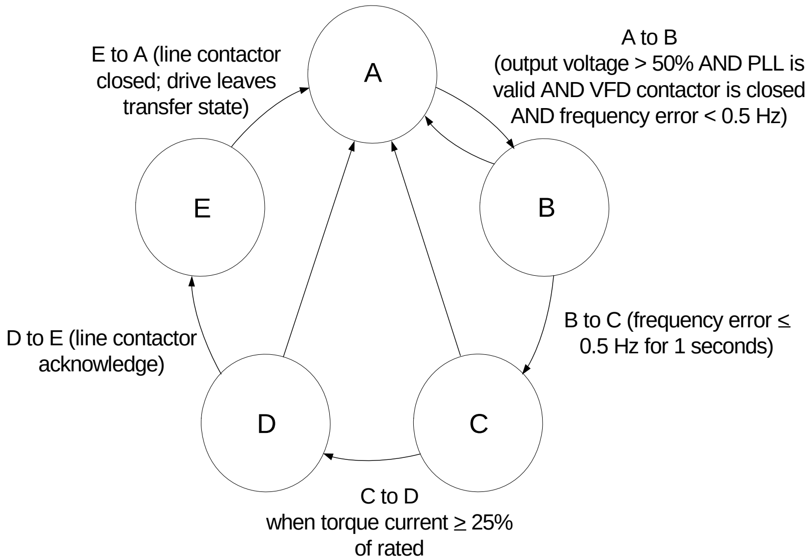

Figure 5-20: Synchronous Transfer State Diagram for "Down Transfer"

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 5-20 and Table 5-11):

Table 5-11: 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.*

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. The ***DownTransferComplete_I*** flag is set false after removing the ***DownTransferRequest_O*** flag.
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 removing 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 5-21 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 5-22. A “down transfer” process is illustrated graphically in Figure 5-23. 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 5-22 and 5-23 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 5-22, and no demand is assumed throughout time period t_9 in Figure 5-23. An overview of the control states of the motors used in the example of Figure 5-22 is given in Table 5-12. A similar overview for Figure 5-23 is given in Table 5-13.

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.

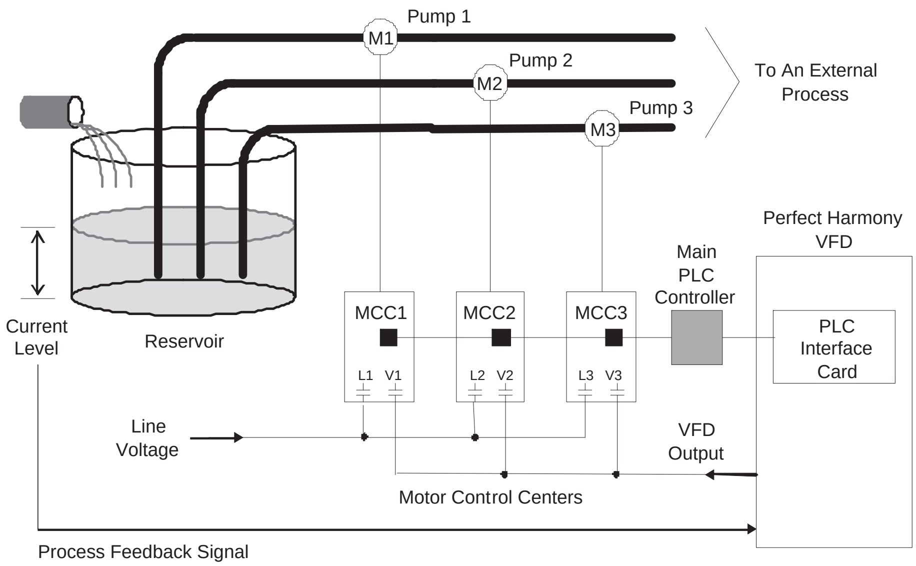

Figure 5-21: Overview of a Sample Transfer Application

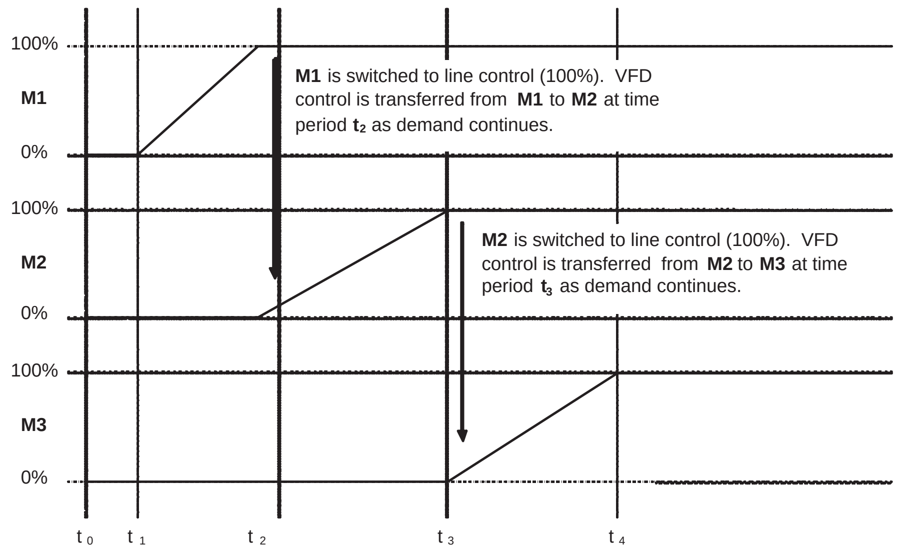

Figure 5-22: Graphical Representation of a Sample “Up Transfer” with Continued Demand

Table 5-12: 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%)

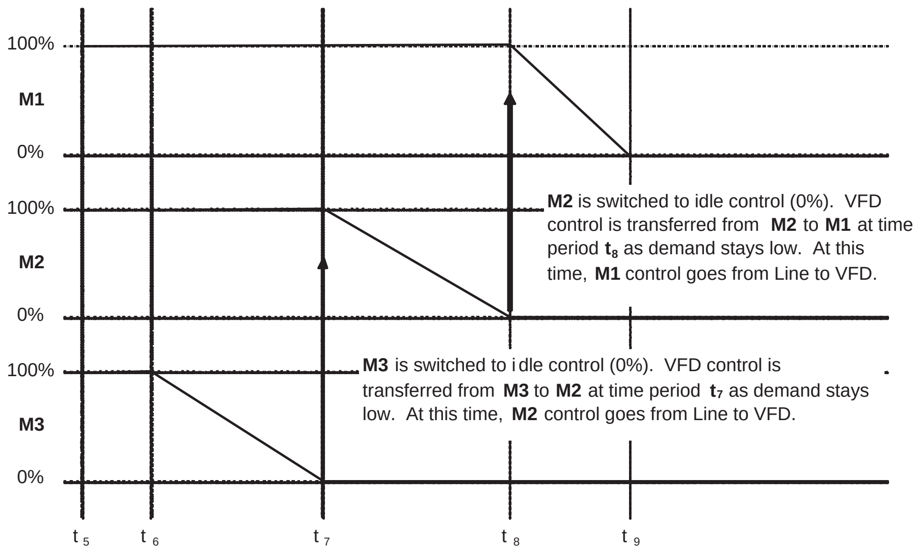

Figure 5-23: Graphical Representation of a Sample "Down Transfer" with No Demand

Table 5-13: 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 5-24.

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.

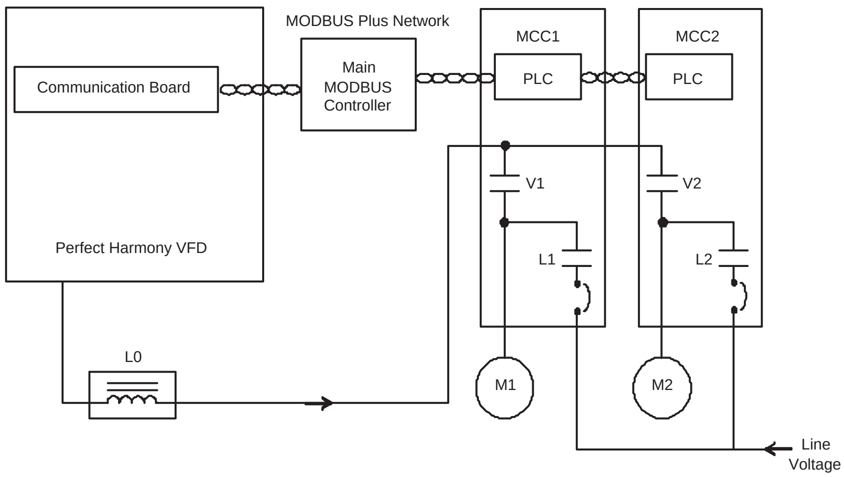

Figure 5-24: Communications Outline Drawing using a Modbus Network Configuration

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 5-25.

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***].
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***].

Note: Removing the ***UpTransferRequest_O*** flag resets the ***UpTransferComplete_I*** flag. If the ***UpTransferComplete_I*** flag is required for other logic, it must be latched.

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.

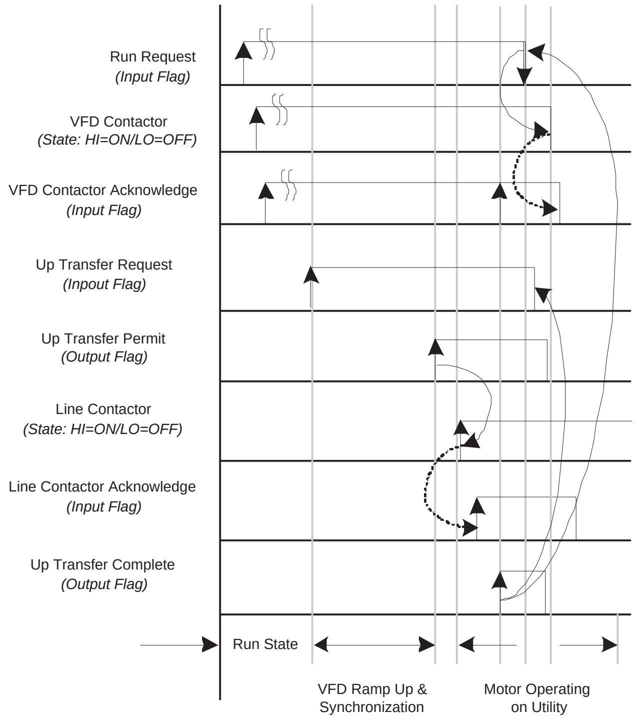

Figure 5-25: State Changes During Up Transfer Sequence

The ↑↓ arrows indicate transitions that are used by the customer interface (for e.g., a PLC) to control the process.

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 5-26) 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."

> **Note:** Removing the ***DownTransferRequest_O*** flag resets the ***DownTransferComplete_I*** flag. If the ***DownTransferComplete_I*** flag is required for other logic, it must be latched.

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.

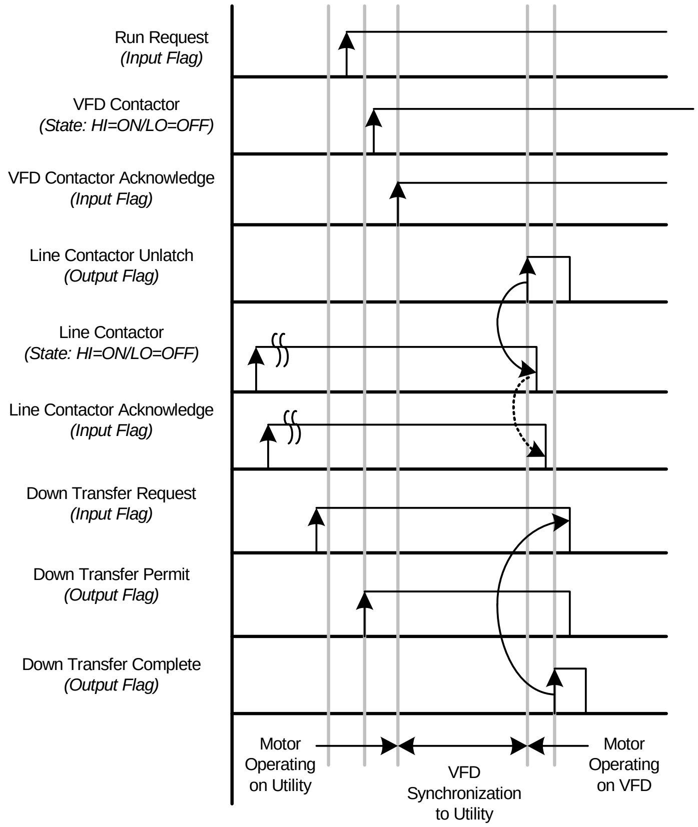

Figure 5-26: State Changes during Down Transfer Sequence

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

5.16.9 Required Signals

Table 5-14 lists descriptions of signals that are required for synchronous transfer operation.

Table 5-14: 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, after which the *DownTransferComplete_I* goes false as well.

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 5-15. This information is also available in Chapter 4 of this manual.

Table 5-15: 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 $\pi/180$ and then entered.

5.17 Sequence for Up Transfer with SM Control

5.17.1 Introduction

This section provides detailed information on synchronous machine states when enabling a Synchronous Machine synchronous transfer (sync transfer).

5.17.2 Synchronous Transfer with Synchronous Machines

5

Synchronous transfer with a synchronous machine (SM) is essentially the same as with an induction machine (IM) with the addition of transfer of the control of the motor field winding excitor from or to the drive to or from an external source. So to add to the requirements of sync transfer with SM's, an analog signal from the drive is required to control the field current, while another from the controller to the drive, is required to read the output of the external controller. Also for handshaking, with a required external controller, a minimum of two digital inputs and two digital outputs is required to provide adequate handshaking between the drive and the external controller. For most applications, this external controller takes the form of a separate PLC as shown in Figure 5-27.

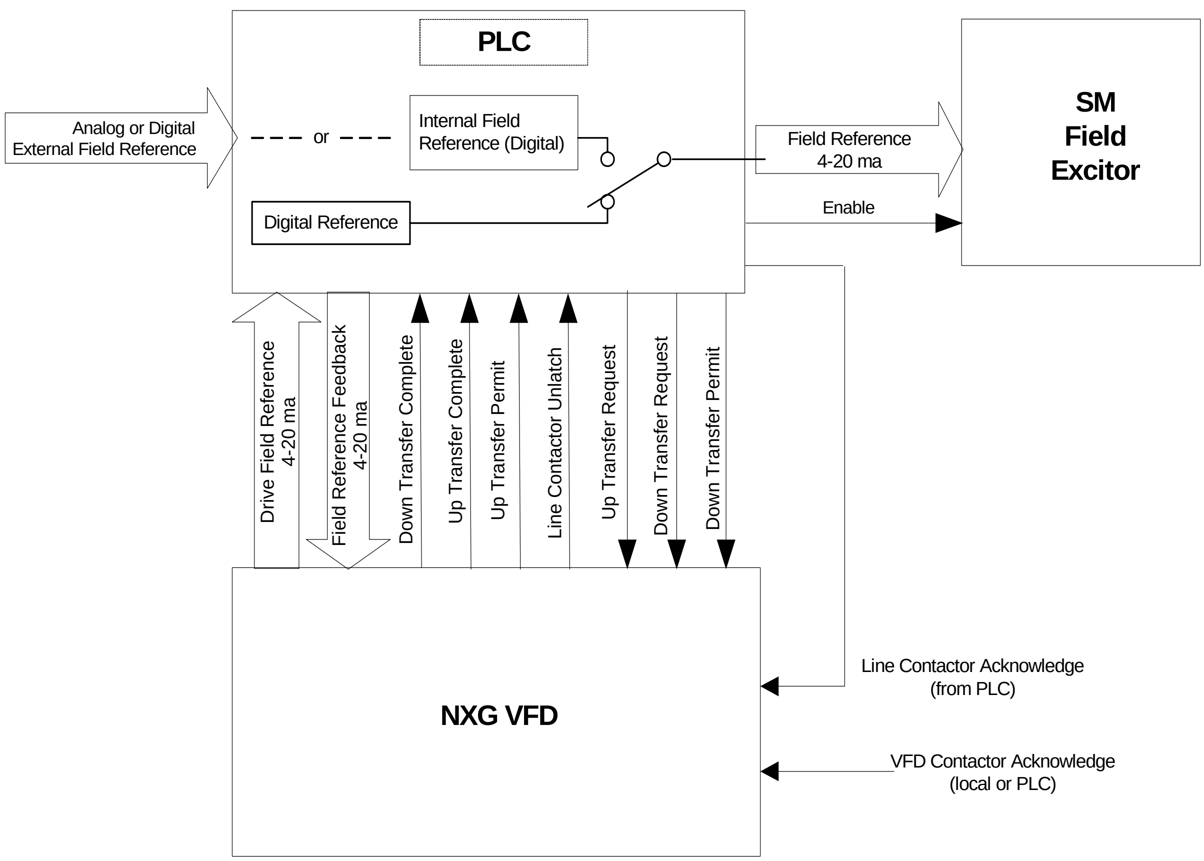

Figure 5-27: Block Diagram of Required Signals for SM Field Control Synchronous Transfer

5.17.3 Up Transfer of SM

Up transfers are accomplished by taking the SM motor up to speed on the VFD to match the frequency and then the phase of the line. This is accomplished the same as for an IM, by using the drive input line frequency as a velocity reference. The main difference comes after the synchronization and when both contactors are closed simultaneously. At this point the control has to be transferred from the drive to an external field controller. When the field transfer 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 in order to initiate transfer.
2. Initiate the transfer with the transfer request system flag (***UpTransferRequest_O***) when a transfer is desired. Other requirements are that the ***DownTransferRequest_O*** flag must be false, The line contactor must be open, the phase sequence must be proper, the VFD contactor must be closed (needed for run), and sufficient drive voltage capability must exist. 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 in this chapter), 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:

Table 5-16: Five States of Up Transfer State Machine

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.*

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).

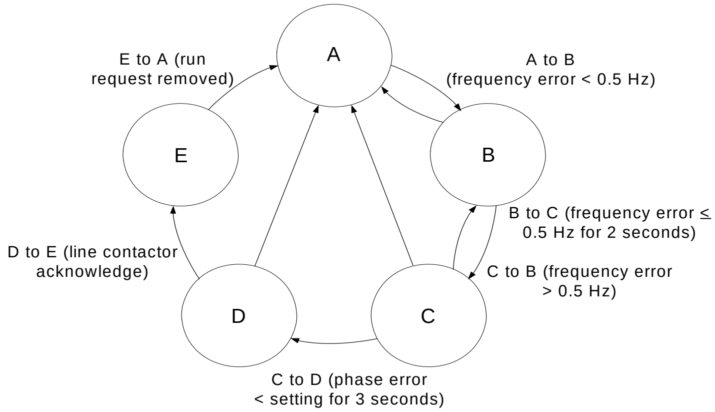

Figure 5-28: Synchronous Transfer State Diagram for “Up Transfer”

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 that 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. This same flag, “***UpTransferPermit_I***”, is also used to transfer control of the field current to an external source. The external logic must switch from using the drive field reference, to an external source for the reference to the field excitor. There is no other handshaking signal to acknowledge the completion of this event. The external logic must ensure that both the field control switch is complete along with the line contactor enabled before returning the acknowledgement of the line contactor closure.

8. 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”.

9. 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 and the field excitor. **The drive should be able to be completely de-energized at this point with no detrimental effect on the operation of the SM. Field control is completely under the control of an external source.**

> **Note:** Removing the ***UpTransferRequest_O*** flag resets the ***UpTransferComplete_I*** flag. If it is required for other logic, it must be latched.

10. 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, or if a drive fault or 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.

Any failure of the field excitor control transfer must be indicated to the drive by aborting the pickup signal for the line contactor and the removal of the transfer request. This will abort the operation and the drive will continue to maintain control of the motor.

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.

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

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 5-29).

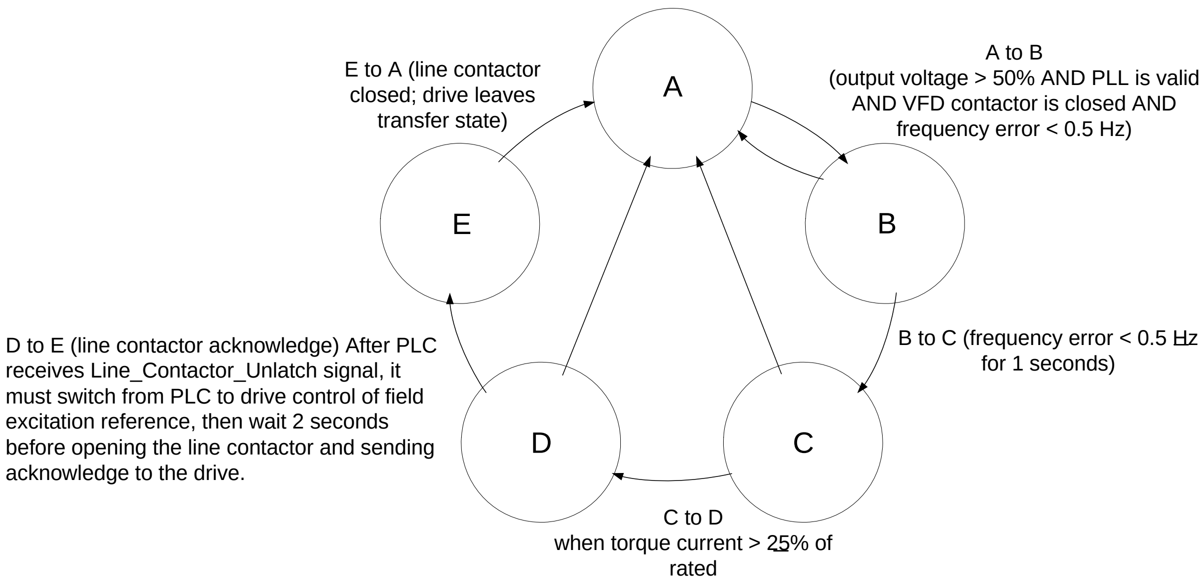

Figure 5-29: Synchronous Transfer State Diagram for “Down Transfer”

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 5-17):

Table 5-17: 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

**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 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.

> **Note:** The ***DownTransferComplete_I*** flag goes false once the ***DownTransferRequest_O*** is removed.

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

Figures 5-30 and 5-31 are the timing diagrams for the signal interface for Down Transfer using NXG SM control. 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.

Figures 5-30 and 5-31 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 5-31. It determines the source for the field exciter reference.

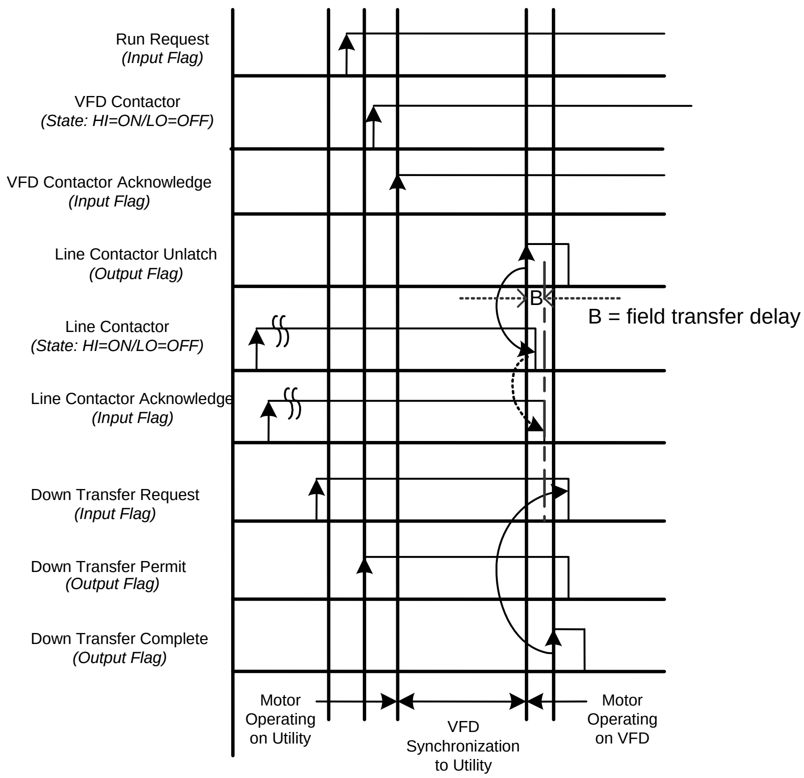

Figure 5-30: State Changes During Down Transfer Sequence in SM Control

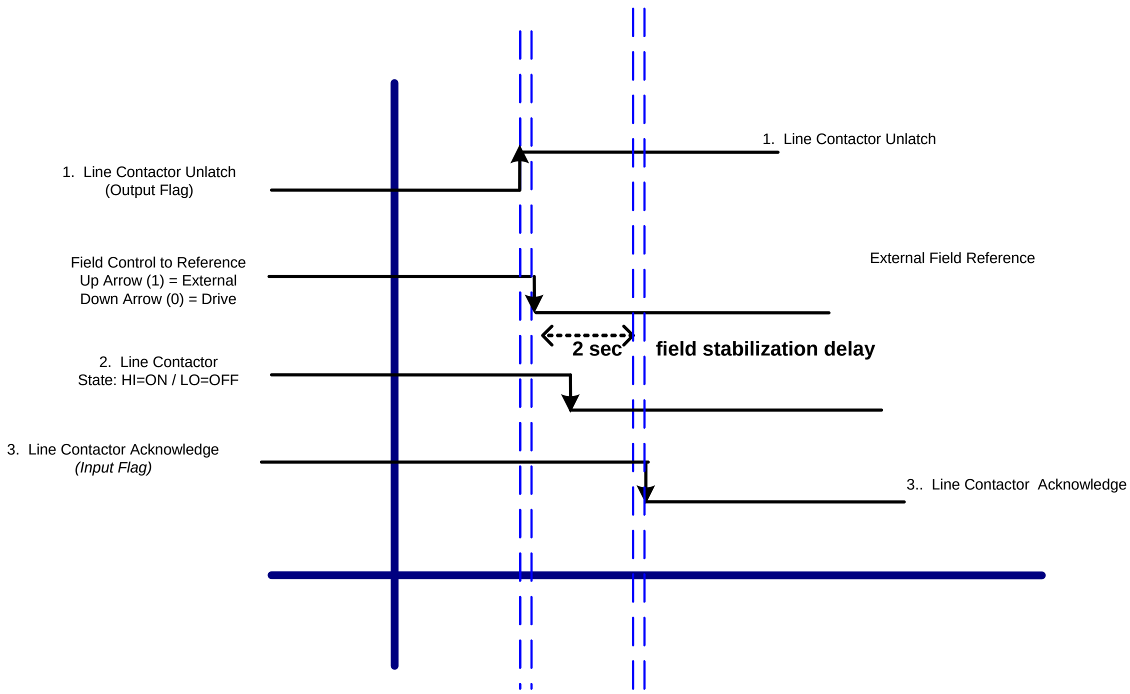

Figure 5-31: SM Down Transfer Delay (Detail 'B' Enlarged)

5.19 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 5-18 describes the Spinning Load menu.

Table 5-18: 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.

5.20 Precharge

This section provides descriptions for NXG Control of the various Precharge methods used in the Perfect Harmony, HV Harmony, Parallel, and MicroHarmony Drives.

5.20.1 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 six 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 uses a method and circuitry built directly into the cells and is not currently used. All six 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 six types of precharge, the following applies:

- The complete precharge procedure must be complete within 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.

Note: For precharge overvoltage protection, the fundamental frequency component is used instead of the RMS input voltage. This new variable is named "IP Voltage Fundamental Magnitude".

Note: Precharge Type 1, 2 and 3 are SOP driven and require the designated precharge SOP flags to control the I/O for the precharge and main contactors unless otherwise noted. Type 5 and 6 control the I/O directly - not through SOP flags.

5.20.2 Type 1 Precharge

The first precharge type is shown in Figure 5-32. 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.

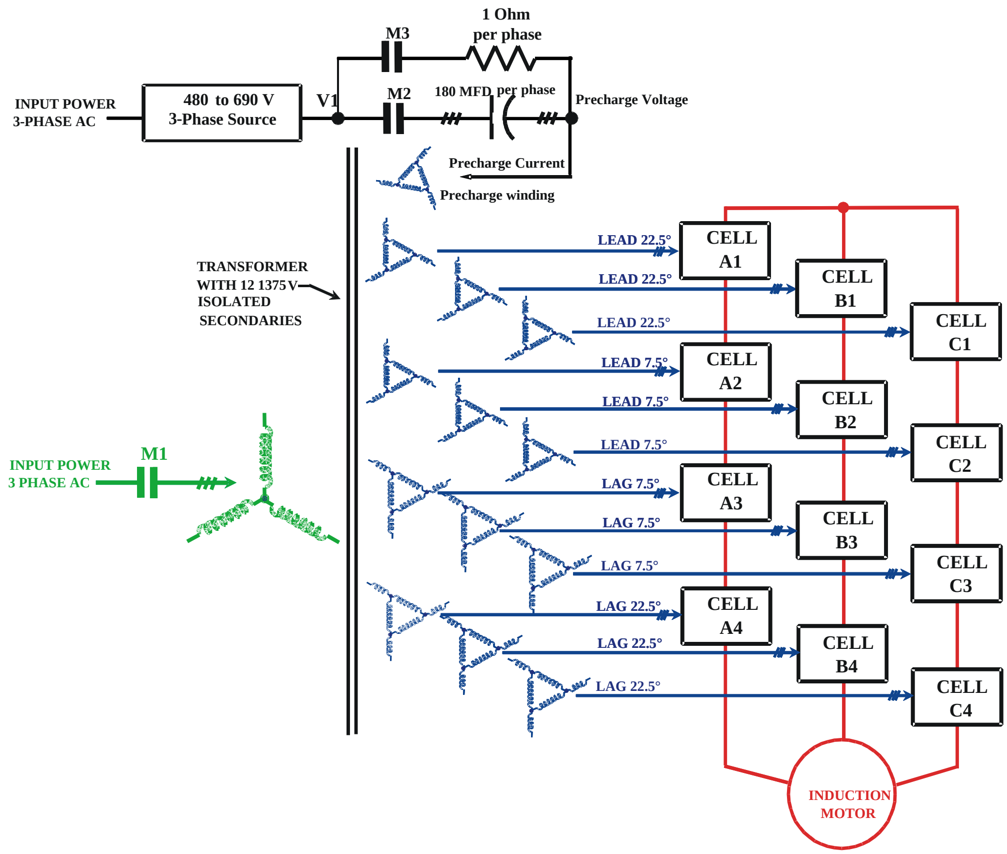

Figure 5-32: Type 1 Precharge Component Connections Diagram

The following sequence describes Type 1 Precharge. Figure 5-32 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 primary voltage should stabilize and should not increase any further. If the primary voltage increases beyond 115% 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 Figure 5-33) is issued. Failure to remove the command will result in a Precharge timeout Precharge Fault.

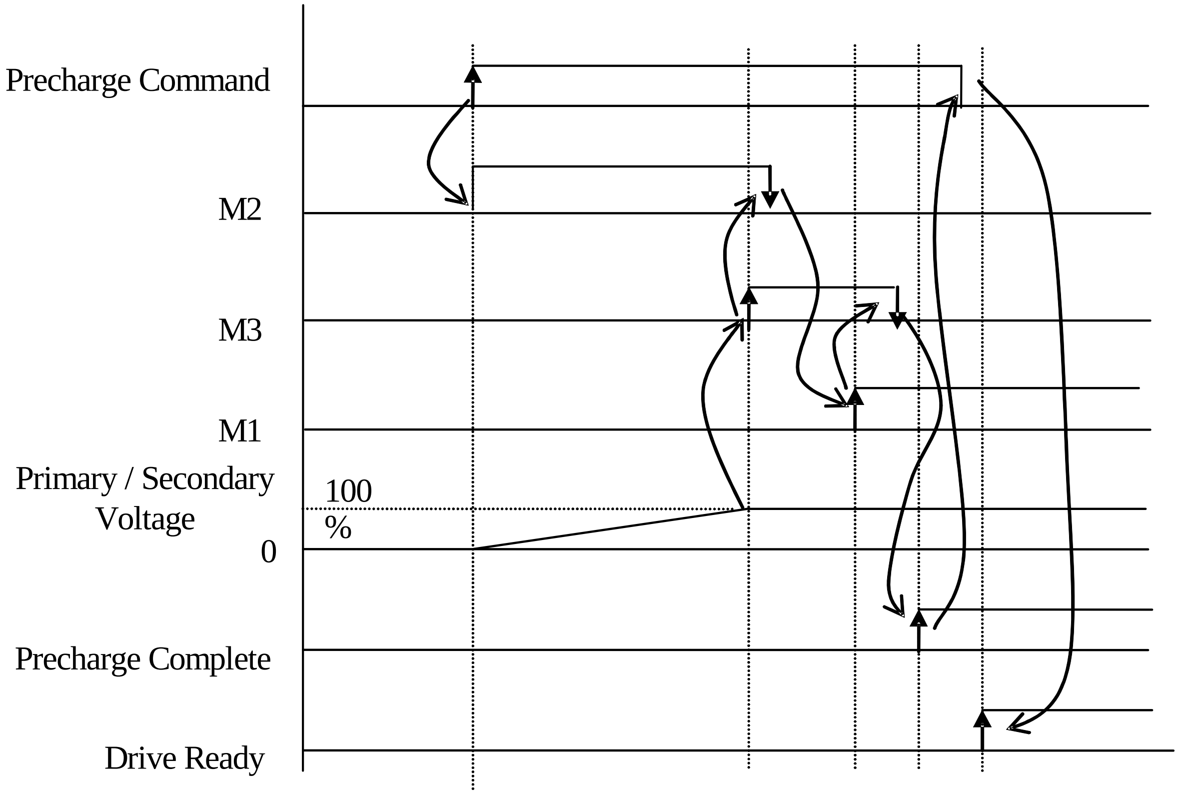

Figure 5-33: Type 1 Precharge

5.20.3 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 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 5-34, 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.

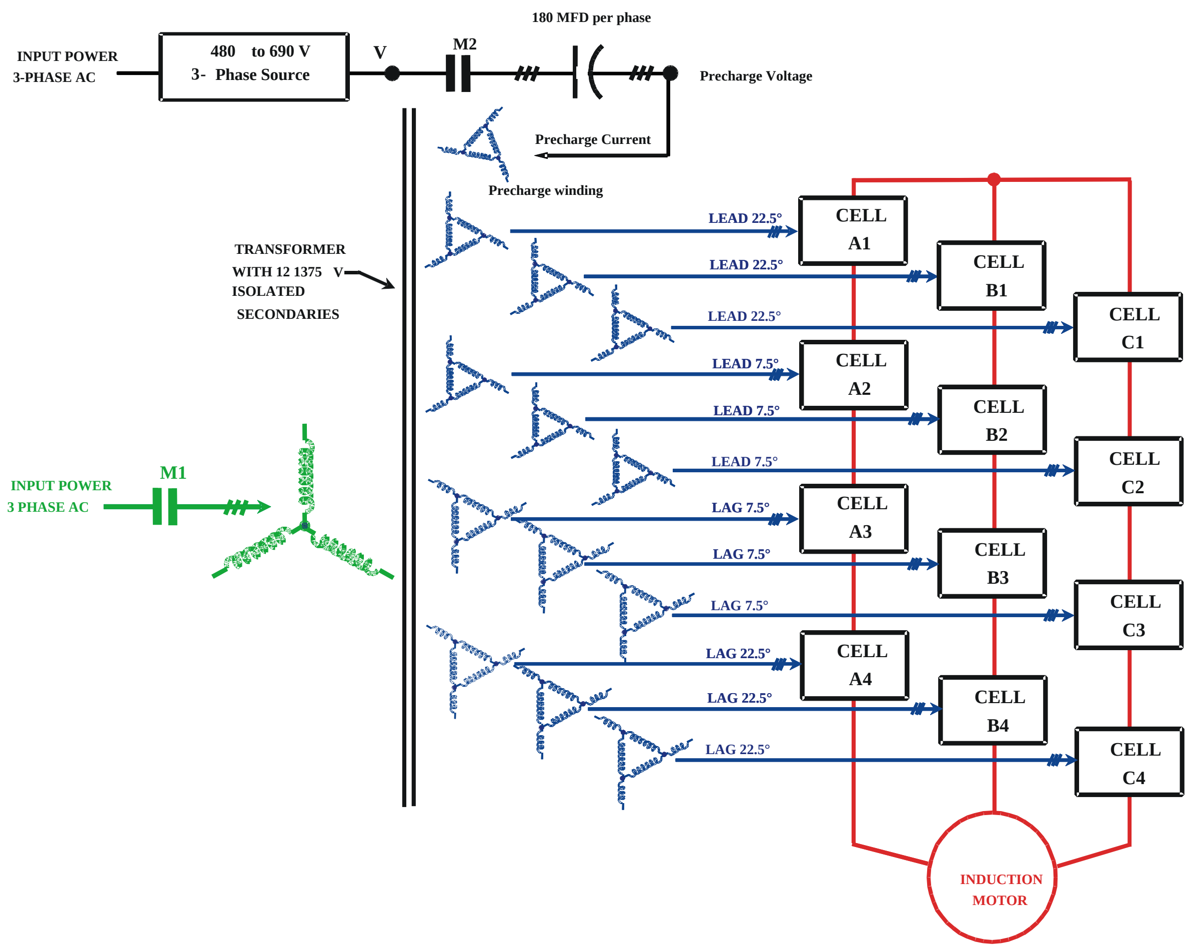

Figure 5-34: Type 2 Precharge Component Connections Diagram

The following sequence describes Type 2 Precharge. Figure 5-34 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 115%, 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).

> **Note:** A one to two second delay should be employed to allow the voltage in the transformer to decay with this flag going true, until the Digital output controlling M1 goes true. This will help prevent inrush and Excessive drive losses during precharge.

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.

5.20.4 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 Figure 5-35, 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.

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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.

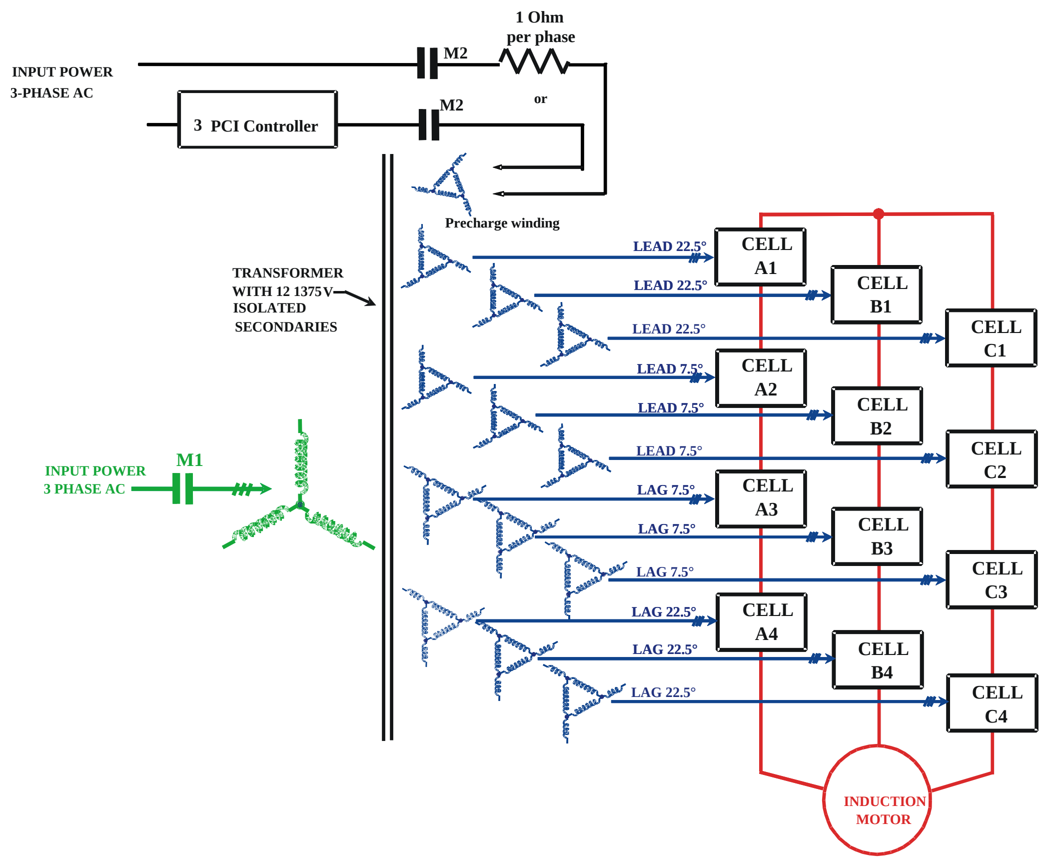

Figure 5-35: Type 3 Precharge Component Connections Diagram

5.20.5 Type 4 Precharge (Not applicable to any existing Perfect Harmony Drives)

This type of Precharge makes the delay before cell diagnostics begins, adjustable, via parameter Precharge delay time (ID 2636).

5.20.6 Precharge Faults

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 1.15 PU (115%) 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.

5.20.7 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.

5.20.8 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.

5.20.9 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 operate independent of precharge state. The best means to accomplish this is through independent, series-connected contactors or pilot relays.

5.21 Precharge for Advanced Protocol Cells Software Description Introduction

Note: For precharge overvoltage and undervoltage protection during precharge, the fundamental frequency component is used instead of the RMS input voltage. This new variable is named "IP Voltage Fundamental Magnitude".

Note: The WCIII 750V AP type cells **must** use “Type 5 Open” or “Type 6 Closed” precharge.

The software provides the WCIII cells with dedicated I/O for precharge and input protection. HV has no “dedicated” I/O.

Notes:

- **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: *“NXGII I/O Breakout Board”* standard assignments document *Rev “AA” 9-12-08 - A5E02334712A_AA* dated 9-12-08.**

5.21.1 Type 5 (Open) Precharge

Type 5 precharge was designed for WCIII drives exclusively. It uses 3 precharge contactors M2, M3, and M4, along with controlling the main contactor (M1). It is designed so that M1 will not close until after M4 opens. This designates Type 5 precharge as a ‘Break_before-Make’, or “open” precharge type.

Type 5 precharge can be implemented only with the NXGII Standard I/O board using the digital I/O Breakout board due to the dedicated I/O controlled directly through the NXG code.

The precharge power circuitry is identical to Type 6, and if in place, either type can be used. The only exception is an additional signal, “In-sync”, from a sync check relay for Type 6 – that is required to complete precharge.

Note: On any precharge fault, the event log must be examined for the cause, and the problem must be corrected before proceeding to another attempt. See Table 5-20 at the end of this section for event log messages and potential issues.

5.21.1.1 Type 5 Precharge Circuit

The precharge circuit consists of a collection of capacitors, resistors, and contactors mounted in the FPC cabinet on the input section of the drive. (Refer to Figure 5-36). On the left is the low voltage precharge source coming in through the precharge circuit breaker. On the right side is the connection to the precharge secondary windings of the input transformer. Voltage during precharge is monitored through the input attenuators on the primary side of the transformer (not shown). The M1 contactor connects the MV source to the primary.

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Caution!

During precharge, Medium voltage is present on the primary side of the input transformer even though the MV Contactor is not closed!

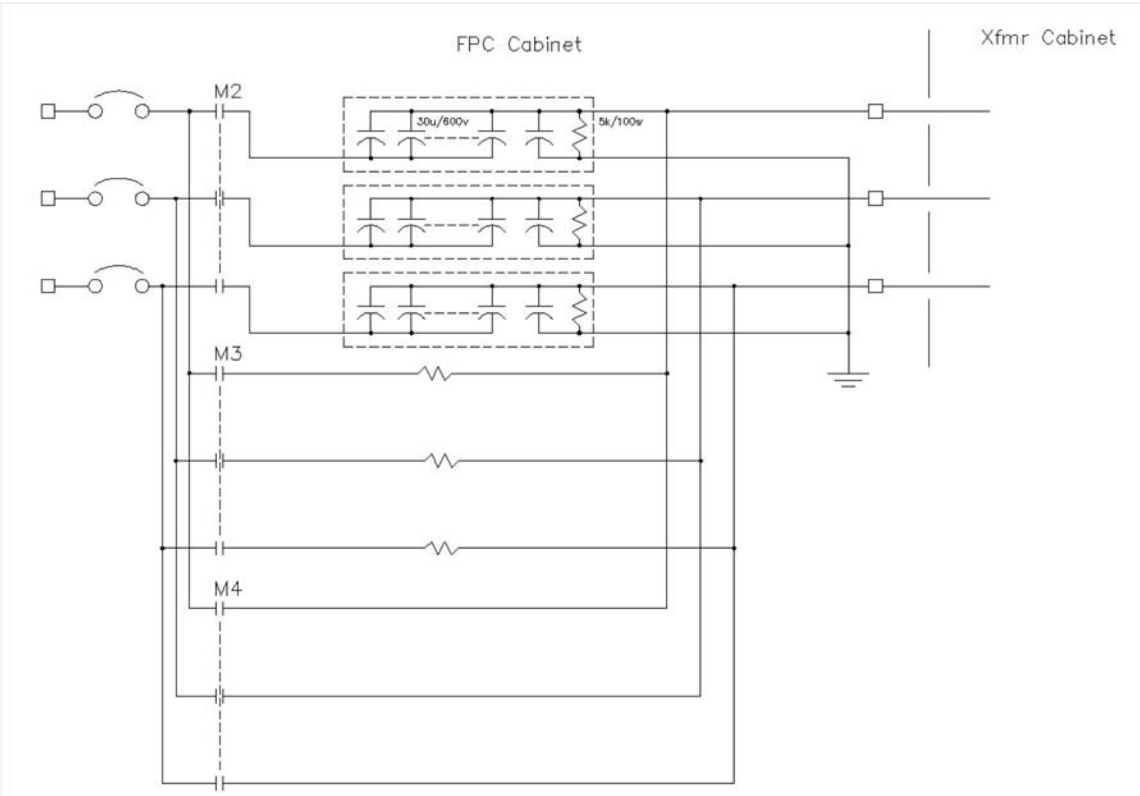

Figure 5-36: Type 5 & 6 Precharge Circuit Schematic

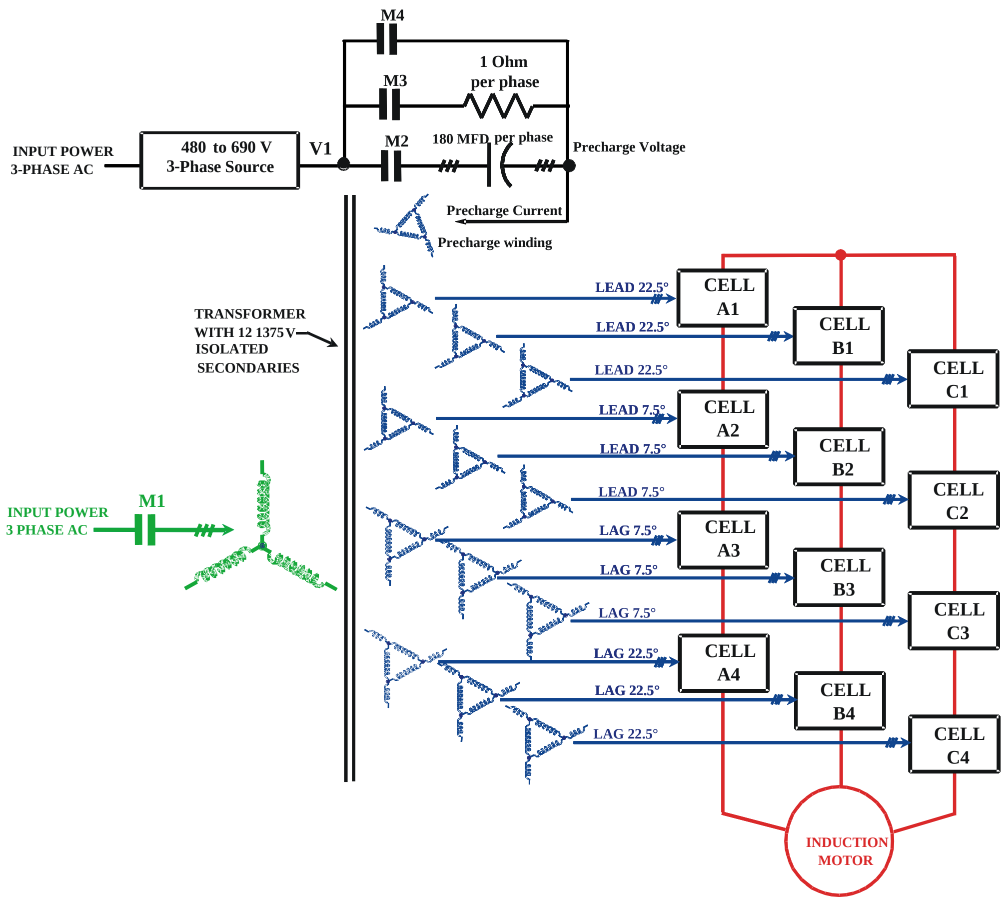

Figure 5-37: Type 5&6 Precharge Component Connections Diagram

The precharge contactors are controlled directly by the NXG code and require no SOP interaction with the exception of the start precharge command.

Precharge is initiated by setting the SOP flag ***"StartCellPrecharge_O"*** true. It must be maintained throughout the entire precharge sequence until complete, else it will result in a precharge fault. At the end of a successful precharge cycle, the ***"PrechargeComplete_I"*** SOP flag is set true. No other SOP flags are necessary to perform precharge.

5.21.1.2 Parameter Settings

Type 5 precharge only has two settings in the parameters for normal operation. Two additional ones are for Maintenance (or Service) mode of operation.

- Precharge Enable (ID 2635 in Cell Menu) to "Type 5 Open" (see Figure 5-38)
- Cell Voltage (ID 2550) must be valid for the Precharge cell type selected (750V AP – 2Q or 4Q). These are the two settings that are defined for the WCIII drive. (see Figure 5-39)
- Precharge Service Mode (ID 2637) – completes precharge with M4 closed. M1 never closes. This is for troubleshooting purposes.
- Precharge Service Start (ID 2638) – starts the service mode of precharge from the menu rather than through an SOP flag.

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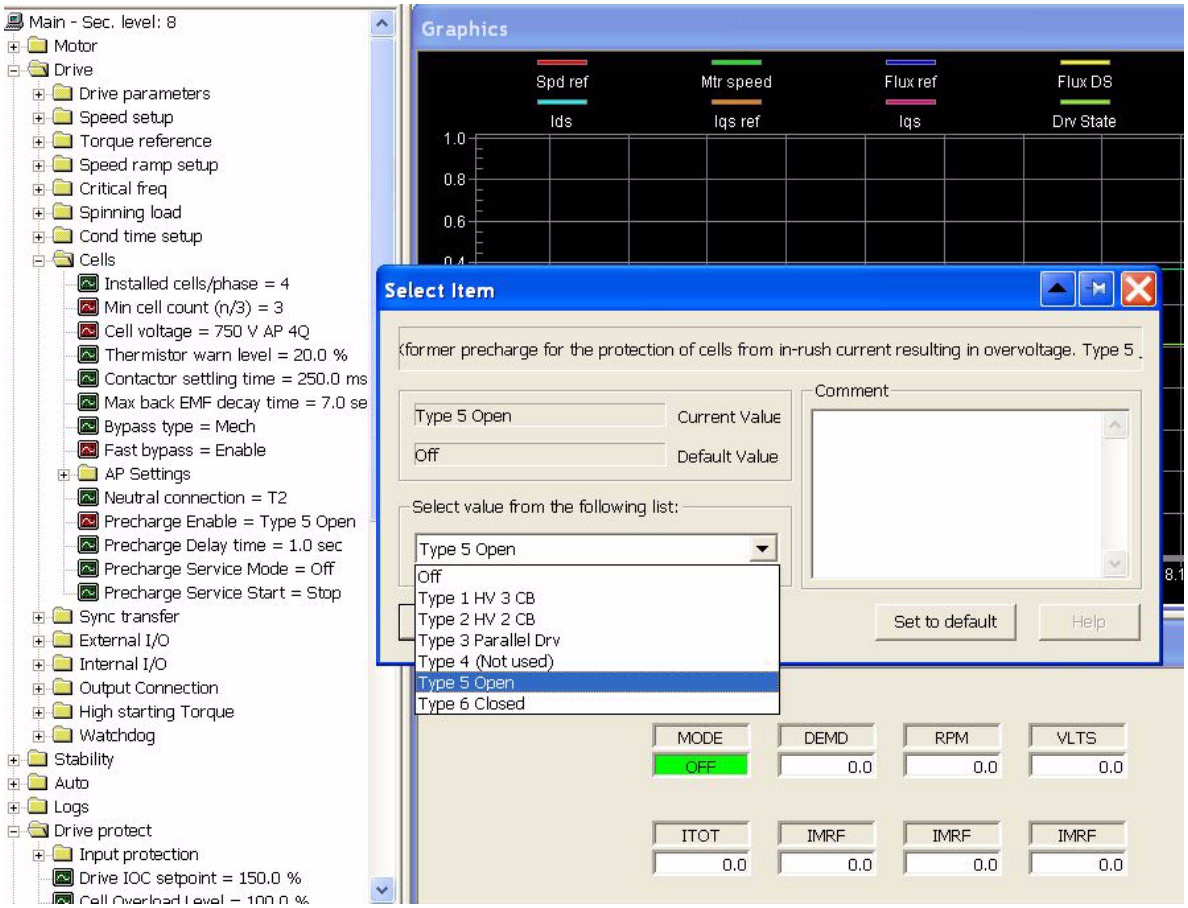

Figure 5-38: Selecting Type 5 Open from Pick List

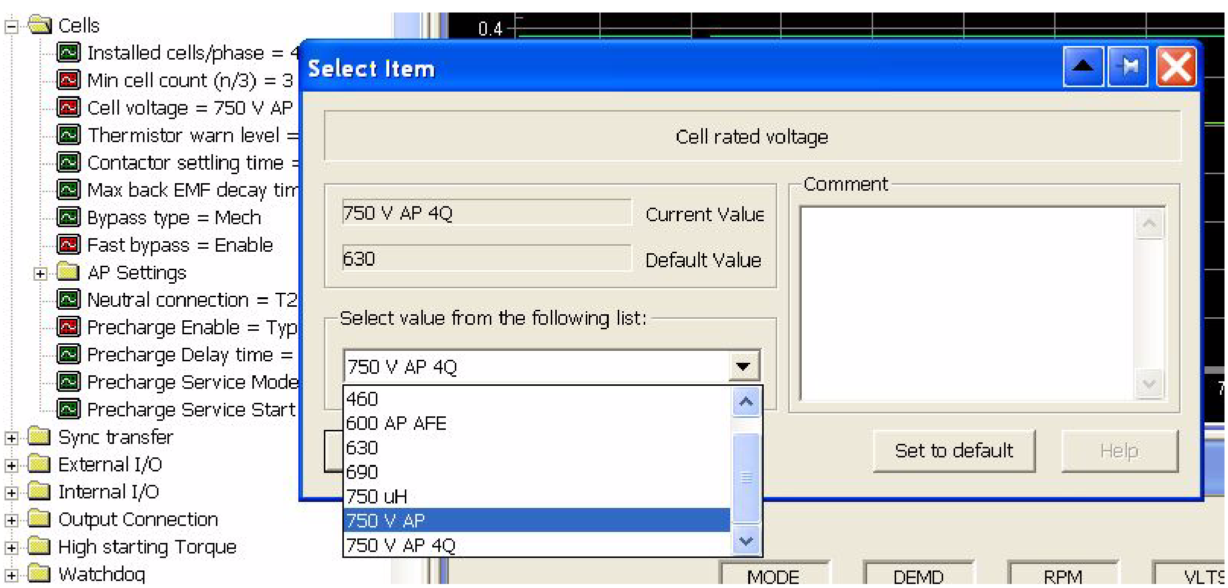

Figure 5-39: Selecting a WCIII Cell

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5.21.1.3 Dedicated I/O

Type 5 precharge reads inputs and controls outputs directly with no intervention from the SOP. It uses the following I/O from the NXGII Standard I/O Breakout board.

- Output to close M1 – DO-9
- Output to close M2 – DO-10
- Output to close M3 – DO-11
- Output to close M4 – DO-12
- Output to trip Precharge Breaker – DO-13
- Output to M1 Permissive – DO-14
- Output to trip LFR – DO-15 (Input protection)
- M1 Close Ack – DI-2E – P18
- M2 Close Ack – DI-3D – P15
- M3 Close Ack – DI-0E – P16
- M4 Close Ack – DI-1E – P17
- LFR Status – DI-3E (Input protection)
- Start Cell Precharge – DI-2D (assigned but not dedicated – need SOP flag set from this input)

5.21.1.4 SOP Flags

The following are SOP flags associated with Type 5 precharge.

Table 5-19: SOP Flags

Flag	Description
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
DriveReadyToPrecharge_I	All conditions met for type 5 precharge to start (as described below)
PrechargeInProgress_I	Type 5 precharge is in progress
PrechargeComplete_I	Precharge has completed successfully (with no errors) as described below.
PrechargeBreakerOpened_I	Precharge breaker has opened (Alarm) – if a precharge contactor is showing closed and the command is to have it open, the precharge breaker trips but the drive does not fault once precharge is complete.
PrechargeContactorAlarm_I	A precharge contactor acknowledge differs from command (half second delay)
PreChrgM1ContactorFault_I	M1 failed to properly operate during precharge

5.21.1.5 Precharge Pre-Conditions

The entire precharge sequence can be monitored through an externally connected monitor or through the Debug Tool set to the “Drive Misc Status Flags 2” (Ctrl-Y on keyboard or menu selection in the tool). The “DriveReadyToPrecharge” flag in the lower right corner must be set true for precharge to begin. Monitor the progress on the ‘MedVolts’, ‘Precharge State’, and ‘PrechargeExitState’ variables on the right side.

Every Step in the precharge sequence is logged in the event log – including any fault conditions that abort precharge. Also the exit condition from the precharge thread is logged.

If all of the following conditions exist, the ***“DriveReadyToPrecharge_I”*** flag will be true (1). If any of these conditions are not met, the flag will be set false, therefore this flag can be used as part of the conditions to start precharge. Precharge cannot be initialized or started if this flag is not true. Once precharge commences, the flag goes false and will remain false until all conditions are again met.

Type 5 precharge selected
Drive not running
Type 750V AP (2Q or 4Q) cell selected
MV is low
Output to M1 Permissive is open (DO-2d – P14)
Output to close M1 is open (DO-1c – P9)
Precharge thread state is in initial condition (PC_FINISHED)
M1 is open (M1 Close Ack – DI-2e – P18)
M2 is open (M2 Close Ack – DI-3d – P15)
M3 is open (M3 Close Ack – DI-0e – P16)
M4 is open (M4 Close Ack – DI-1e – P17)
No Medium Low Fault
LFR not tripped and latched (due to Input Protection)
No precharge fault exists
MV is not disabled (***MainInputVoltageDisable_O*** = true) Or Maintenance or Service mode is enabled.
No Precharge Circuit breaker alarm active
No precharge contactor alarm active
No precharge main contactor fault
No Input protection fault

If any cells were in bypass prior to losing MV, their respective bypass contactor will be opened since the bypass contactor power supply is energized by one phase of the MV input. During the subsequent precharge, if the cell is detected as faulted, then precharge will pause indefinitely until a manual drive reset is activated. Precharge will then proceed and the detected faulted cell will be bypassed after precharge is completed.

Note: If any cells were in bypass prior to losing MV, their respective bypass contactor will be opened since the bypass contactor power supply is energized by one phase of the MV input. During the subsequent precharge, if the cell is detected as faulted, then precharge will pause indefinitely until a manual drive reset is activated. Precharge will then proceed and the detected faulted cell will be bypassed after precharge is completed.

Setting ***“StartCellPrecharge_O”*** to true initiates the precharge sequence. **Precharge will not initiate if the *DriveReadyToPrecharge_I* is not true, or any of the above conditions are not met.**

The following variables can be monitored on the Host Tool Graphic display: Precharge State “PreChrg St” (scaling 1.0 and offset 0.0) and Precharge Voltage “PreCharg V” (scaling 1.0 and offset -1.0). Plot time is set to 33.33 seconds. The display should look similar to Figure 5-40 after a successful Type 5 precharge.

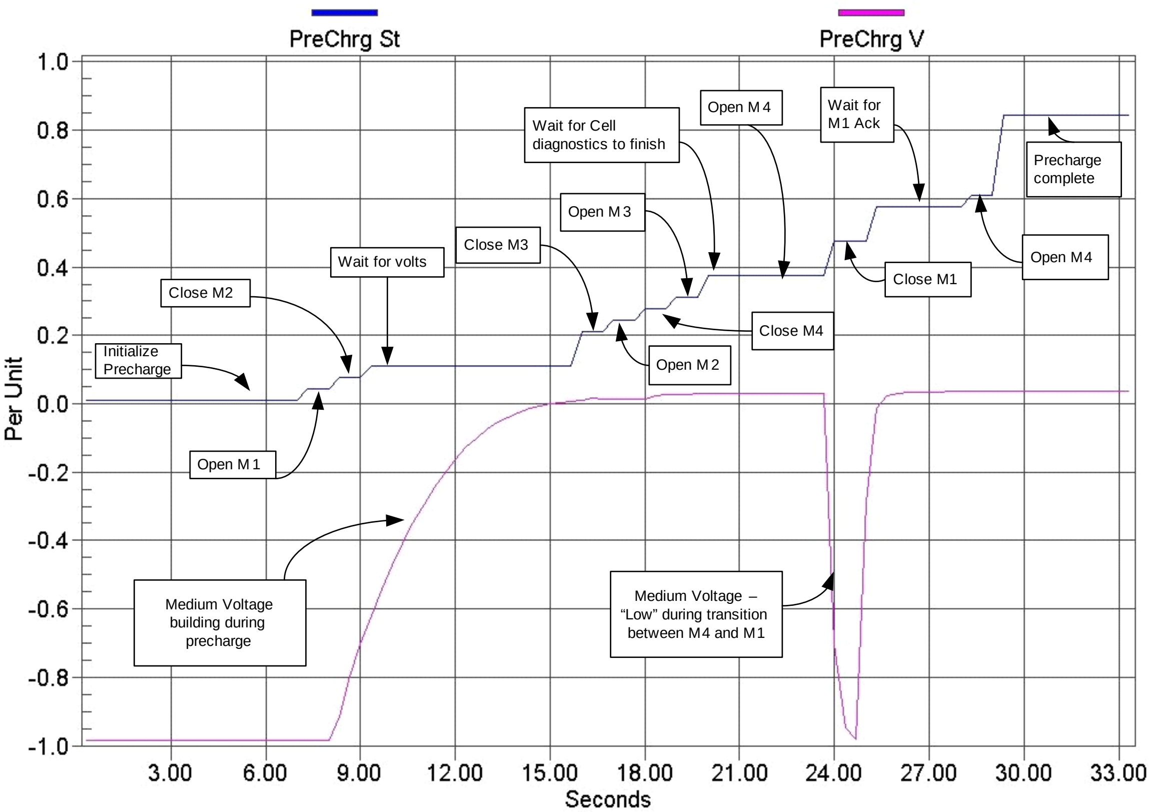

Figure 5-40: Successful Precharge plot on the Host Tool

After precharge is finished, there should be no precharge faults. The Event Log records each state with an entry. The event log should look similar to the following Event Log excerpt for a normal successful precharge with no cell faults.

10/17/08 10:49:59 Precharge Start type 5 (Open)

10/17/08 10:50:00 Precharge: Open M1

10/17/08 10:50:01 Precharge: Close M2

10/17/08 10:50:01 Precharge: Waiting for voltage buildup...

10/17/08 10:50:03 Medium Voltage - OK

10/17/08 10:50:09 Precharge: Close M3

10/17/08 10:50:10 Precharge: Open M2

10/17/08 10:50:11 Precharge: Close M4

10/17/08 10:50:12 Precharge: Open M3

10/17/08 10:50:12 Precharge: Waiting for cell diagnostics to finish...

10/17/08 10:50:16 Precharge: Cell diagnostics is complete

10/17/08 10:50:16 Medium Voltage - LOW

10/17/08 10:50:17 Precharge: Open M4

10/17/08 10:50:17 Precharge: Close M1

10/17/08 10:50:17 Medium Voltage - OK

10/17/08 10:50:20 Precharge: Waiting for M1 to close...

10/17/08 10:50:21 Precharge complete: No errors

10/17/08 10:50:21 Precharge exit status - NO_ERRORS

If Maintenance or Service mode is selected, the following message will show following the “Precharge: Cell diagnostics is complete”. In this mode M4 stays closed and M1 never closes. Also the setting of the ***“MainInputVoltageDisable_O”*** SOP flag has no affect in Maintenance or Service mode.

Precharge: Cell diagnostics is complete

Precharge: Maintenance mode enabled

Precharge complete: No errors

If a cell is faulted during precharge, it will pause indefinitely waiting for a fault reset. If this occurs the following message appears in the event log following the opening of M3:

Precharge: Open M3

Precharge: Waiting for reset...

Precharge: Waiting for cell diagnostics to finish...

Since fast bypass is disabled during precharge, any faulted cells will not be reset or bypassed until after precharge is complete. Also only fault messages will display on either the keypad or Host Tool – there is no message to reset the drive, but this is required.

Note: Since a cell fault is a fatal fault, the ***FatalFault_I*** SOP flag cannot be used to set the ***“MainInputVoltageDisable_O”*** flag, or to remove the ***“StartCellPrecharge_O”***. Doing either during precharge will abort precharge with a precharge fault.

5.21.1.6 Type 5 Precharge sequence

Type 5 precharge is controlled entirely through the NXG drive code and can only be enabled for WCIII drives. Once started, precharge goes through the following sequence.

- Drive is ready to precharge – all conditions met and ***DriveReadyToPrecharge_I*** is true.
- Start Precharge – set the ***StartCellPrecharge_O*** flag true through the SOP. This starts the precharge thread. (For Maintenance or service mode, precharge is started by the “Precharge Service Start” (2638) when Precharge Service mode is selected (2637).)
- M1 is commanded to open (it should already be open, but this is a precautionary step). All precharge contactors are issued an open command as well.
- Once M1 is confirmed open, M2 is commanded to close.
- With M2 closed, the drive input voltage should begin to climb and the drive waits until 90% of rated voltage is achieved. The precharge capacitors provide a resonant circuit with the input inductance allowing a lower secondary input voltage to charge to 90% of rated drive input voltage through the secondary.
- When the input voltage reaches 60% of rated, cell diagnostics begins and Medium voltage is considered ‘OK’.

- Once the input voltage reaches 90% of rated input voltage (plus tap setting), M3 is commanded to close to dampen the resonance and maintain the voltage. Failure to connect the resistors could result in an overvolt-age
condition on the cells.
- When M3 is closed, M2 is commanded open.
- When M2 is open, M4 is commanded closed. M4 provides holding voltage with no resistance drop. This lowers the power rating requirement on the precharge damping/holding resistors.
- When M4 is closed, M3 is commanded open. This total sequence with M3 open and M4 closed must be completed in 30 seconds or a timeout will occur resulting in a precharge fault.
- The drive then waits for Cell Diagnostics to complete. If a cell is faulted, precharge waits for a fault reset. The fault reset only acknowledges the fault and cell diagnostics exits so that precharge can continue. Any faulted cells will be bypassed on exit if bypass is enabled.

Note: When a cell fault is detected, the fault will display on the keypad. The drive will wait until reset, but will trip if an overvoltage, cell under-voltage, or input protection fault occurs, or if the precharge is aborted, or the MV falls below 80% (as read through the input attenuators). No other indication is given that a reset is required.

Note: A cell fault - at any time - is a fatal fault and will set the ***“FatalFault_I”*** SOP flag. Therefore this flag should not be used to remove the ***“StartCellPrecharge_O”*** (precharge enable flag).

- When cell diagnostics is complete, M4 is commanded to open. This results in a drop in input voltage, but the cell capacitors are completely charged. (If Service mode is selected, precharge completes at this point with M4 closed and MV stays on through the precharge source.)
- When M4 is open, M1 is enabled to close. This is done through two separate digital outputs on the breakout board – M1 close permissive (DO-14), and Precharge Complete-M1 Close (DO-9).
- The drive will then wait for the M1 contactor to close. It senses this through the Digital Input for the M1 Acknowledge (DI-2E). The M1 contactor must close to prevent discharge of the cell capacitors, and so must be closed before a low cell bus voltage alarm is received.
- Once the M1 acknowledge is received, precharge is complete and the drive is connected to the MV source and ready to run. The precharge thread is exited and the exit state is recorded in the event log along with all other recorded precharge events in the sequence.

Note: The drive run is inhibited until precharge has successfully completed.

5.21.1.7 Precharge Exit States and Associated Event log text

When the precharge thread exits, the status is recorded in the event log (following the entire sequence from beginning to end). Aside from a normal precharge, there are conditions under which a precharge fault or alarm occurs. The following is a list of exit status conditions and associated event log entries and any associated faults.

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Table 5-20: Precharge Exit States and Associated Event log text

Exit State	Description	Event Log Messages & Faults/Alarms
NO_ERRORS	Precharge is successful (including service mode) – No fault	• "Precharge: Maintenance mode enabled" • "Precharge complete: No errors" • "Precharge exit status – NO_ERRORS"
M1_OPEN	Precharge aborted when M1 failed to open initially (should never get this since M1 open is a precondition).	• "Precharge: M1 failed to open" • "Precharge exit status - M1_OPEN" • Fault Message – "PreChrg M1 Contactor Flt"
M2_CLOSE	M2 failed to acknowledge after 1 second delay following command to close	• "Precharge: M2 failed to close" • "Precharge exit status - M2_CLOSE" • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm"
USER_ABORT	Precharge enable (StartCellPrecharge_O) is set false before precharge is complete. Depending on where in the precharge algorithm the change is detected will determine the message. All result in a precharge fault.	• "Precharge enable removed while waiting for volts to build up" • "Precharge enable removed before close M3" • "Precharge enable removed after M3 closed" • "Precharge enable removed after M2 opened" • "Precharge enable removed after M4 closed" • "Precharge enable removed after open M3" • "Precharge enable removed while waiting for reset" • "Precharge enable removed while waiting for Cell Diags to complete" • "Precharge enable removed after cell diags" • "Precharge exit status - USER_ABORT" • Fault Message – "Precharge Fault"

Exit State	Description	Event Log Messages & Faults/Alarms
TIME_OUT_ABORT	Precharge took longer than 30 seconds to close M4 and open M3	• "Timeout exceeded 30 secs to reach voltage" • "Timeout exceeded 30 secs closing M3" • "Timeout exceeded 30 secs opening M2" • "Timeout exceeded 30 secs closing M4" • "Timeout exceeded 30 secs opening M3" • "Precharge exit status - TIME_OUT_ABORT" • Fault Message – "Precharge Fault"
M3_CLOSE	M3 failed to acknowledge after 1 second delay following command to close	• "Precharge: M3 failed to close" • "Precharge exit status - M3_CLOSE" • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm"
M2_OPEN	M2 failed to acknowledge after 1 second delay following command to open	• "Precharge: M2 failed to open" • "Precharge exit status - M2_OPEN" • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm" • Alarm Message – "PreChrg Breaker Opened"
M4_CLOSE	M4 failed to acknowledge after 1 second delay following command to close or voltage dropped after M4 acknowledge open confirmed.	• "Precharge: M4 failed to close" • "Low Cell DC bus occurred after M4 commanded open" • "Precharge exit status – M4_CLOSE" • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm"

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Exit State	Description	Event Log Messages & Faults/Alarms
M3_OPEN	M3 failed to acknowledge after 1 second delay following command to open	• "Precharge: M3 failed to open" • "Precharge exit status – M3_OPEN • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm" • Alarm Message – "PreChrg Breaker Opened"
WAIT_FOR_RESET	Loss of Medium Voltage while waiting for a fault reset	• "Lost MV waiting for reset" • "Precharge exit status – WAIT_FOR_RESET • Fault Message – "Precharge Fault"
M4_OPEN	M4 failed to acknowledge after 1 second delay following command to open	• "Precharge: M4 failed to open" • "Precharge exit status - M4_OPEN" • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm" • Alarm Message – "PreChrg Breaker Opened"
MAIN_USER_OPEN	M1 contactor disabled during precharge (not in service mode)	• "Main contactor disabled while waiting for volts to build" • "Input Contactor (M1) inhibited waiting for reset" • "Input Contactor (M1) inhibited after cell diags" • "Input Contactor (M1) inhibited after opening M4" • "M1 disabled while waiting for M1 to close" • "Precharge exit status - MAIN_USER_OPEN" • Fault Message – "Precharge Fault"
USER_ABORT_M1_CLOSE	Precharge enable "StartCellPrecharge_O" removed while waiting for M1 to close	• "Loss of Precharge enable while waiting for M1 to close" • "Precharge exit status - USER_ABORT_M1_CLOSE" • Fault Message – "Precharge Fault"

Exit State	Description	Event Log Messages & Faults/Alarms
M1_OPEN_LOWDC	Low cell DC bus voltage detected while waiting for M1 to close	• "Low cell DC bus occurred while waiting for M1 to close" • "Precharge exit status - M1_OPEN_LOWDC" • Fault Message – "PreChrg M1 Contactor Flt"
M1_CLOSE_WITH_NOMV	Medium Voltage has gone low (below 80%) either while waiting for M1 to close or after an acknowledge.	• "MV Low while waiting for M1 to close" • "M1 closed but no MV detected" • "Precharge exit status - M1_CLOSE_WITH_NOMV" • Fault Message – "PreChrg M1 Contactor Flt"
M1_OPEN_WITH_FAULT	Medium voltage is detected but no M1 acknowledge is present after 3 seconds of waiting.	• "MV detected but no M1 contactor ack while waiting for M1 to close" • "Precharge exit status - M1_OPEN_WITH_FAULT" • Fault Message – "PreChrg M1 Contactor Flt"

Exit State	Description	Event Log Messages & Faults/Alarms
INPUT_OV	If the input MV (Fundamental voltage vector magnitude calculated from the primary attenuators and corrected for tap setting) goes above 115%, an overvoltage condition exists that will abort precharge.	• "Input Over Voltage occurred while waiting for volts to build" • "Voltage exceeded the trip level before close M3" • "Voltage exceeded the trip level after close M3" • "Voltage exceeded the trip level after open M2" • "Voltage exceeded the trip level after close M4" • "Voltage exceeded the trip level after open M3" • "Voltage exceeded the trip level waiting for fault reset" • "Voltage exceeded the trip level waiting for Cell Diags to complete" • "Voltage exceeded the trip level after cell diags - before M4 open" • "Voltage exceeded the trip level after open M4" • "Voltage exceeded the trip level waiting for M1 to close" • "Precharge exit status - INPUT_OV" • Fault Message – "Precharge Fault"

Exit State	Description	Event Log Messages & Faults/Alarms
INPUT_PROTECTION	An input protection has occurred during precharge and precharge must abort.	• "Protection fault or LFR detected while waiting for volts to build" • "Protection fault or LFR detected before close M3" • "Protection fault or LFR detected after close M3" • "Protection fault or LFR detected after open M2" • "Protection fault or LFR detected after close M4" • "Protection fault or LFR detected after open M3" • "Input protection fault or LFR detected waiting for reset" • "Input Protection or LFR detected after cell diagnostics" • "Input Protection fault or LFR detected after open M4" • "DSP Cell Protection fault while waiting for M1 to close" • "Input Protection fault or LFR detected while waiting for M1 to close" • "Precharge exit status - INPUT_PROTECTION" • Fault Message – "Precharge Fault"
UNKNOWN	An unusual exit from the precharge thread which should never occur.	• "Precharge exit status - UNKNOWN" • Fault Message – "Precharge Fault"

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5.21.1.8 Fault or Exception Conditions During Precharge

Table 5-21: Fault or Exception Conditions During Type 5 Precharge

Fault or Exception Condition Description	Event Log Messages & Faults/Alarms
After M1 commanded open - following delay of 1 second	• "Precharge: M1 failed to open"
After M2 commanded close – following delay of 1 second	• "Precharge: M2 failed to close"
While waiting for voltage to climb	• "Precharge enable removed while waiting for volts to build up" • "Main contactor disabled while waiting for volts to build" • "Input Over Voltage occurred while waiting for volts to build" • "Protection fault or LFR detected while waiting for volts to build" • "Timeout exceeded 30 secs to reach voltage"
Following voltage reaching 0.9 PU	• "Protection fault or LFR detected before close M3" • "Voltage exceeded the trip level before close M3" • "Precharge enable removed before close M3"
After M3 commanded close – following delay of 1 second	• "Precharge: M3 failed to close" • "Protection fault or LFR detected after close M3" • "Timeout exceeded 30 secs closing M3" • "Voltage exceeded the trip level after close M3" • "Precharge enable removed after M3 closed"
After M2 commanded open – following delay of 1 second	• "Precharge: M2 failed to open" • "Protection fault or LFR detected after open M2" • "Timeout exceeded 30 secs opening M2" • "Voltage exceeded the trip level after open M2" • "Precharge enable removed after M2 opened"
After M4 commanded close – following delay of 1 second	• "Precharge: M4 failed to close" • "Protection fault or LFR detected after close M4" • "Timeout exceeded 30 secs closing M4" • "Voltage exceeded the trip level after close M4" • "Precharge enable removed after M4 closed"
After M3 commanded open – following delay of 1 second	• "Precharge: M3 failed to open" • "Protection fault or LFR detected after open M3" • "Timeout exceeded 30 secs opening M3" • "Voltage exceeded the trip level after open M3" • "Precharge enable removed after M3 opened"

Fault or Exception Condition Description	Event Log Messages & Faults/Alarms
Cell fault exists – waiting (indefinitely) for fault reset (only if a cell fault exists) **Caution! Before pressing the fault reset be sure to understand the specifics of this type of fault by viewing the event log. For example closing M1 on low cell DC Bus voltage could result in extreme damage to the Cell and the System. Pulling a cell F.O. link to allow Precharge to complete is highly inadvisable.**	• "Precharge: Waiting for reset..." (indicates cell fault exists and reset is required) • "Voltage exceeded the trip level waiting for fault reset" • "Input protection fault or LFR detected waiting for reset" • "Lost MV waiting for reset" • "Precharge enable removed while waiting for reset" • "Input Contactor (M1) inhibited waiting for reset"
Waiting for cell diagnostics to complete (whether or not there are cell faults)	• "Voltage exceeded the trip level waiting for Cell Diags to complete" • "Precharge enable removed while waiting for Cell Diags to complete"
After cell diagnostics completes and before M4 commanded open	• "Voltage exceeded the trip level after cell diags - before M4 open" • "Input Protection or LFR detected after cell diagnostics" • "Input Contactor (M1) inhibited after cell diags" • "Precharge enable removed after cell diags"
After M4 commanded open – following delay of 1 second	• "Precharge: M4 failed to open" • "Input Protection fault or LFR detected after open M4" • "Voltage exceeded the trip level after open M4" • "Input Contactor (M1) inhibited after opening M4" • "Low Cell DC bus occurred after M4 commanded open"
After M1 commanded close – waiting for M1 acknowledge	• "DSP Cell Protection fault while waiting for M1 to close" • "Input Protection fault or LFR detected while waiting for M1 to close" • "Voltage exceeded the trip level waiting for M1 to close" • "Low cell DC bus occurred while waiting for M1 to close" • "Loss of Precharge enable while waiting for M1 to close" • "M1 disabled while waiting for M1 to close"
After three second delay – still waiting for M1 acknowledge	• "MV detected but no M1 contactor ack while waiting for M1 to close"
After M1 acknowledge received	• "M1 closed but no MV detected"

Table 5-22: Type 5 Precharge Thread 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
M3_CLOSE	M3 commanded to close
M2_OPEN	M2 commanded to open
M4_CLOSE	M4 commanded to close
M3_OPEN	M3 commanded to open **Note:** Must get to this point within 30 seconds or a precharge fault will occur.
WAIT_FOR_RESET	Cell fault detected during precharge. **Note:** No timeout fault - will wait indefinitely. **User must issue reset to continue precharge.**
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
M1_CLOSE	M1 commanded to close
WAIT_FOR_M1_ACK	System is waiting for the acknowledge from the M1 contactor
PC_COMPLETE	Precharge is finished

5.21.2 Type 6 (Closed) Precharge

Type 6 precharge is designed for WCIII drives exclusively. and uses 4 contactors M1, M2, M3, and M4. It is designed so that M4 will not open until M1 closes. This designates type 6 precharge as a 'Make before Break', or "closed" precharge type. Type 6 precharge can be implemented only on the 'new' I/O board using the digital I/O Breakout board.

Type 6 precharge can be implemented only with the NXGII Standard I/O board using the digital I/O breakout board due to the dedicated I/O controlled directly through the NXG code.

Note: On any precharge fault, the event log must be examined for the cause, and the problem must be corrected before proceeding to another attempt. See Table 5-24 at the end of this section for event log messages and potential issues.

5.21.2.1 Type 6 Precharge Circuit

The precharge circuit consists of a collection of capacitors, resistors, and contactors mounted in the FPC cabinet on the input section of the drive. (Refer to Figure 5-41). On the left is the low voltage precharge source coming in through the precharge circuit breaker. On the right side is the connection to the precharge secondary windings of the input transformer. Voltage during precharge is monitored through the input attenuators on the primary side of the transformer (not shown). The M1 contactor connects the MV source to the primary.

The precharge power circuitry is identical to type 5, and if in place, either type can be used. The only exception is an additional signal, "In-sync", from a sync check relay – that is required to complete precharge.

Caution!

During precharge, Medium voltage is present on the primary side of the input transformer even though the MV Contactor is not closed!

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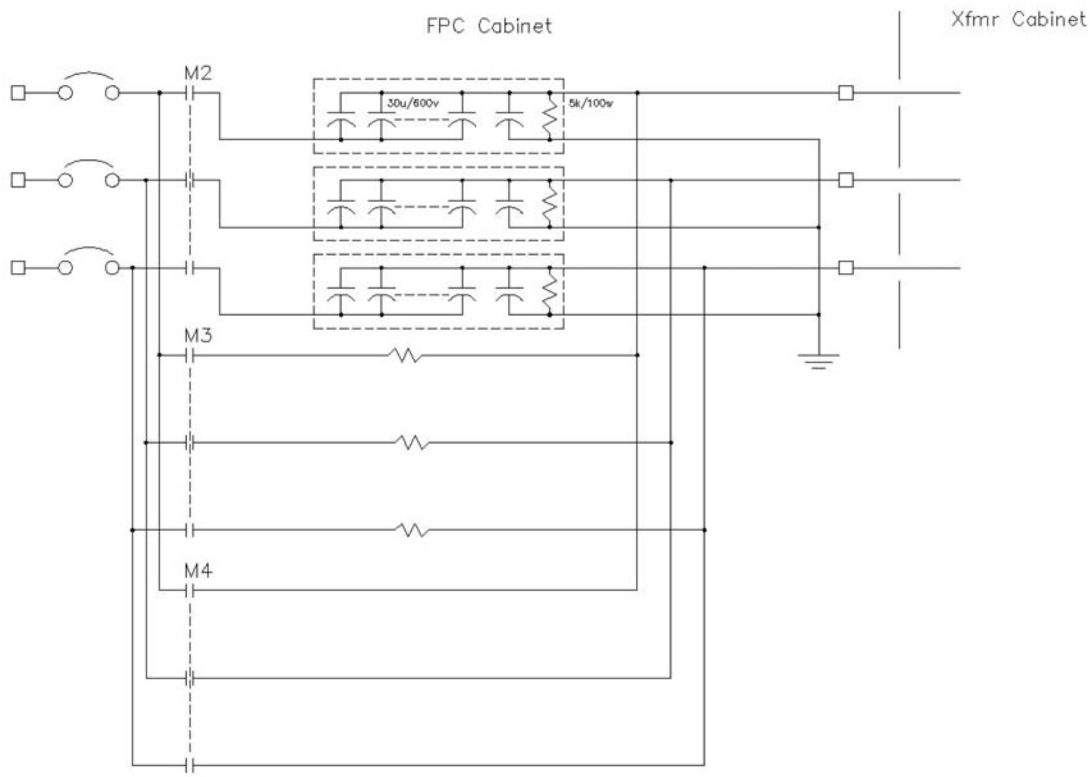

Figure 5-41: Type 5 & 6 Precharge Circuit Schematic

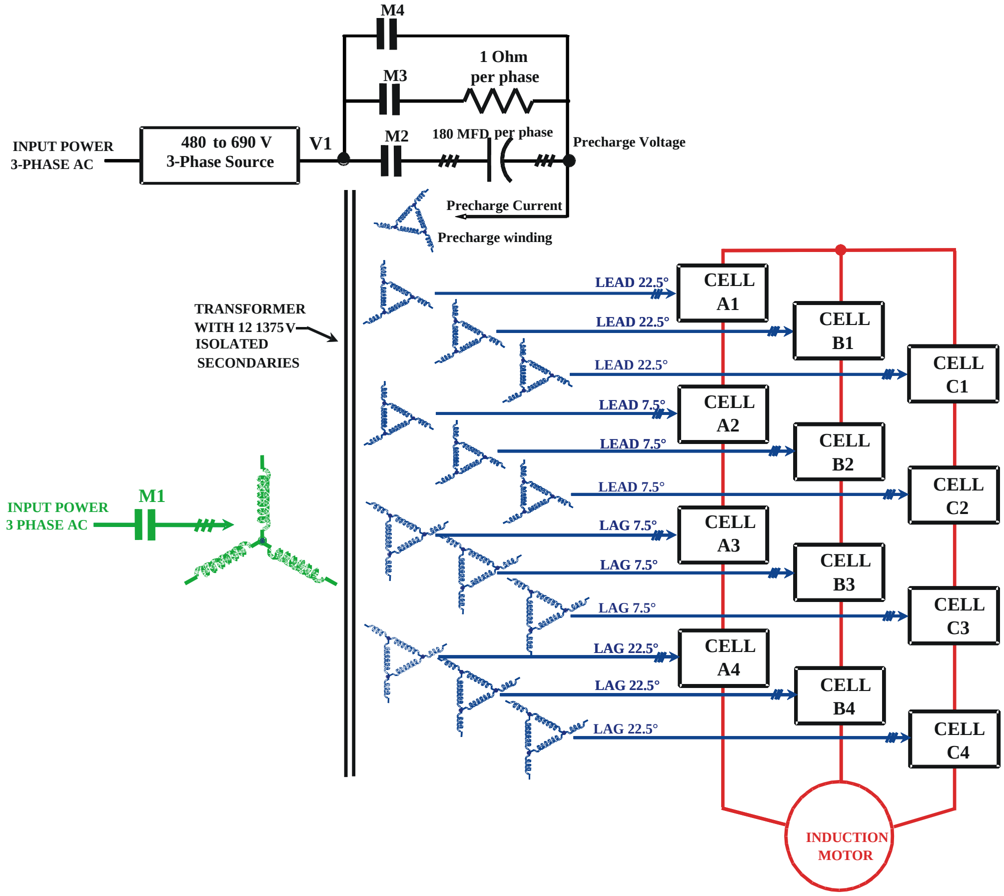

Figure 5-42: Type 5 & 6 Precharge Component Connections Diagram

The precharge contactors are controlled directly by the NXG code and require no SOP interaction with the exception of the start precharge command.

Precharge is initiated by setting the SOP flag ***"StartCellPrecharge_O"*** true. It must be maintained throughout the entire precharge sequence until complete, else it will result in a precharge fault. At the end of a successful precharge cycle, the ***"PrechargeComplete_I"*** SOP flag is set true. No other SOP flags are necessary to perform precharge.

5.21.2.2 Parameter Settings

Type 6 precharge only has two settings in the parameters for normal operation. Two additional ones are for Maintenance (or Service) mode of operation.

- Precharge Enable (ID 2635 in Cell Menu) to "Type 6 Closed" (see Figure 5-43)
- Cell Voltage (ID 2550) must be valid for the Precharge cell type selected (750V AP – 2Q or 4Q). These are the two settings that are defined for the WCIII drive. (see Figure 5-39)
- Precharge Service Mode (ID 2637) – completes precharge with M4 closed. M1 never closes. This is for troubleshooting purposes only.
- Precharge Service Start (ID 2638) – starts the service mode of precharge from the menu rather than through an SOP flag.

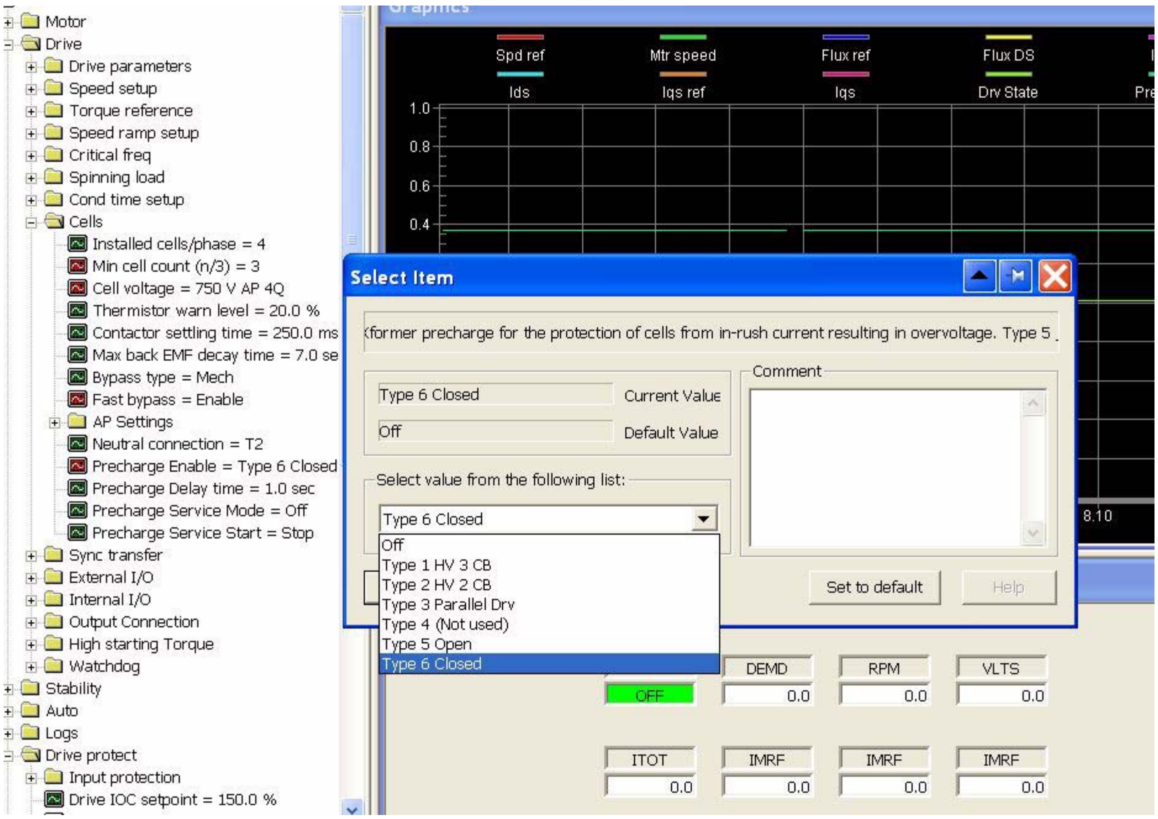

Figure 5-43: Selecting Type 6 Closed from Pick List

5.21.2.3 Dedicated I/O

Type 6 precharge reads inputs and controls outputs directly with no intervention from the SOP. It uses the following I/O from the NXGII Standard I/O Breakout board.

- Output to close M1 – DO-9
- Output to close M2 – DO-10
- Output to close M3 – DO-11
- Output to close M4 – DO-12
- Output to trip Precharge Breaker – DO-13
- Output to M1 Permissive – DO-14
- Output to trip LFR – DO-15 (Input protection)
- Input – M1 Close Ack – DI-2E – P18
- Input – M2 Close Ack – DI-3D – P15
- Input – M3 Close Ack – DI-0E – P16
- Input – M4 Close Ack – DI-1E – P17
- Input – LFR Status – DI-3E (Input protection)
- Input – Start Cell Precharge – DI-2D (assigned but not dedicated – need SOP flag set from this input)
- Input – In-Sync permissive – DI-2B – P6

5.21.2.4 SOP Flags

The following are SOP flags associated with Type 6 precharge.

Table 5-23: SOP Flags

Flag	Description
StartCellPrecharge_O	Starts or Aborts precharge
MainInputVoltageDisable_O	Prevents the main medium voltage contactor from closing. Setting this flag aborts the precharge if it is in progress and not in service mode.
SetIPFault_O	Forces an input protection fault
DriveReadyToPrecharge_I	All conditions met for type 6 precharge to start (as described below)
PrechargeInProgress_I	Type 6 precharge is in progress
PrechargeComplete_I	Precharge has completed successfully (with no errors) as described below.
PrechargeBreakerOpened_I	Precharge breaker has opened (Alarm) – if a precharge contactor is showing closed and the command is to have it open, the precharge breaker trips but the drive does not fault once precharge is complete.
PrechargeContactorAlarm_I	A precharge contactor acknowledge differs from command (half second delay)
PreChrgM1ContactorFault_I	M1 failed to properly operate during precharge

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5.21.2.5 Precharge Pre-Conditions

The entire precharge sequence can be monitored through an externally connected monitor or through the Debug Tool set to the “Drive Misc Status Flags 2” (Ctrl-Y on keyboard or menu selection in the tool). The “DriveReadyToPrecharge” flag in the lower right corner must be set true for precharge to begin. Monitor the progress on the ‘MedVolts’, ‘Precharge State’, and ‘PrechargeExitState’ variables on the right side.

Every Step in the precharge sequence is logged in the event log – including any fault conditions that abort precharge. Also the exit condition from the precharge thread is logged.

If all of the following conditions exist, the ***“DriveReadyToPrecharge_I”*** flag will be true (1). If any of these conditions are not met, the flag will be set false, therefore this flag can be used as part of the conditions to start precharge. Precharge cannot be initialized or started if this flag is not true. Once precharge commences, the flag goes false and will remain false until all conditions are again met.

Type 6 precharge selected
Drive not running
Type 750V AP (2Q or 4Q) cell selected
MV is low
Output to M1 Permissive is open (DO-2d – P14)
Output to close M1 is open (DO-1c – P9)
Precharge thread state is in initial condition (PC_FINISHED)
M1 is open (M1 Close Ack – DI-2e – P18)
M2 is open (M2 Close Ack – DI-3d – P15)
M3 is open (M3 Close Ack – DI-0e – P16)
M4 is open (M4 Close Ack – DI-1e – P17)

No Medium Low Fault
LFR not tripped and latched (due to Input Protection)
No precharge fault exists
MV is not disabled (***MainInputVoltageDisable_O*** = true) Or Maintenance or Service mode is enabled.
No Precharge Circuit breaker alarm active
No precharge contactor alarm active
No precharge main contactor fault
No Input protection fault

> **Note:** If any cells were in bypass prior to losing MV, their respective bypass contactor will be opened since the bypass contactor power supply is energized by one phase of the MV input. During the subsequent precharge, if the cell is detected as faulted, then precharge will pause indefinitely until a manual drive reset is activated. Precharge will then proceed and the detected faulted cell will be bypassed after precharge is completed.

Setting ***"StartCellPrecharge_O"*** to true initiates the precharge sequence. **Precharge will not initiate if the *DriveReadyToPrecharge_I* is not true, or any of the above conditions are not met.**

The following variables can be monitored on the Host Tool Graphic display: Precharge State "PreChrg St" (scaling 1.0 and offset 0.0) and Precharge Voltage "PreCharg V" (scaling 1.0 and offset -1.0). Plot time is set to 33.33 seconds. The display should look similar to Figure 5-44 after a successful Type 6 precharge.

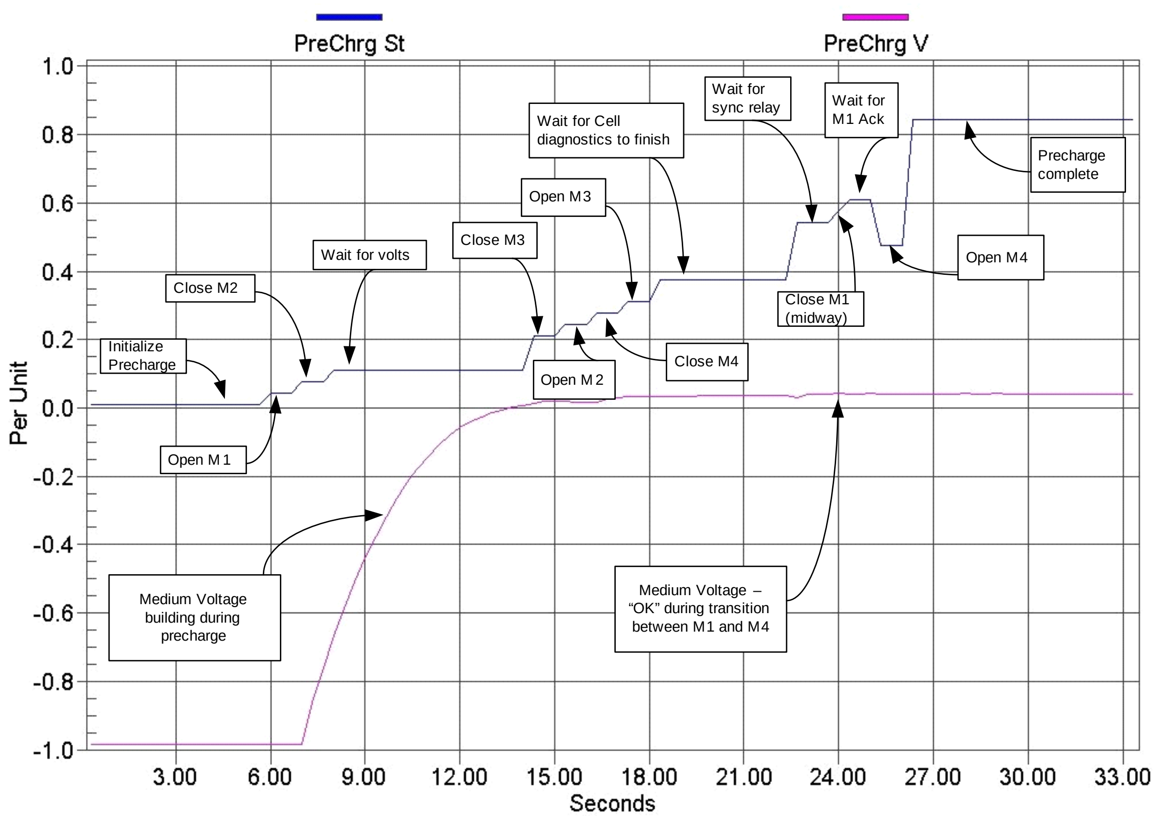

Figure 5-44: Full Successful Precharge plot on the Host Tool

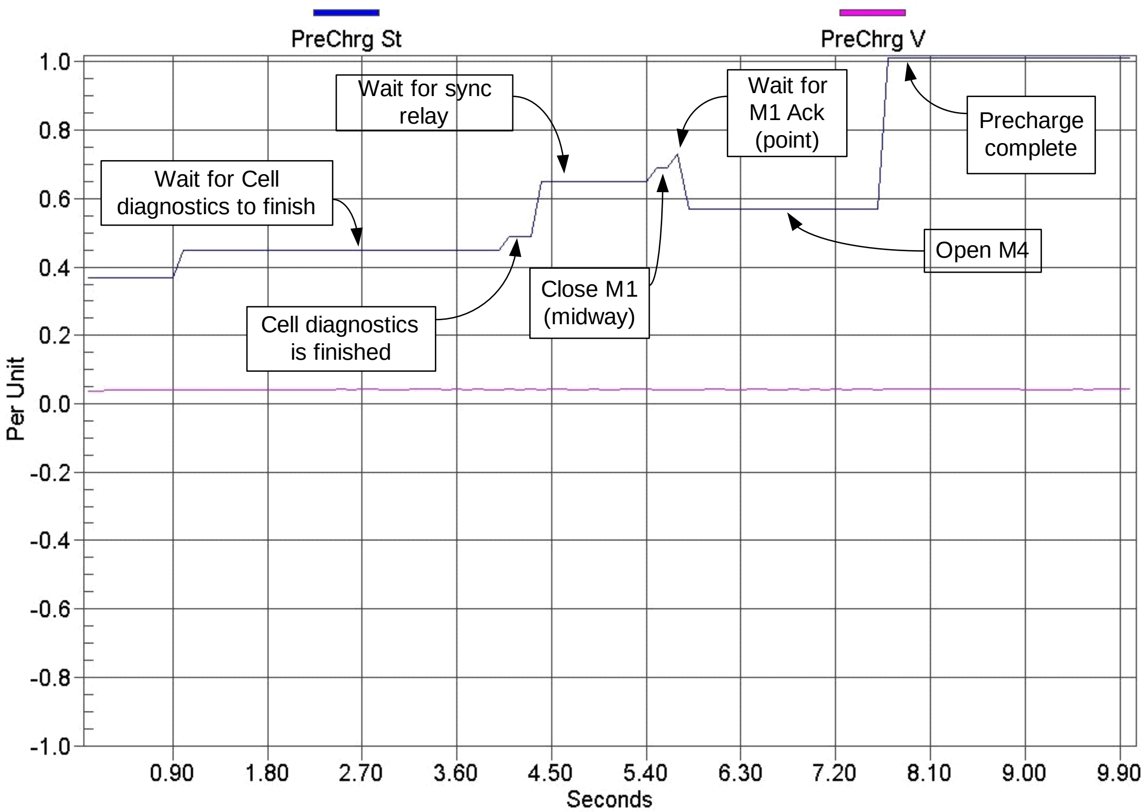

Figure 5-45: Expanded view of M4 to M1 timing

After precharge is finished, there should be no precharge faults. The Event Log records each state with an entry. The event log should look similar to the following Event Log excerpt for a normal successful precharge with no cell faults.

10/17/08 11:54:28 Precharge Start type 6 (Closed)
10/17/08 11:54:29 Precharge: Open M1
10/17/08 11:54:30 Precharge: Close M2
10/17/08 11:54:30 Precharge: Waiting for voltage buildup...
10/17/08 11:54:32 Medium Voltage - OK
10/17/08 11:54:39 Precharge: Close M3
10/17/08 11:54:40 Precharge: Open M2
10/17/08 11:54:41 Precharge: Close M4
10/17/08 11:54:42 Precharge: Open M3
10/17/08 11:54:42 Precharge: Waiting for cell diagnostics to finish...
10/17/08 11:55:01 Precharge: Cell diagnostics is complete
10/17/08 11:55:01 Waiting for In-Synch Relay permissive to close M1
10/17/08 11:55:21 Precharge: Close M1
10/17/08 11:55:21 Precharge: Waiting for M1 to close...
10/17/08 11:55:22 Precharge: Open M4
10/17/08 11:55:23 Precharge complete: No errors
10/17/08 11:55:23 Precharge exit status - NO_ERRORS

If Maintenance or Service mode is selected, the following message will show following the “Precharge: Cell diagnostics is complete”. In this mode M4 stays closed and M1 never closes. Also the setting of the ***“MainInputVoltageDisable_O”*** SOP flag has no affect in Maintenance or Service mode.

Precharge: Cell diagnostics is complete

Precharge: Maintenance mode enabled

Precharge complete: No errors

If a cell is faulted during precharge, it will pause indefinitely waiting for a fault reset. If this occurs the following message appears in the event log following the opening of M3:

Precharge: Open M3

Precharge: Waiting for reset...

Precharge: Waiting for cell diagnostics to finish...

Since fast bypass is disabled during precharge, any faulted cells will not be reset or bypassed until after precharge is complete. Also only fault messages will display on either the keypad or Host Tool – there is no message to reset the drive, but this is required.

> ☝ **Note:** Since a cell fault is a fatal fault, the ***"FatalFault_I"*** SOP flag cannot be used to set the ***"MainInputVoltageDisable_O"*** flag, or to remove the ***"StartCellPrecharge_O"***. Doing either during precharge will abort precharge with a precharge fault.

5.21.2.6 Type 6 Precharge sequence

Type 6 precharge is controlled entirely through the NXG drive code and can only be enabled for WCIII drives. Once started, precharge goes through the following sequence.

- Drive is ready to precharge – all conditions met and ***DriveReadyToPrecharge_I*** is true.
- Start Precharge – set the ***StartCellPrecharge_O*** flag true through the SOP. This starts the precharge thread. (For Maintenance or service mode, precharge is started by the "Precharge Service Start" (2638) when Precharge Service mode is selected (2637).)
- M1 is commanded to open (it should already be open, but this is a precautionary step). All precharge contactors are issued an open command as well.
- Once M1 is confirmed open, M2 is commanded to close.
- With M2 closed, the drive input voltage should begin to climb and the drive waits until 90% of rated voltage is achieved. The precharge capacitors provide a resonant circuit with the input inductance allowing a lower secondary input voltage to charge to 90% of rated drive input voltage through the secondary.
- When the input voltage reaches 60% of rated, cell diagnostics begins and Medium voltage is considered 'OK'.
- Once the input voltage reaches 90% of rated input voltage (plus tap setting), M3 is commanded to close to dampen the resonance and maintain the voltage. Failure to connect the resistors could result in an overvolt-
age
condition on the cells.
- When M3 is closed, M2 is commanded open.
- When M2 is open, M4 is commanded closed. M4 provides holding voltage with no resistance drop. This lowers the power rating requirement on the precharge damping resistors.
- When M4 is closed, M3 is commanded open. This total sequence with M3 open and M4 closed must be completed in 30 seconds or a timeout will occur resulting in a precharge fault.

- The drive then waits for Cell Diagnostics to complete. If a cell is faulted, precharge waits for a fault reset. The fault reset only acknowledges the fault and cell diagnostics will exit so that precharge is free to continue. Any faulted cells will be bypassed on exit if bypass is enabled.

> **Note:** When a cell fault is detected, the fault will display on the keypad. The drive will wait until reset, but will trip if an overvoltage, cell under-voltage, or input protection fault occurs, or if the precharge is aborted, or the MV falls below 80% (as read through the input attenuators). No other indication is given that a reset is required.

- If Service mode is selected, precharge completes at this point with M4 closed and MV stays on through the precharge source.
- When cell diagnostics is complete, the In-Sync signal is checked to determine if M1 can be commanded to close. There is no drop in input voltage, and the cell capacitors maintain their charge. The wait for the In-Sync signal is indefinite as long as MV is maintained (through the M4 contactor), a precharge fault does not occur, and the precharge command is not removed.
- After receiving the In-Sync signal, M1 is commanded to close. This is done through two separate digital outputs on the breakout board – M1 close permissive (DO-14), and Precharge Complete-M1 Close (DO-9).
- The drive will then wait three seconds for the M1 contactor to close. It senses this through the Digital Input for the M1 Acknowledge (DI-2E). Should the M1 acknowledge not return within five seconds, a Precharge M1 contactor fault – “PreChrg M1 Contactor Flt” – will occur and precharge will be aborted.
- Once the M1 acknowledge is received, M4 is commanded to open.
- With the acknowledge of M4 open, three more checks are made prior to completion: the input voltage must be above 80%, the precharge contactors (M2, M3, & M4) must all show open, and the SOP flag ***“MainInputVoltageDisable_O”*** must be false.
- Precharge is complete and the drive is connected to the MV source and ready to run. The precharge thread is exited and the exit state is recorded in the event log along with all other recorded precharge events in the sequence.

> **Note:** The drive run is inhibited until precharge has successfully completed.

5.21.2.7 Precharge Exit States and Associated Event log text

When the precharge thread exits, the status is recorded in the event log (following the entire sequence from beginning to end). Aside from a normal precharge, there are conditions under which a precharge fault or alarm occurs. The following is a list of exit status conditions and associated event log entries and any associated faults or alarms.

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Table 5-24: Precharge Exit States and Associated Event log text

Exit State	Description	Event Log Messages & Faults/Alarms
NO_ERRORS	Precharge is successful (including service mode) – No fault	• “Precharge: Maintenance mode enabled” • “Precharge complete: No errors” • “Precharge exit status – NO_ERRORS”
M1_OPEN	Precharge aborted when M1 failed to open initially (should never get this since M1 open is a precondition).	• “Precharge: M1 failed to open” • “Precharge exit status - M1_OPEN” • Fault Message – “PreChrg M1 Contactor Flt”
M2_CLOSE	M2 failed to acknowledge after 1 second delay following command to close	• “Precharge: M2 failed to close” • “Precharge exit status - M2_CLOSE” • Fault Message – “Precharge Fault” • Alarm Message – “PreChrg Contactor Alarm”
USER_ABORT	Precharge enable (StartCellPrecharge_O) is set false before precharge is complete. Depending on where in the precharge algorithm the change is detected will determine the message. All result in a precharge fault.	• “Precharge enable removed while waiting for volts to build up” • “Precharge enable removed before close M3” • “Precharge enable removed after M3 closed” • “Precharge enable removed after M2 opened” • “Precharge enable removed after M4 closed” • “Precharge enable removed after M3 opened” • “Precharge enable removed while waiting for reset” • “Precharge enable removed while waiting for Cell Diags to complete” • “Precharge enable removed after cell diags” • “Precharge enable removed while waiting for in-sync relay” • “Precharge exit status - USER_ABORT” • Fault Message – “Precharge Fault”

Exit State	Description	Event Log Messages & Faults/Alarms
TIME_OUT_ABORT	Precharge took longer than 30 seconds to close M4 and open M3	• "Timeout exceeded 30 secs to reach voltage" • "Timeout exceeded 30 secs after close M3" • "Timeout exceeded 30 secs opening M2" • "Timeout exceeded 30 secs closing M4" • "Timeout exceeded 30 secs opening M3" • "Precharge exit status - TIME_OUT_ABORT" • Fault Message – "Precharge Fault"
M3_CLOSE	M3 failed to acknowledge after 1 second delay following command to close	• "Precharge: M3 failed to close" • "Precharge exit status - M3_CLOSE" • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm"
M2_OPEN	M2 failed to acknowledge after 1 second delay following command to open	• "Precharge: M2 failed to open" • "Precharge exit status - M2_OPEN" • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm" • Alarm Message – "PreChrg Breaker Opened"
M4_CLOSE	M4 failed to acknowledge after 1 second delay following command to close or voltage dropped after M4 acknowledge confirmed.	• "Precharge: M4 failed to close" • "Precharge exit status – M4_CLOSE" • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm"
M3_OPEN	M3 failed to acknowledge after 1 second delay following command to open	• "Precharge: M3 failed to open" • "Precharge exit status – M3_OPEN" • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm" • Alarm Message – "PreChrg Breaker Opened"
WAIT_FOR_RESET	Loss of Medium Voltage while waiting for a fault reset	• "Lost MV waiting for reset" • "Precharge exit status – WAIT_FOR_RESET" • Fault Message – "Precharge Fault"

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Exit State	Description	Event Log Messages & Faults/Alarms
M4_OPEN	M4 failed to acknowledge after 1 second delay following command to open	• "Precharge: M4 failed to open with M1 closed" • "Precharge: One of the precharge contactors is still closed" • "Precharge exit status - M4_OPEN" • Fault Message – "Precharge Fault" • Alarm Message – "PreChrg Contactor Alarm" • Alarm Message – "PreChrg Breaker Opened"
MAIN_USER_OPEN	M1 contactor disabled during precharge (not in service mode)	• "Main contactor disabled while waiting for volts to build" • "Input Contactor (M1) inhibited waiting for reset" • "Input Contactor (M1) inhibited after cell diags" • "Input Contactor (M1) inhibited waiting for in-sync relay" • "Low Cell DC Bus voltage aborted precharge" • "Precharge: MainInputVoltageDisable_OSOP flag opened main input" • "Precharge exit status - MAIN_USER_OPEN" • Fault Message – "Precharge Fault"
USER_ABORT_M1_CLOSE	Precharge enable (StartCellPrecharge_O) removed while waiting for M1 to close	• "Loss of Precharge enable while waiting for M1 to close" • "Precharge exit status - USER_ABORT_M1_CLOSE" • Fault Message – "Precharge Fault"
M1_CLOSE_LOWDC	A cell reported low DC bus voltage while waiting for M1 to close	• "Low cell DC bus occurred while waiting for M1 to close" • "Precharge exit status - M1_CLOSE_LOWDC" • Fault Message – "PreChrg M1 Contactor Flt"
M1_OPEN_WITH_NOMV	Medium Voltage has gone low (below 80%) while waiting for M1 to close	• "MV Low while waiting for M1 to close" • "Precharge exit status - M1_OPEN_WITH_NOMV" • Fault Message – "PreChrg M1 Contactor Flt"

Exit State	Description	Event Log Messages & Faults/Alarms
M1_CLOSE_WITH_NOMV	Medium Voltage has gone low (below 80%) after an M1 acknowledge.	• Precharge: "M1 closed but no MV detected" • "Precharge exit status - M1_CLOSE_WITH_NOMV" • Fault Message – "PreChrg M1 Contactor Flt"
M1_OPEN_WITH_FAULT	Medium voltage is detected but no M1 acknowledge is present after 5 seconds of waiting.	• "Precharge: 5 second timeout while waiting for M1 to close" • "Precharge exit status - M1_OPEN_WITH_FAULT" • Fault Message – "PreChrg M1 Contactor Flt"
INPUT_OV	If the input MV (Fundamental voltage vector magnitude calculated from the primary attenuators and corrected for tap setting) goes above 115%, an overvoltage condition exists that will abort precharge.	• "Input Over Voltage occurred while waiting for volts to build" • "Voltage exceeded the trip level before close M3" • "Voltage exceeded the trip level after close M3" • "Voltage exceeded the trip level after open M2" • "Voltage exceeded the trip level after close M4" • "Voltage exceeded the trip level after open M3" • "Voltage exceeded the trip level waiting for fault reset" • "Voltage exceeded the trip level during cell diags" • "Voltage exceeded the trip level after cell diags - before M1 close" • "Voltage exceeded the trip level waiting for in-sync relay" • "Voltage exceeded the trip level waiting for M1 to close" • "Precharge exit status - INPUT_OV" • Fault Message – "Precharge Fault"

Exit State	Description	Event Log Messages & Faults/Alarms
INPUT_PROTECTION	An input protection has occurred during precharge and precharge must abort.	• "Protection fault or LFR detected while waiting for volts to build" • "Protection fault or LFR detected after close M3" • "Protection fault or LFR detected after open M2" • "Protection fault or LFR detected after close M4" • "Protection fault or LFR detected after open M3" • "Input protection fault or LFR detected waiting for reset" • "Input Protection or LFR detected after cell diagnostics" • "Input protection fault or LFR detected waiting for in-sync relay" • "DSP Cell Protection fault while waiting for M1 to close" • "Input Protection fault or LFR detected while waiting for M1 to close" • "Input protection fault or LFR detected after M1 closed and M4 opened" • "Precharge exit status - INPUT_PROTECTION" • Fault Message – "Precharge Fault"
WAIT_FOR_SYNC	Drive lost MV while waiting for In-Sync digital input.	• "Lost MV waiting for in-sync relay" • "Precharge exit status - WAIT_FOR_SYNC" • Fault Message – "Precharge Fault"
M1_CLOSE	M1 contactor detected closed while waiting for In-Sync digital input	• "Input Contactor (M1) detected closed waiting for in-sync relay" • "Precharge exit status - M1_CLOSE" • Fault Message - "PreChrg M1 Contactor Flt"
UNKNOWN	An unusual exit from the precharge thread which should never occur.	• "Precharge exit status - UNKNOWN" • Fault Message – "Precharge Fault"

5.21.2.8 Fault or exception Conditions During Precharge

Table 5-25: Fault or exception Conditions During Type 6 Precharge

Fault or Exception Condition Description	Event Log Messages & Faults/Alarms
After M1 commanded open - following delay of 1 second	• "Precharge: M1 failed to open"
After M2 commanded close – following delay of 1 second	• "Precharge: M2 failed to close"
While waiting for voltage to climb	• "Precharge enable removed while waiting for volts to build up" • "Main contactor disabled while waiting for volts to build" • "Input Over Voltage occurred while waiting for volts to build" • "Protection fault or LFR detected while waiting for volts to build" • "Timeout exceeded 30 secs to reach voltage"
Following voltage reaching 0.9 PU	• "Protection fault or LFR detected before close M3" • "Voltage exceeded the trip level before close M3" • "Precharge enable removed before close M3"
After M3 commanded close – following delay of 1 second	• "Precharge: M3 failed to close" • "Protection fault or LFR detected after close M3" • "Timeout exceeded 30 secs closing M3" • "Voltage exceeded the trip level after close M3" • "Precharge enable removed after M3 closed"
After M2 commanded open – following delay of 1 second	• "Precharge: M2 failed to open" • "Protection fault or LFR detected after open M2" • "Timeout exceeded 30 secs opening M2" • "Voltage exceeded the trip level after open M2" • "Precharge enable removed after M2 opened"
After M4 commanded close – following delay of 1 second	• "Precharge: M4 failed to close" • "Protection fault or LFR detected after close M4" • "Timeout exceeded 30 secs closing M4" • "Voltage exceeded the trip level after close M4" • "Precharge enable removed after M4 closed"
After M3 commanded open – following delay of 1 second	• "Precharge: M3 failed to open" • "Protection fault or LFR detected after open M3" • "Timeout exceeded 30 secs opening M3" • "Voltage exceeded the trip level after open M3" • "Precharge enable removed after M3 opened"

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Fault or Exception Condition Description	Event Log Messages & Faults/Alarms
Cell fault exists – waiting (indefinitely) for fault reset (only if a cell fault exists) **Caution!** **Before pressing the fault reset be sure to understand the specifics of this type of fault by viewing the event log. For example closing M1 on low cell DC Bus voltage could result in extreme damage to the Cell and the System. Pulling a cell F.O. link to allow Precharge to complete is highly inadvisable.**	• "Precharge: Waiting for reset..." (indicates cell fault exists and reset is required) • "Voltage exceeded the trip level waiting for fault reset" • "Input protection fault or LFR detected waiting for reset" • "Lost MV waiting for reset" • "Precharge enable removed while waiting for reset" • "Input Contactor (M1) inhibited waiting for reset"
Waiting for cell diagnostics to complete (whether or not there are cell faults)	• "Voltage exceeded the trip level waiting for Cell Diags to complete" • "Precharge enable removed while waiting for Cell Diags to complete"
After cell diagnostics completes and before check for In-Sync input	• "Voltage exceeded the trip level after cell diags - before M1 close" • "Input Protection or LFR detected after cell diagnostics" • "Input Contactor (M1) inhibited after cell diags" • "Precharge enable removed after cell diags"
While waiting for In-Sync digital input	• "Voltage exceeded the trip level waiting for in-sync relay" • "Input protection fault or LFR detected waiting for in-sync relay" • "Lost MV waiting for in-sync relay" • "Low Cell DC Bus voltage aborted precharge" • "Input Contactor (M1) inhibited waiting for in-sync relay" • "Precharge enable removed while waiting for in-sync relay" • "Input Contactor (M1) detected closed waiting for in-sync relay"

Fault or Exception Condition Description	Event Log Messages & Faults/Alarms
After M1 commanded close – waiting for M1 acknowledge	• “DSP Cell Protection fault while waiting for M1 to close” • “Input Protection fault or LFR detected while waiting for M1 to close” • “Voltage exceeded the trip level waiting for M1 to close” • “Low cell DC bus occurred while waiting for M1 to close” • “Loss of Precharge enable while waiting for M1 to close” • “M1 disabled while waiting for M1 to close” • “MV Low while waiting for M1 to close” • “Precharge: 5 second timeout while waiting for M1 to close”
After M4 commanded open – following delay of 1 second	• “Precharge: M4 failed to open with M1 closed” • “Input protection fault or LFR detected after M1 closed and M4 opened” • “Precharge: MainInputVoltageDisable_O SOP flag opened main input” • “Precharge: One of the precharge contactors is still closed” • “Precharge: M1 closed but no MV detected”

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Table 5-26: Type 6 Precharge Thread 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
M3_CLOSE	M3 commanded to close
M2_OPEN	M2 commanded to open
M4_CLOSE	M4 commanded to close
M3_OPEN	M3 commanded to open **Note:** Must get to this point within 30 seconds or a precharge fault will occur.
WAIT_FOR_RESET	Cell fault detected during precharge. **Note:** No timeout fault - will wait indefinitely. **User must issue reset to continue precharge.**
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
WAIT_FOR_SYNC	The precharge thread will wait indefinitely for the In-Sync digital input before proceeding. **Note:** No timeout fault - will wait indefinitely for In-Sync digital input to continue precharge.
M1_CLOSE	M1 commanded to close
WAIT_FOR_M1_ACK	System is waiting for the acknowledge from the M1 contactor
M4_OPEN	M4 commanded to open
PC_COMPLETE	Precharge is finished

5.21.3 Precharge Service Mode (Type 5 and 6)

Precharge service mode can be used for initial testing of the precharge circuit itself, as well as for diagnostic work which requires the cells to be powered. Service mode is available and works the same for both type 5 and type 6 precharge.

The main contactor will not close in this mode. Once M4 closes (refer to Figure 5-36), the cells are fully charged from the secondary winding of the transformer.

Warning!

Use of the Precharge Service Mode applies full charge to the Cells, and MV to the drive transformer primary. Use Extreme caution when using this mode.

Note: Precharge service mode enables the drive to run with the M1 (Main) contactor disconnected, but should run with either the load disconnected or with a very light load for a short period of time. The precharge circuitry is all that is powering the cells and is not meant for continuous or heavy-duty service.

The precharge sequence for service mode follows:

1. Turn on Precharge service mode by setting parameter Precharge Service Mode (ID 2637) to “On” (see Figure 5-46).
2. Start the sequence by using the Precharge Service Start (ID 2638) parameter (see Figure 5-47). If precharge completes when using this mode, the start menu will automatically return to stop. Selecting Stop before precharge is complete will abort the precharge with a fault.
3. Select the start again to retry the service mode.
4. First the precharge contactors M2, M3, M4, and the main contactor, M1 are commanded to be open. These are preconditions to start, but this is done as assurance that they are open.
5. M2 then closes. This switches in the charging capacitor bank to begin resonant precharge.
6. At 90% rated input voltage (plus tap settings), M3 closes to switch in the resistor bank in parallel with the capacitor bank. This dampens the resonance so that the voltage will not climb higher.
7. M2 opens, disconnecting the charging capacitor bank.
8. M4 closes to connect power directly to the precharge winding in parallel with the resistor bank. This is done since the resistor bank is not rated for continuous application of power to the transformer.
9. M3 opens, disconnecting the resistor bank.
10. This entire sequence must be achieved in 30 seconds or the precharge sequence aborts and the drive will generate a precharge fault.
11. At this point the drive ready to run should be enabled for diagnostic purposes only.

To turn off this mode, set Precharge service mode to “Off.” This will result in the M4 contactor dropping out. The entire precharge sequence must then be activated normally in order to turn on MV power through the M1 contactor.

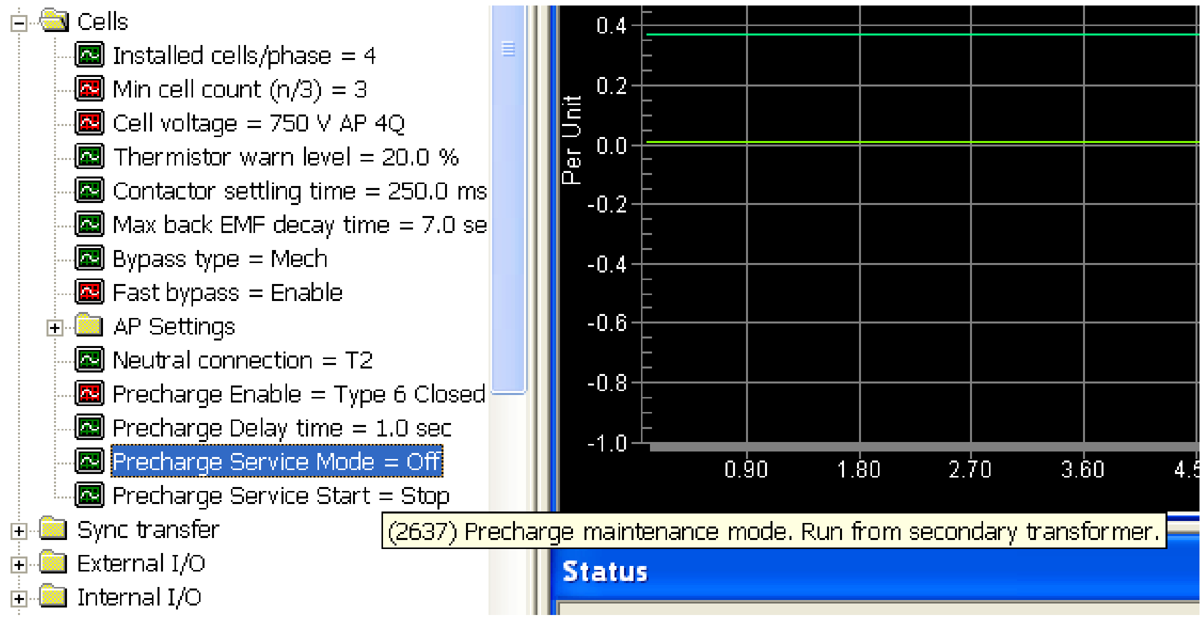

Figure 5-46: Precharge Service Mode On/Off

Figure 5-47: Starting Precharge Service Mode

5.21.4 Debugging Tools - Type 5 and 6 Precharge

The precharge states can be tracked in ToolSuite (for details, see Section 5.21.1 for Type 5 and Section 5.21.2 for Type 6 Precharge), 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 5-27 but is saved as the last state of the precharge thread when exited). Table 5-27 provides a list of additional Status Flags in the debug tool.

Table 5-27: Drive Miscellaneous Status Flags Debug Screen

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	PrechargeInProgress_I	0
M2 Close	0	MaintModeTest	0
M3 Close	0	MaintStartTest	0
M4 Close	0	PrchCompleteM1Close	0
M1 ACK	0	CellBusLowFlag_I	0
M2 ACK	0	CircuitBreakerOpened	0
M3 ACK	0	Precharge Start Cmd	0
M4 ACK	0	M1OpenWithoutCmd	0
StartCellPrecharge_O	0	PrechargeComplete_I	0
PreChrgMediumVoltageFault	0	InputProtect trip (LFR)	0
PreChrgContactorFailure	0	DriveReadyToPrecharge	0

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Table 5-28: 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
PreChrgMediumVoltageFault	If set, triggers a medium voltage fault that was caused in precharge process
PreChrgContactorFailure	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 precharge 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
Precharge ExitState	Exit state of precharge thread. **Note:** 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” or “750V AP 4Q”. **Note**: Must be set to run Type 5 or Type 6 Precharge

Flag	Description
PrechargeInProgress_I	Indicates that the precharge function is active
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”
PrchCompleteM1Close	The secondary M1 output enable has closed
CellBusLowFlag_I	State of SOP flag that indicates low DC bus voltage on a cell Used to trigger precharge
CircuitBreakerOpened	The precharge Circuit Breaker has been commanded to open
Precharge Start Cmd	All conditions are met to be able to start precharge and a precharge start has been issued
M1OpenWithoutCmd	Indicates M1 has opened, but was not commanded to be open
PrechargeComplete_I	Precharge has completed successfully and the drive is ready to run
InputProtect trip (LFR)	A drive input protection has been detected and the LFR has been tripped
DriveReadyToPrecharge	All conditions are met for precharge and a precharge start command can be issued

5.21.5 Cell Diagnostics Changes for Type 5 and 6 Precharge

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, the cell diagnostics thread will exit normally.

If cell faults:

1. If Fast Bypass is on:
   Fast bypass is disabled during precharge. The drive will respond in manual bypass only - requiring a fault reset. If cell fault occurs during precharge, drive will wait until reset is issued, then precharge has the possibility of completing. If cell can be 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 be bypassed, it will be bypassed once M1 is closed. The fault reset is delayed until after precharge is complete.
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 and the drive will remain faulted.
4. If no cell faults:
   Precharge will complete.

Note: A cell fault is always a drive fault and is handled as such. The ***FatalFault_I*** flag is set true. A fault reset is required to reset this flag.

5.22 Synchronous Motor with DC Brushless Exciter

5.22.1 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.

5.22.2 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.

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 5-48 shows the various stages of drive operation in this mode.

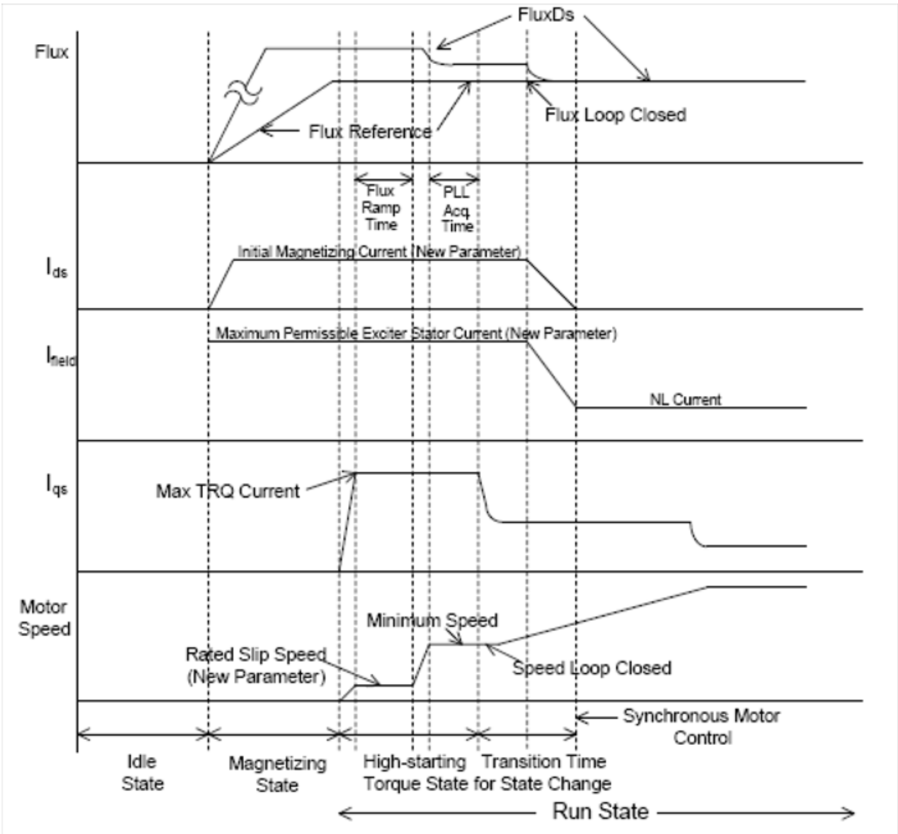

Figure 5-48: Perfect Harmony Operation with a Synchronous Motor with a Brushless DC Exciter

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.

5.22.3 Parameters

Table 5-29: Synchronous Motor with DC Brushless Exciter Parameters

Parameter	ID	Units	Default	Min	Max	Description
Control loop type	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.

5.22.4 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.

5.23 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.

5.23.1 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.

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5.23.2 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 5-49).

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

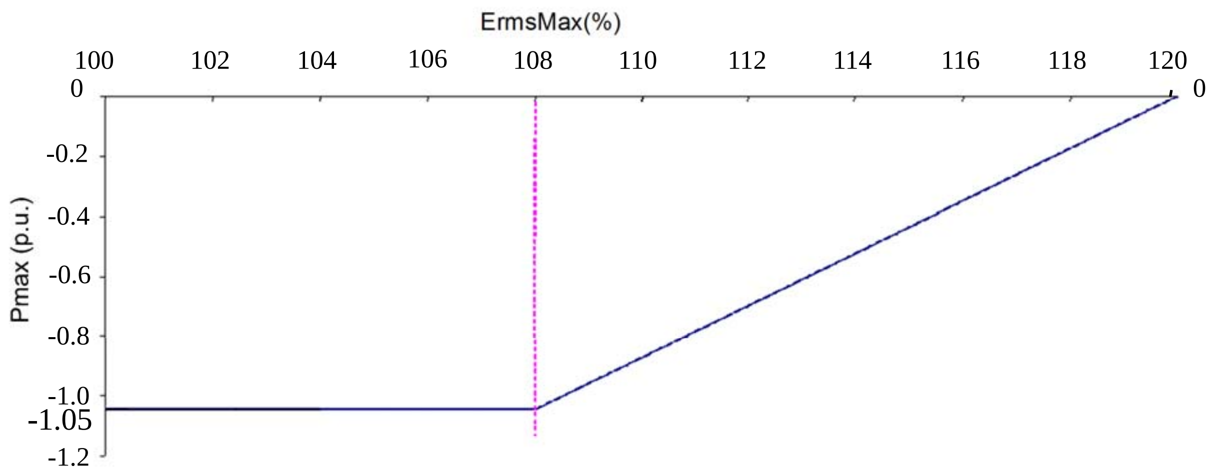

Figure 5-49: Pmax in Regen with Respect to Erms

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.

5.23.3 Parameters

Table 5-30: 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*

5.24 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 5-50 depicts a generalized view of Torque Mode.

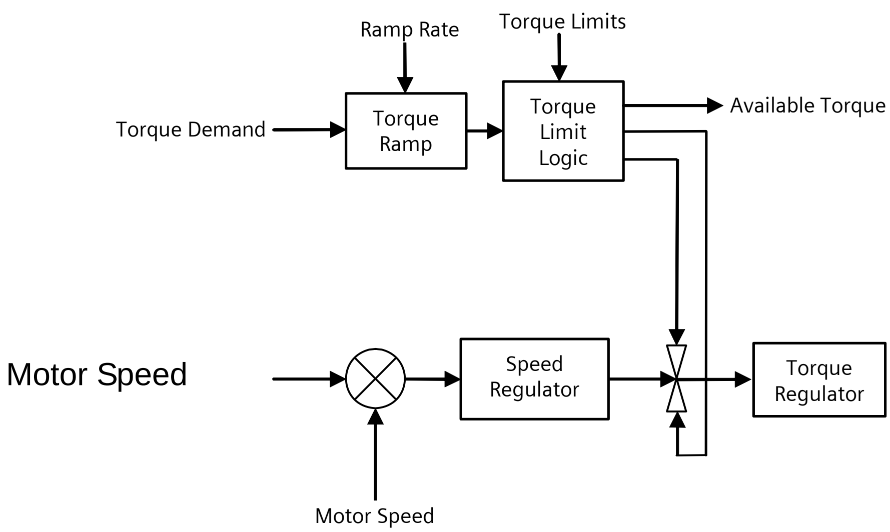

Figure 5-50: Torque Mode

Note: The Speed Demand is set to the motor speed limit as shown in Figure 5-50.

The Torque Demand can be sent to the VFD in one of three ways (see Figure 5-51):

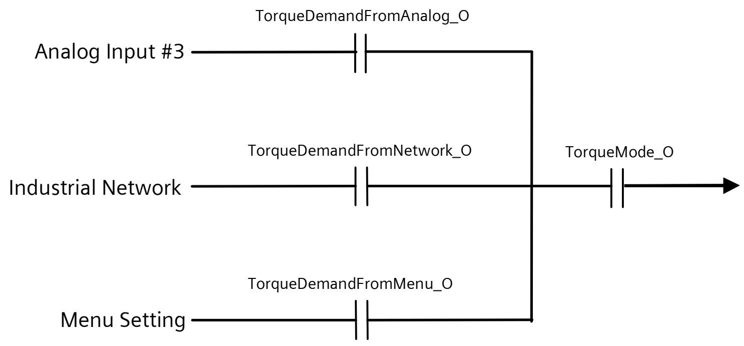

Figure 5-51: Torque Demand Options

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.

5.24.1 Parameters

Location: Drive → Drive Parameters → Torque Reference

Table 5-31: Parameters for Torque Mode

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.
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.

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5.24.2 SOP Flags

System Program flags used to control various aspects of the torque mode.

Table 5-32: SOP Flags for 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 Table 5-31). If all three flags are evaluated as true for some reason, the default will be the 'Menu Setting.'

5.25 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.

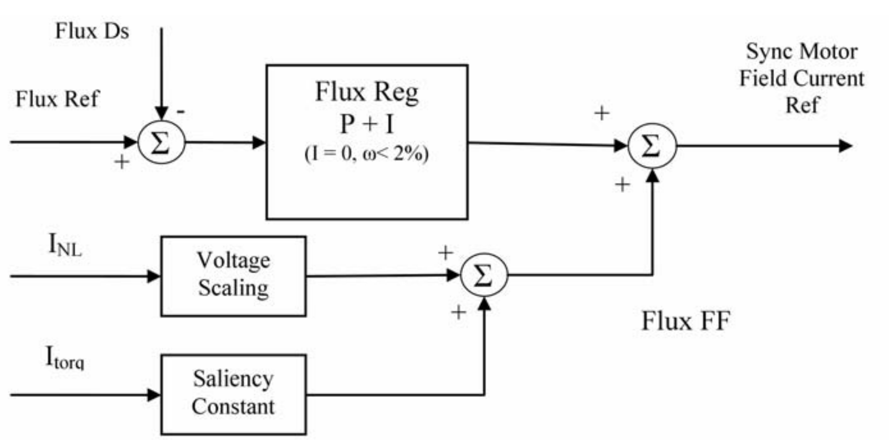

Figure 5-52: SM Flux FF

5.25.1 Parameters

Location: Motor → Motor Parameters

Table 5-33: Parameters for Flux Feed-Forward

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.

5.26 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.

Note: This watchdog must be enabled if any system critical I/O is being used, in order to shut down all processing threads. Failure to do so may allow external interrupts to keep some threads alive after the control threads are no longer functioning. For the Wago thread, the Wago timeout parameter must also be enabled to return to a default state once this thread is stopped. Otherwise the Wago System will maintain last values indefinitely.

5.26.1 Parameters

Location: Drive → Drive Parameters → Watchdog

Table 5-34: Parameters for CPU Watchdog

Parameter	ID	Units	Default	Min	Max	Description
Watchdog	2970		Sub-menu			Found under parent menu - Drive parameters
Enable Watchdog	2971		Enable			Enables the CPU watchdog with a fixed 20 second trip time

5.27 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.

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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.

5.27.1 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 5-53 for the speed and torque profiles.

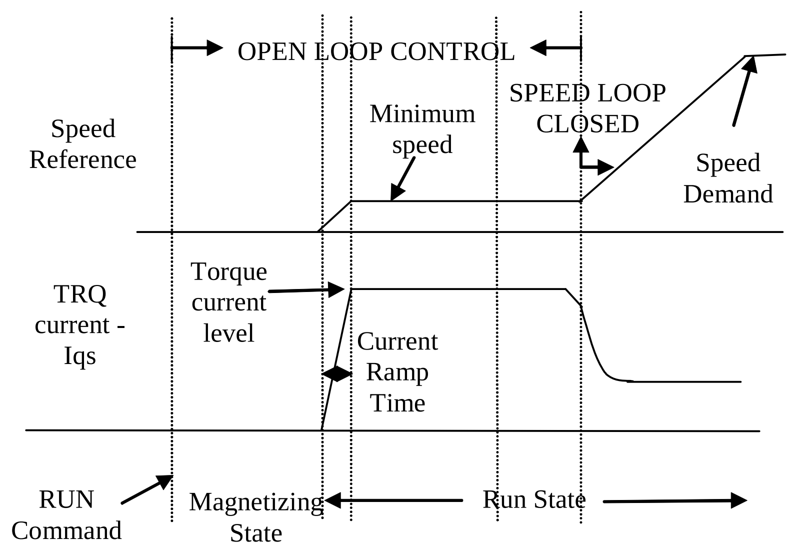

Figure 5-53: High Starting Torque - SM and PMM

5.27.2 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 5-54. 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
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.

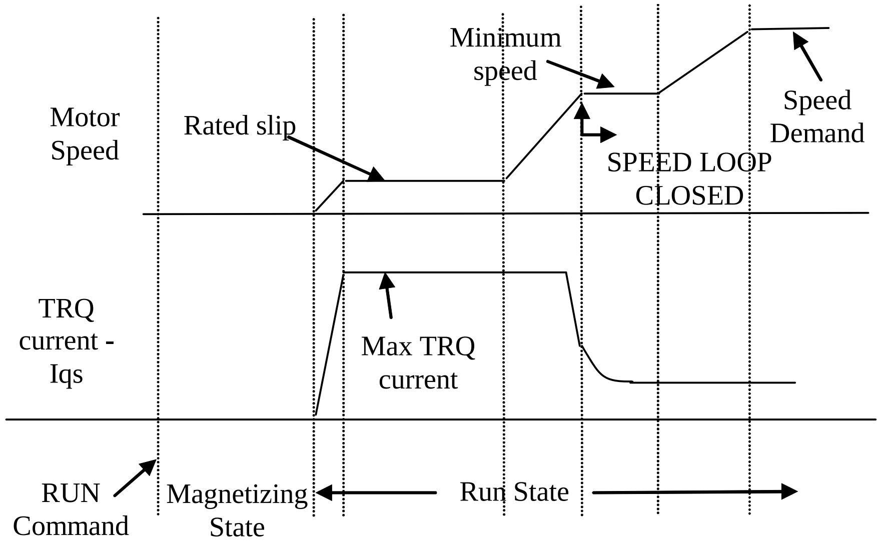

Figure 5-54: High Starting Torque - IM (V/Hz)

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5.27.3 Parameters

Table 5-35: Parameters for High Torque Starting Mode

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.

5.28 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).

5.28.1 Parameters

Location: Drive → Drive Protect → Input Protection

Table 5-36: Parameters for Excess Drive Loss 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	12	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.

5.28.2 SOP Flags

This detection is always enabled and defaults to an alarm - not a fault.

Table 5-37: SOP Flags for Excess Drive Loss Protection

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

5.29 Cable Inductance Compensation

Long cable applications present a challenge as the cables become a significant contribution to the overall load impedance. 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

5.29.1 Parameters

Location: Drive → Drive Parameters → Output Connection

Table 5-38: Parameter for Cable Inductance Compensation

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)

5.30 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).

5.30.1 Parameters

Location: Motor → Limits

Table 5-39: Parameters for Loss of Field Fault

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.
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.

5.30.2 SOP Flags

This detection is always enabled when SM control is selected and defaults to a fault.

Table 5-40: SOP Flags for Loss of Field 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

5.31 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.

5.31.1 Parameters

Location: Drive → Drive Protect → Input Protection

Table 5-41: Parameters for External Flux

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.

5.31.2 SOP Flag

Only one flag is required in the SOP to use this feature.

Table 5-42: SOP Flag for External Flux

Flag Name	Description
FluxDemandFromNetwork_O	Set ‘TRUE’ for use of flux demand through the network register

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CHAPTER

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 NXGII, or if the System I/O board is used, the test points are the same; however, the amplitudes of all signals are ½ (50%) of what is stated for the NXG System Interface board.

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.

Notes:

- Some Perfect Harmony 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 5.20 *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 5.20 *Precharge* for more details, and check the product manual.

The steps in Table 6-2 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 precharge only after precharge is **thoroughly** tested, see product manual for details.
	Warning! **Any system that contains precharge must be energized following the precharge sequence anytime MV is applied.**
7	DISABLE Spinning Load using Drive (2) → Spinning Load (2420) → Spinning Load Mode (2430).

Step	Description
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).
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.

<table>
<tr><th>Step</th><th>Description</th></tr>
<tr><td>12</td><td>
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.

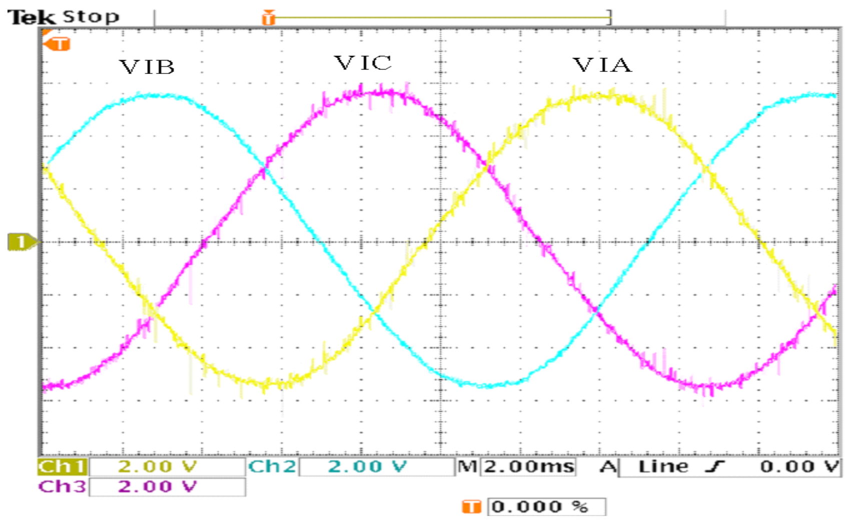
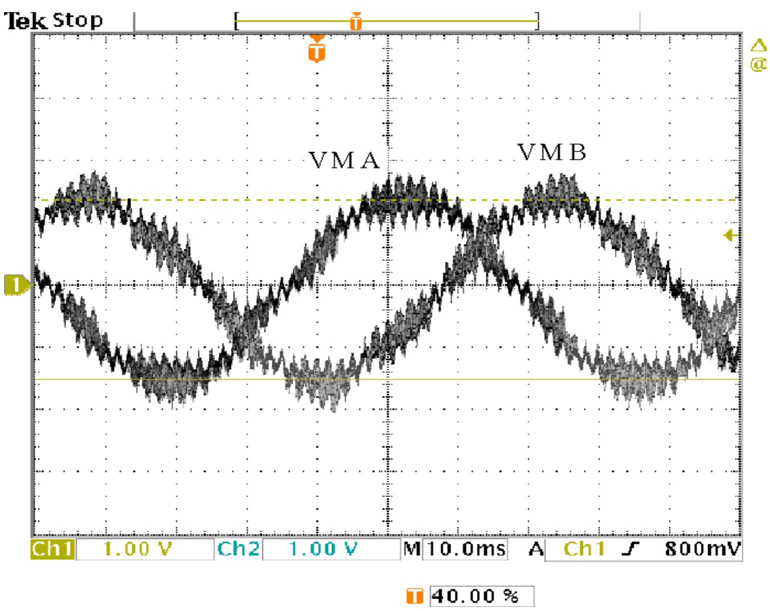


Figure 6-1: AC Input Voltages at test-points VIA, VIB and VIC on System Interface Card

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.
</td></tr>
<tr><td></td><td>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.</td></tr>
</table>

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 6-2 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%.

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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 → 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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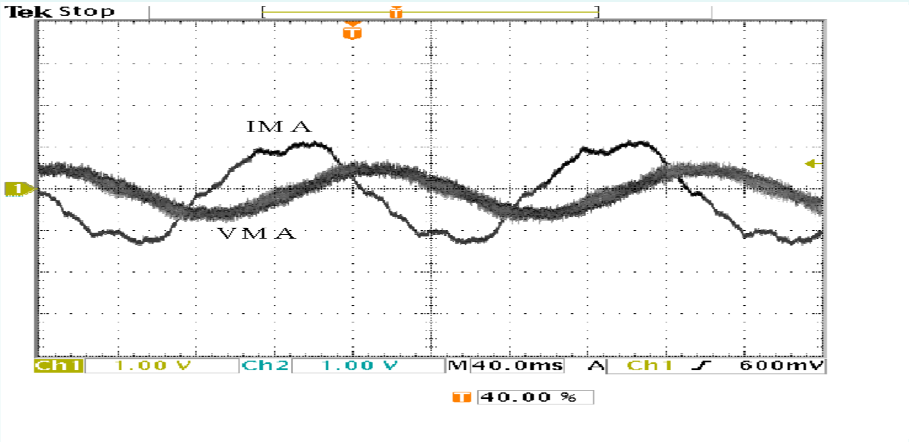
Step	Description
10	• Operate the drive with a Speed Demand of 10%. Observe the AC output voltage feedback and motor current for phase A on test-points VMA and IMA using an oscilloscope. • Since the motor is unloaded, the current waveform should lead the voltage waveform by almost 90° (see Figure 6-3). 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.

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

Step	Description
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
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%

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, Section 5.7.4) **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.

Step	Description
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.
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 [a]). 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 [b]). 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 Table 6-5. See Figure 6-5 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.

> **Note:** Feedback values shown in parentheses in Tables 6-5 and 6-6 apply to the Standard I/O board.

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 (0.54)	0.38 (0.19)
25	15	2.70 (1.35)	0.96 (0.48)
50	30	5.40 (2.70)	1.91 (0.96)
75	45	8.10 (4.05)	2.87 (1.44)
100	60	10.80 (5.40)	3.82 (1.91)

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 (2.50)	3.54 (1.77)
Input Voltage	(Rated Input Voltage L-L) / 1.732	5.4 (2.70)	3.82 (1.91)
Output Current	Output Current Rating (≡ Cell Rating)	5.0 (2.50)	3.54 (1.77)
Output Voltage	(Rated Output Voltage L-L) / 1.732	5.4 (2.70)	3.82 (1.91)
Examples: Output Current Scaling: Cell current rating ≡ 3.54 Vrms (1.77 Vrms) Output Voltage Scaling: [(Rated output voltage L-L) / 1.732] * 1.414 ≡ 5.4 Vpeak (2.70 Vpeak)			

(a)

(b)

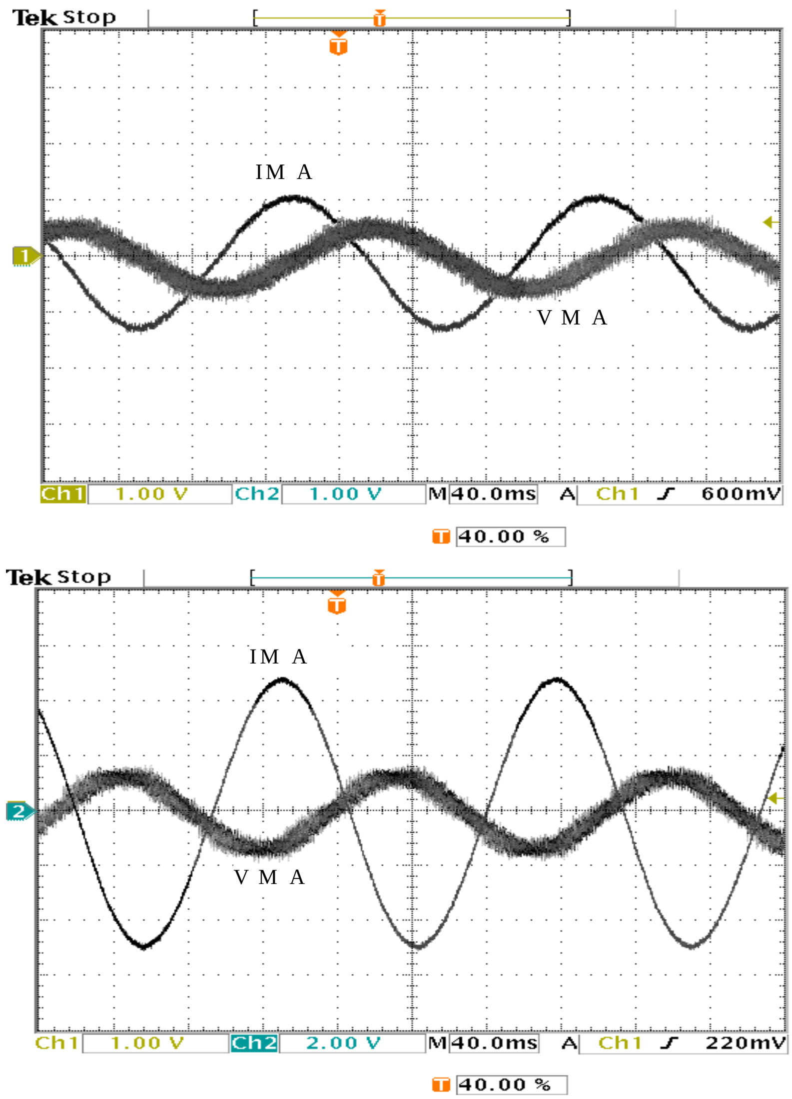


Figure 6-4: AC Motor Voltage and Motor Current at test-points VMA and IMA at 10% speed in Open Loop Vector Control (a) Unloaded Operation and (b) Full Load Operation

(a)

(b)

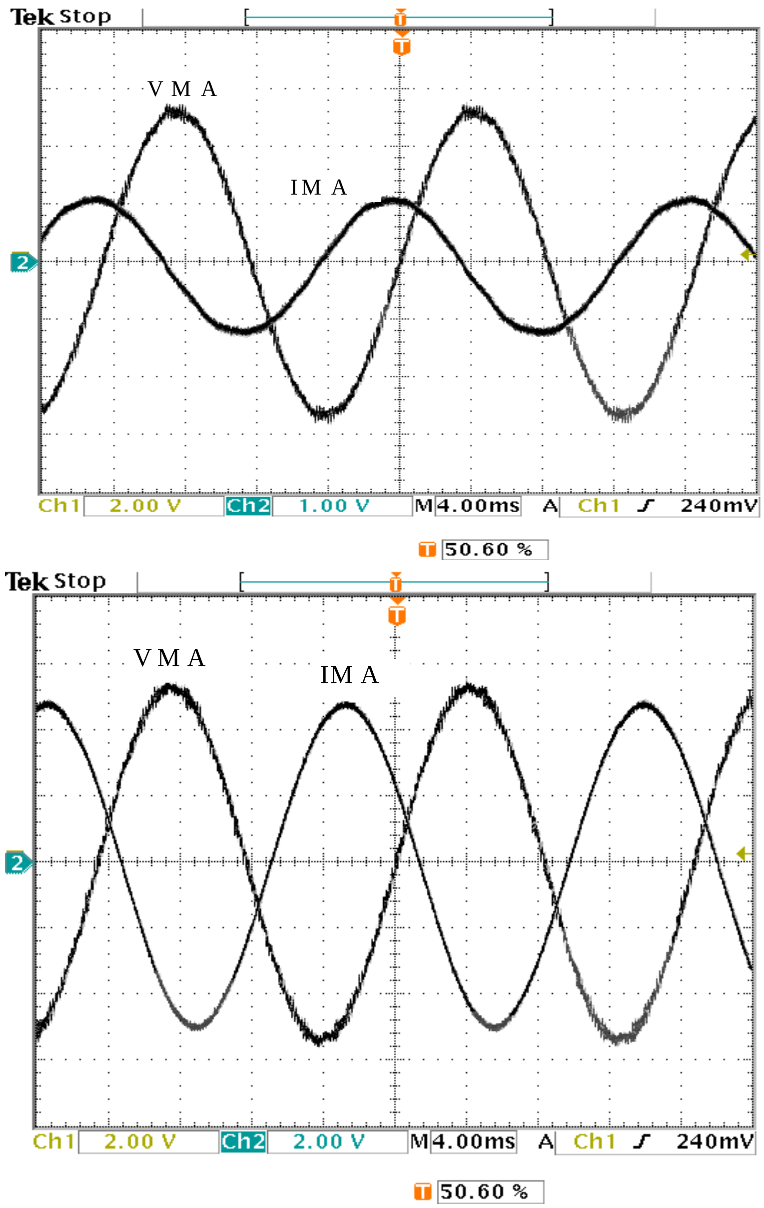


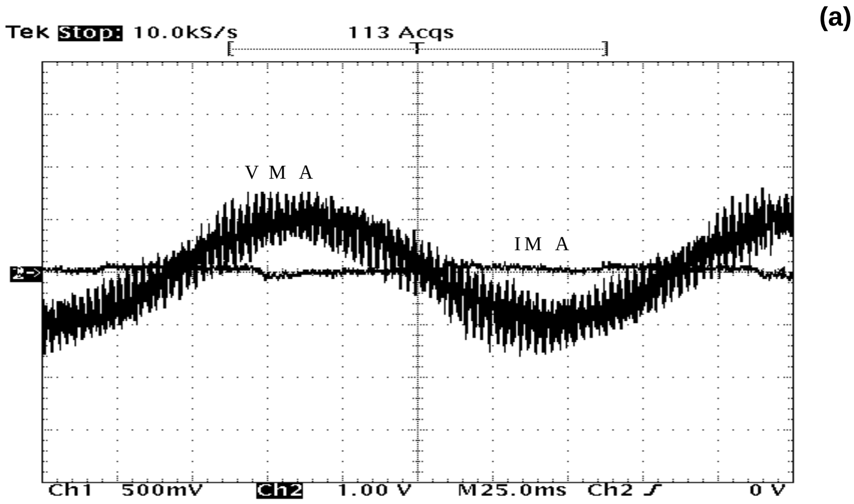
Figure 6-5: AC Motor Voltage and Motor Current at test-points VMA and IMA At 100% Speed in Open Loop Vector Control (a) Unloaded Operation, and (b) Full Load Operation

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 Const (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 6-7**.** 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 Figure 6-7 (b). However, at high speeds, the current regulator gains are insufficient to maintain sinusoidal output currents when the distortion is due to motor pole construction.



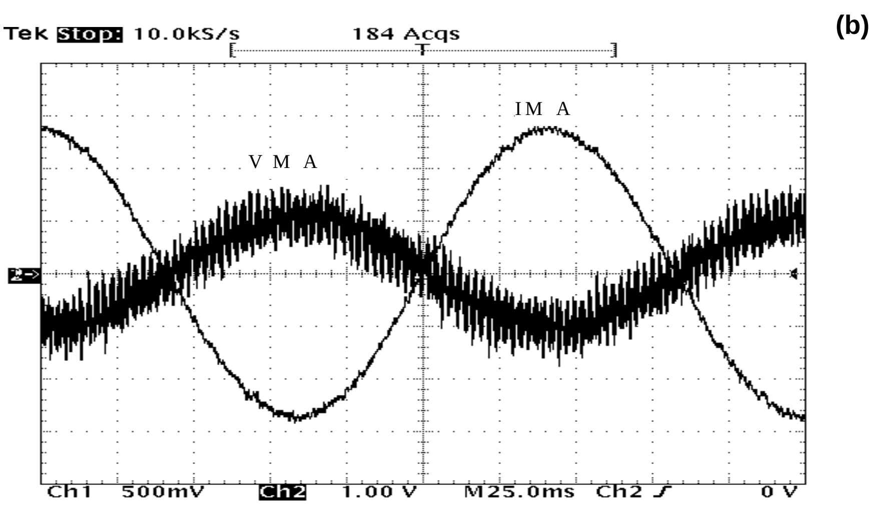


Figure 6-6: AC Motor Voltage and Motor Current at Test-points VMA and IMA at 10% speed with Synchronous Motor Control (a) Unloaded and (b) 75% torque operation

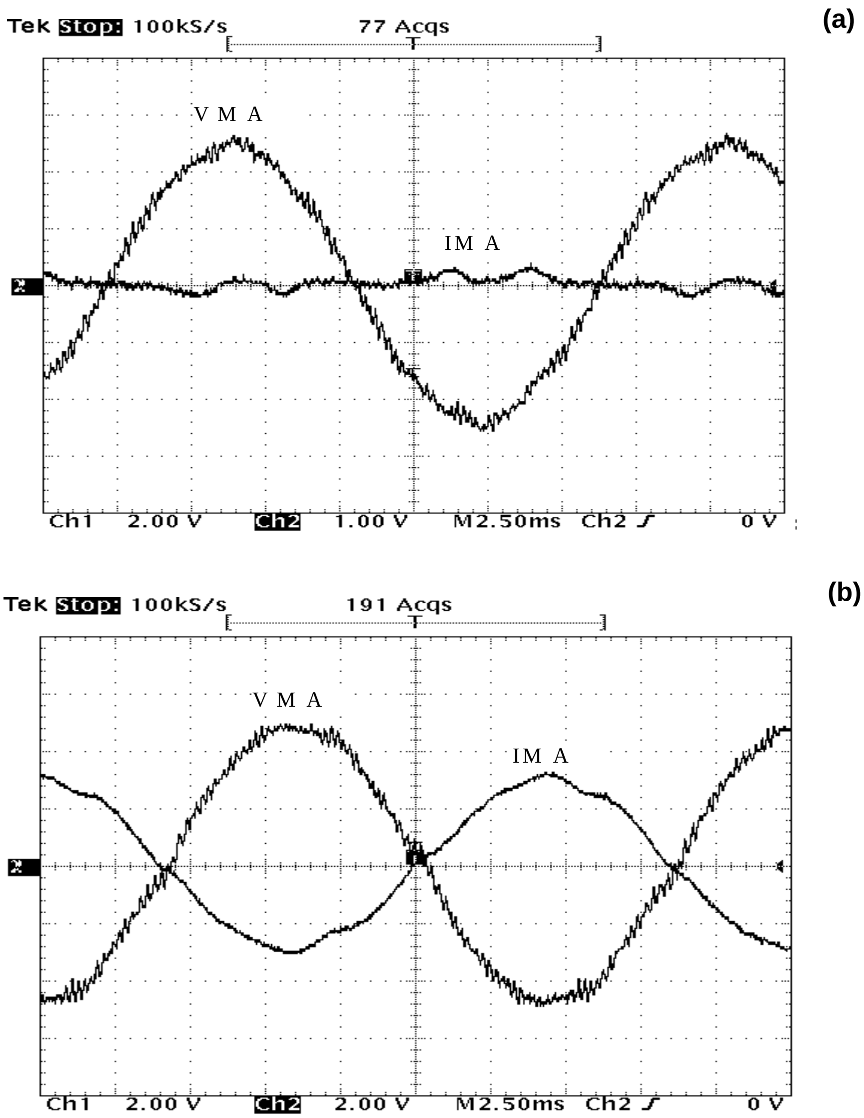


Figure 6-7: AC Motor Voltage and Motor Current at Test-points VMA and IMA at 100% speed with Synchronous Motor Control (a) Unloaded and (b) 75% torque operation

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:

- Auto-Tuning is **optional**, but is recommended for applications in which high performance, as stated below, is required.
- 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.

Warning!

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.

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.

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)

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 * 2 * ∏ * 60 Filter_inductance [in Henries] / Drive_base_impedance [in ohms]

%Filter_capacitance = 100.0 * 2 * ∏ * 60 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 Table 6-12 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.

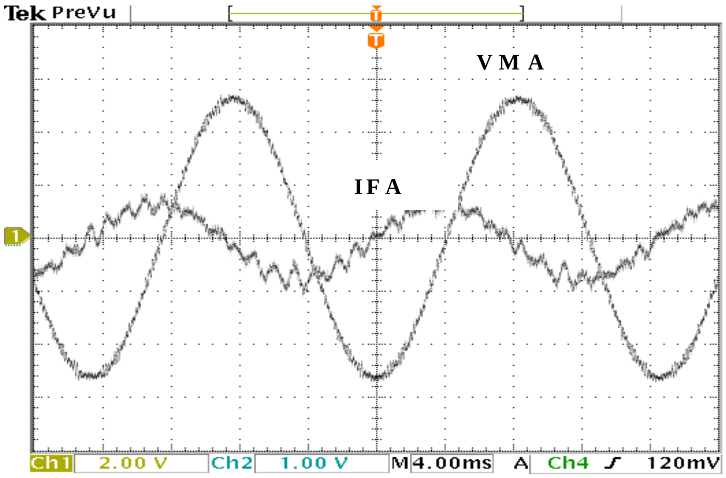


Figure 6-8: Drive Output Voltage and Filter Capacitor Current on test-points VMA and IFA, respectively, to determine if filter CT wiring is correct

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′.

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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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CHAPTER
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.

Note: When the fault log is full of unacknowledged faults or alarms (greater than 256), this message will show on the display “Fault/Alarm log” “overflow”. This may be caused by an alarm or several that occur and are not manually reset to “acknowledge” the alarm. An alarm sets and resets itself with no external intervention. However, an alarm is never acknowledged until the fault reset button (or remote fault reset) is true - with no fault to reset.

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.

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 4.3.1 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 4.3.1 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 4.3.1 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 Appendix E for a list of Auto Resettable 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.

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 7-2 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: On NXGII, or if the System I/O board is used, the test points are the same; however, the amplitudes of all signals are ½ (50%) of what is stated for the NXG System Interface board.

Table 7-2: 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.

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.
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.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
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 precharge, 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).
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.

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Fault Display	Type	Enable	Potential Causes and Corrective Actions
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.
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.

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. **Action** 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. **Action** 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. **Actions** **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. **Actions** **1.** Check load conditions. **2.** Check proper settings for drive and motor ratings.
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. **Actions** **1.** Check load conditions. **2.** Check proper settings for drive and motor ratings.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
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.

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. **Note:** This is increased by the code to 95% for induction motors with 10 or more poles. 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. **Note:** During high starting torque mode, the trip time used is the flux ramp rate. **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.

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. **Note:** This drive protection will not function properly if the input CT's are installed incorrectly. This would be indicated by negative input power (on a 2 Quadrant system).
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.

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.

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** Reset drive control power. Check that all boards are seated properly. 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.

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:** NXGII 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.

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 failure. **Note:** It is essential that the (CPU) Watchdog is enabled (ID 2971) to properly detect and respond to this situation.
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.

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).
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.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
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.
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.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
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.
Coolant Cond > 5 µS	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.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
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.
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.

<table>
<tr><th>Fault Display</th><th>Type</th><th>Enable</th><th>Potential Causes and Corrective Actions</th></tr>
<tr><td>Coolant Tank Level < 30 inches</td><td>A</td><td>SOP</td><td>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.</td></tr>
<tr><td>Coolant Tank Level < 20 inches</td><td>F/A</td><td>SOP</td><td>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.</td></tr>
<tr><td>Low Coolant Flow < 60%</td><td>A</td><td>SOP</td><td>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.</td></tr>
</table>

Fault Display	Type	Enable	Potential Causes and Corrective Actions
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** **1.** Check physical input connected to SOP flag. **2.** Check sensor. **3.** Check for faulty fan. **4.** Check for obstruction.
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.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
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.
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.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
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.
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.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
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.
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.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
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.
Cell Bypass Fault	F	Fixed	**Cause** The cell failed to go into bypass when commanded to do so. **Action** **1.** Check bypass system, contactor MV Bypass board, and Modulator board. **2.** 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.

Fault Display	Type	Enable	Potential Causes and Corrective Actions
xx Bypass Avail Warning xx=cell that is faulted	A	Fixed	**Cause** Cell level bypass unavailable alarm. Only if bypass is used but not active. **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).
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 7-3 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 7-3: 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.
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.

Fault Display	Type	Enable	Potential Causes and Possible Corrective Actions
xx Control Power	F	Fixed	**Cause** MV is OK, 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.
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.

Fault Display	Type	Enable	Potential Causes and Possible Corrective Actions
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 **VDC** 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.
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.

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 7-4.

Note: Not every cell type has switching and blocking tests. Refer to the individual product manual for details.

Table 7-4: 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.

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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.

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 Table 7-5.

Note: 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 7-5: 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: 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. On the Standard Keypad, the modes are displayed in two lines at the left of the keypad display (see Figure 7-1):

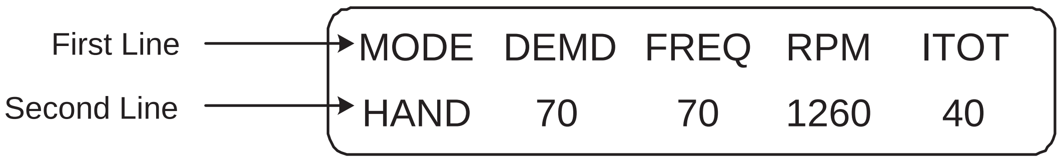

Figure 7-1: Standard Keypad Mode Display

On the Multi-Language Keypad, the modes are displayed in two lines at the top of the keypad display (see Figure 7-2):

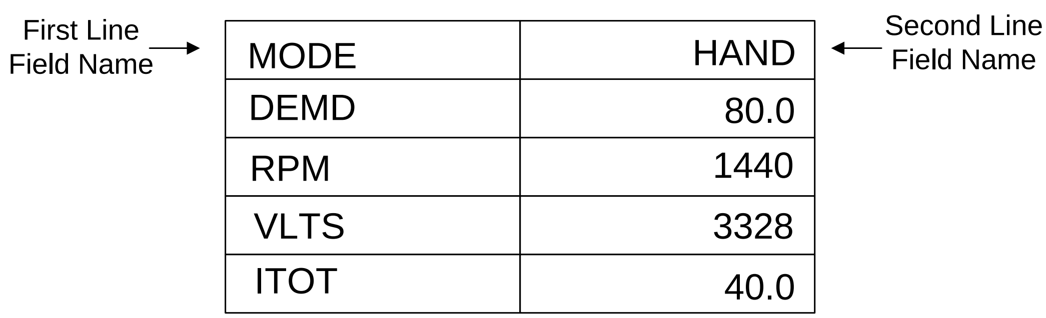

Figure 7-2: Multi-Language Keypad Mode Display

Tables 7-6 and 7-7 list the mode displays for the first and second lines of the fixed display field, respectively. The second column of the tables (Code) lists the abbreviated message that is shown on the display of the drive. The fourth column lists descriptions of the operating modes. Further descriptions of possible limit situations and troubleshooting tips are listed in the subsections that follow.

Table 7-6: 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 torque 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, by decreasing the motor torque.
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 allowable.
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 torque limit due to external analog limit while in torque mode.
12	ENLM	External network Limit	Drive is in torque limit due to external network limit while in torque mode.
13	EMLM	External menu Limit	Drive is in torque limit due to external menu limit while in torque mode.
14	CIMB	Cell Imbalance Limit	AFE cells in regen limit when the sum of the three phase voltage gains exceed 3 PU. Each phase voltage gain is equal to the number of installed cells per phase, divided by the active cells in that phase.

Order	Code	Meaning	Description
15	RLBK	Roll back	Appears during acceleration if drive has reached its torque limit setting.
16	RGEN	Regeneration	During normal deceleration, this message will be displayed when the drive is operating in regen torque limit.
17	BRKG	Dual frequency braking	Appears while drive is decelerating with dual frequency braking enabled.
18	OVLT	Regen Limit for 6-step	Indicates that the 6-step regeneration torque limit is in effect. It is set when the cell voltage gets too high, and serves to reduce the regen torque limit to limit the energy flow from the output (motor) to the cells to prevent overvoltaging the cells.
19	BYPS	Cell bypassed	Indicates that one or more cells are in bypass.
20	PRCH	Precharge	One of the precharge modes is selected and the drive is precharging, or ready to precharge.
21	OLTM	Open loop test mode	Appears if drive control algorithm is set to open loop test mode.
22	MODE	Normal mode display	This is the typical display message during normal operation.

Table 7-7: 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 or passing through the magnetizing drive state.
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” attempting to transfer the motor to the input line.
7	DXFR	Down transfer state	The drive is in the “Down Transfer State” attempting 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. This “mode” is entirely determined by setting the SOP flag. It does not affect NXG operation.
14	HAND	Hand mode	Appears if the drive is running under normal conditions.
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.

If the mode display shows one of the torque limit modes above, the drive may be in speed rollback mode, and 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 1.800.333.7421. Check product manual for parts identification.

3. Check all causes of torque limit.

7.6.1 Speed Rollback

This is a feature of the speed regulator to prevent windup of the integrator term when the regulator enters the non-linear state of being in torque limit.

The output of the regulator, which is the torque current reference, is clamped to one of the torque limits. This sets the internal indicator as to whether the minimum limit or maximum limit is the active limit. The integrator is prevented from winding up any further past the limit.

In the command generator algorithm, the speed ramp output (the speed regulator input) is "rolled back" so that it maintains the speed regulator in saturation (at the clamp limit) but then resets the ramp internal storage to at that level.

This allows for a smooth transition when the limiting condition is removed. In recovery, the ramp will then continue on from that point, to the desired speed demand until the speed regulator is satisfied and the output speed matches the desired speed.

This action prevents a sudden speed or torque step should the torque limiting source (usually the load) suddenly change. This allows for a smooth transition from the non-linear operating condition.

7.6.1.1 SOP Indication of a limiting condition

When a Torque limit is in effect and the Speed Rollback condition is in effect, the torque limit causing the rollback can be indicated by one of the following indicator flags.

These flags are different than normal SOP flags. Once they are set, they will remain set until a command is issued from the SOP to reset them. This is true even if the condition causing the speed rollback is transitory. As shown in Table 7-8, the first 10 flags are specific indicators, the 11th flag is a generic flag that will be set when any rollback is in effect, and the 12th flag is toggled within the SOP to reset the latch on the other flags.

> **Note:** The idea of the latched flags is to prevent missing any conditions during a transitory rollback.

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Table 7-8: Speed Rollback Indicator Flags

Speed Rollback Indicator Flag	Description
MenuTorqRollback_I	Indicates Menu torque limit is causing rollback
CellOverloadRollback_I	Indicates cell overload is causing rollback
SinglePhaseRollback_I	Indicates single phase condition is causing rollback
UndervoltageRollback_I	Indicates Under voltage condition is causing rollback
FldWeakeningRollback_I	Indicates field weakening is causing rollback
TolRollback_I	Indicates thermal overload (TOL) is causing rollback
Network1Rollback_I	Indicates Network1 torque limit is causing rollback
Network2Rollback_I	Indicates Network2 torque limit is causing rollback
AnalogInRollback_I	Indicates Analog input torque limit is causing rollback
OverVoltRegenRollback_I	Indicates that regen rollback for 6 step overvoltage is active
ARollbackOccurred_I	Indicates any rollback has occurred (global generic flag)
ResetIndicatorFlags_O	Resets all the above latching indicator flags
SpeedRollupActive_I	Indicates that the drive is in the regen limit rollback state. This is known as "Rollup" since the ramp output is adjusted as for motoring torque limit Rollback, but the result is a speed reference higher than before the limit condition occurs. This flag is not latched.

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7.6.1.2 Disabling the Speed Rollup

Speed rollback (rollup) is a normal process during ramp stopping, or in full 4 quadrant control. However, not all processes are conducive to the speed rollback operation when the drive is in a regen limit.

Other processes may find it unacceptable when the torque limit occurs during the regeneration quadrant in the motor, resulting in what has been termed "Speed Rollup". This is when the torque limit is preventing the motor from regening too quickly. The ramp is still affected, but the ramp output will be forced to go up in speed to get to the equilibrium point of the speed reference (the input of the speed regulator) to maintain the regulator just inside the saturation point.

This is generally true if the load is slowing down more than the speed ramp, resulting in a regen condition of the motor. The ramp will "rollup" to prevent the speed error from climbing too high. This type of load is referred to as an "over-hauling" load. An example might be a pump with a large column of liquid or a draft fan with air flow pushing back on the blade. These would tend to push the motor in the reverse direction requiring the drive to "regen" to a stop before going forward. In 4 quadrant drive applications, this type of load is more common.

Two SOP flags can be used to identify, or disable this condition.

Table 7-9: Speed Rollup Control Flags

Speed Rollback Control Flag	Description
DisableSpeedRollup_O	This flag disables the speed rollback completely – for both minimum and maximum limits (in motoring and in regeneration of the motor)
SpeedRollupActive_I	This flag is set when the regen limit is in effect and a rollup condition exists.

A special condition can occur in lightly loaded drives - usually on test stands where small motors are used on a much bigger drive, or if a transorb in the output voltage feedback goes bad. With rollup in this case, the drive can be seen as "running away" with the speed reference going higher than the commanded speed (Speed Demand). Disabling Speed Rollup will eliminate this condition.

7.6.1.3 Operation of Speed Rollup Disable

The Speed Rollup Disable flag can be set in two ways, either setting the SOP flag true, or setting it conditionally. In either case, when enabled it works as follows.

When a rollup condition exists, the drive will set the ***SpeedRollupActive_I flag***. This can be used in the SOP as an indicator, but is not required in the operation of this feature.

When the motor is above 10% rated speed, the feature will simply disable rollback of the speed ramp, and the ramp will work normally. This may cause a larger speed error since nothing is limiting the speed reference - the output of the ramp and input to the speed regulator. But since the speed regulator output - the regen torque reference - is already clamped, the condition will be transparent to the system.

When the ramp feedback goes below 10% of rated, it goes into a special hold mode that does not let it go any lower until the speed feedback gets down to 10%. Once the motor speed feedback goes below 10%, the speed rollup is disabled, and the drive will continue to run as if the feature is disabled.

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.

Setting the input protection fault produces the fault message "Input Protection Fault". An external key-switch is required for resetting the fault and the LFR.

☝ **Note:** For Gen IV and WCIII cells, the input protection is handled entirely via the dedicated I/O on the System I/O and Breakout board. Refer to section 7.7.6 below.

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.

7.7.2 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 defaulted to 5.0% during “Idle” State and to 7.0% during “Run” State. When the calculated losses exceed the reference losses, a drive trip is issued and this condition is annunciated as “Excessive Drive Losses.” 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 7.7.4 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.

The excessive drive loss algorithm is always enabled, but can be set as an alarm for cells other than WCIII or Gen IV via a system program flag.

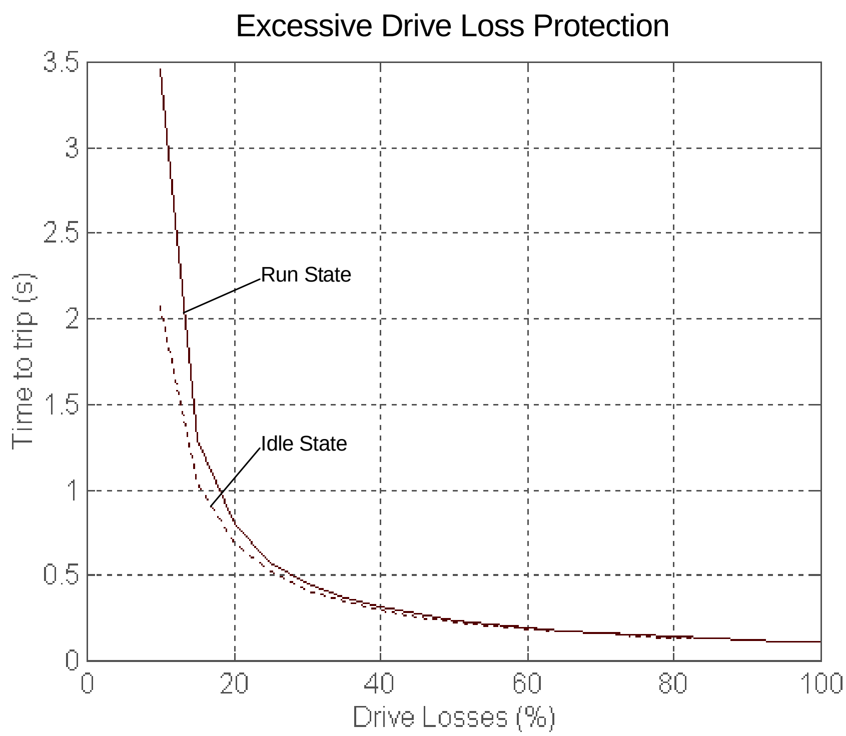

Figure 7-3: Excessive Drive Loss Protection

7.7.3 Cell Based Protection Faults

Newer cells with the AP protocol may have additional cell-based input protection sensing. Please refer to the product manual for details. These include arc flash detection, over-voltage with cell in bypass, and over-current with cell in bypass. These are cell dependent. If the cells contain these faults, they too will trigger an input protection fault.

7.7.4 SOP Triggered Input Protection

External events can be used to trigger an input protection fault. This is accomplished through the use of the SOP flag "***SetIPFault_O***". Setting this true for any SOP logic statement will result in generating an Input Protection fault.

7.7.5 Transformer Over-Temperature and Loss of Cooling

This is an example of the use of the SOP input protection flag. The output of this logic would be simply setting the "***SetIPFault_O***" and the LFR and tripping the MV breaker.

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 transformer temperature is above the Alarm 1 temperature, the second set opens when the transformer temperature is above the Alarm 2 temperature. Two outputs, one output corresponding to each set, are read by the control logic. A Xfrmr Temperature Alarm 1 is issued when one or more Alarm 1 switches open, and a Xfrmr Temperature Alarm 2 is issued when one or more Alarm 2 switches open. When both these conditions exist for 30 seconds, a Xfrmr Over Temp Fault is generated that causes the drive to trip.

A flow sensor monitors liquid coolant flow through the Water Cooled Drive. The implementation and use of this sensor are application dependent. As a standard default, the alarm “Loss of Coolant Flow” is issued whenever the detected coolant flow rate is below a pre-set level (acceptable operational limits) for a pre-set amount of time.

The SOP program can be used to trip the input Medium Voltage Breaker (if dedicated I/O is not active) when the conditions of Xfrmr Temperature Alarm 1, Xfrmr Temperature Alarm 2, and Loss of Coolant Flow exist simultaneously.

7.7.6 Dedicated I/O For Input Protection

For the Gen IV and WCIII, the drive NXG software controls the I/O involved with input protection. No intervention is required for activating this usage other than selecting one of these cell types. The SOP flags that would normally be associated with these inputs and outputs are disabled, and have no effect when the associated cells are selected. These are the inputs and outputs dedicated in this manner to the input protection algorithm.

IDO_14 - M1 permissive (allows the circuit to close M1 to be completed by the customer) - This opens with an input protection fault. Closes after the input protection fault is reset (including the LFR).

IDO_15 - This delivers a one second pulse to trip the LFR with an input protection fault.

DI-3E - LFR Status – (Input protection) reports the status of the LFR (Latch Fault Relay)

7.8 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, do not use Windows Explorer to update any flash files.

It is required to utilize the Configuration Update Tool (refer to the *ToolSuite Manual*) to update drive software or to copy or clone drive settings. Proper utilization of this tool can help prevent corruption of the flash media. The Drive Tool should be used for adding or removing SOP files.

Also, removing control power while a flash write operation is in progress can also corrupt the flash disk. Wait one minute before removing control power after a drive fault or parameter change, to allow sufficient time for the flash write to complete. Both the event log and parameter configuration file reside on the flash disk.

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CHAPTER

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* (A1A902291) 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* (A1A902291).

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*.

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_I, ExternalDigitalInput01b_I) or switch (e.g., KeypadManualStart_I), 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 the *ToolSuite Manual* for more details in its use. The entire compilation of the SOP can be summarized in Figure 8-1.

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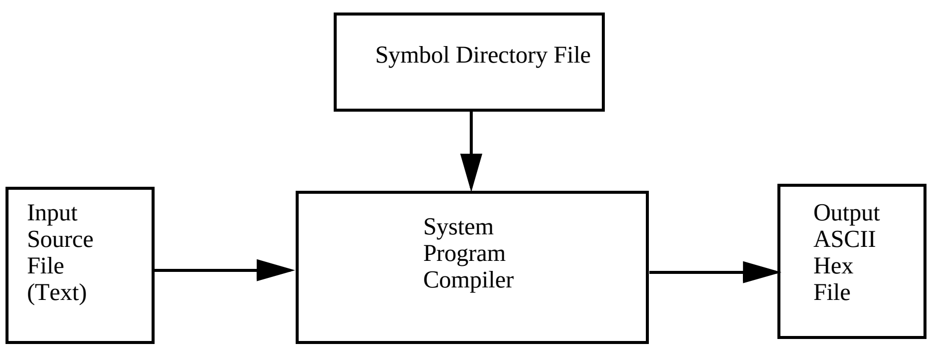

Figure 8-1: Block Diagram of the Compile Process

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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APPENDIX

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 - 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) 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 - 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 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- Also referred to as the 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 - 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.

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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APPENDIX

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	Micro
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

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

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

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
NXGII	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

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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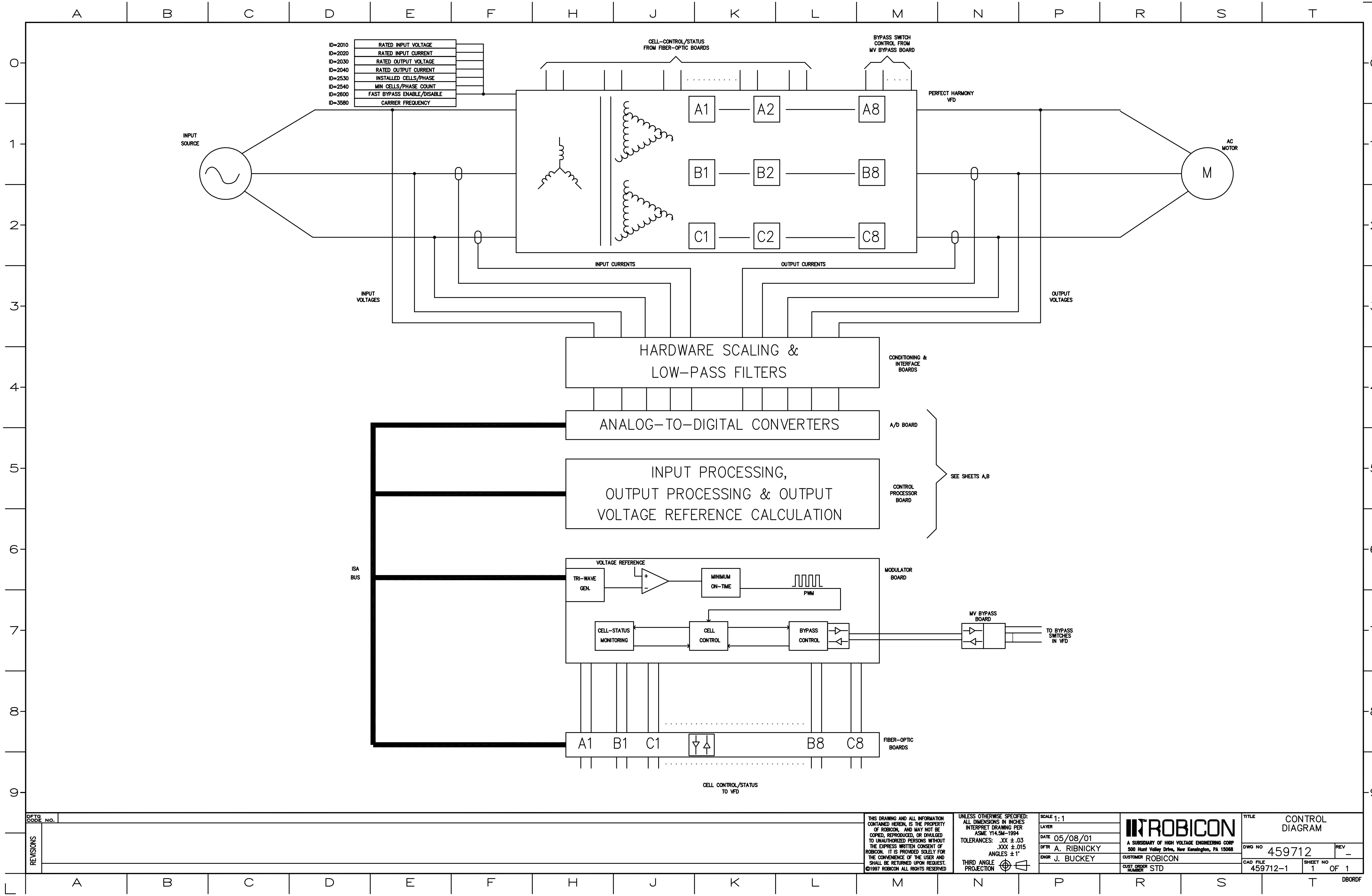
APPENDIX

C System Control Drawings

This appendix contains the System Control diagrams for a Perfect Harmony drive with Next Gen Control:

- Perfect Harmony Control Diagram drawing number A1A459712
- Command Generator Diagram drawing number A1A459713 rev. BI
- Input/Output Process Diagram drawing number A1A459717 rev. BD

C



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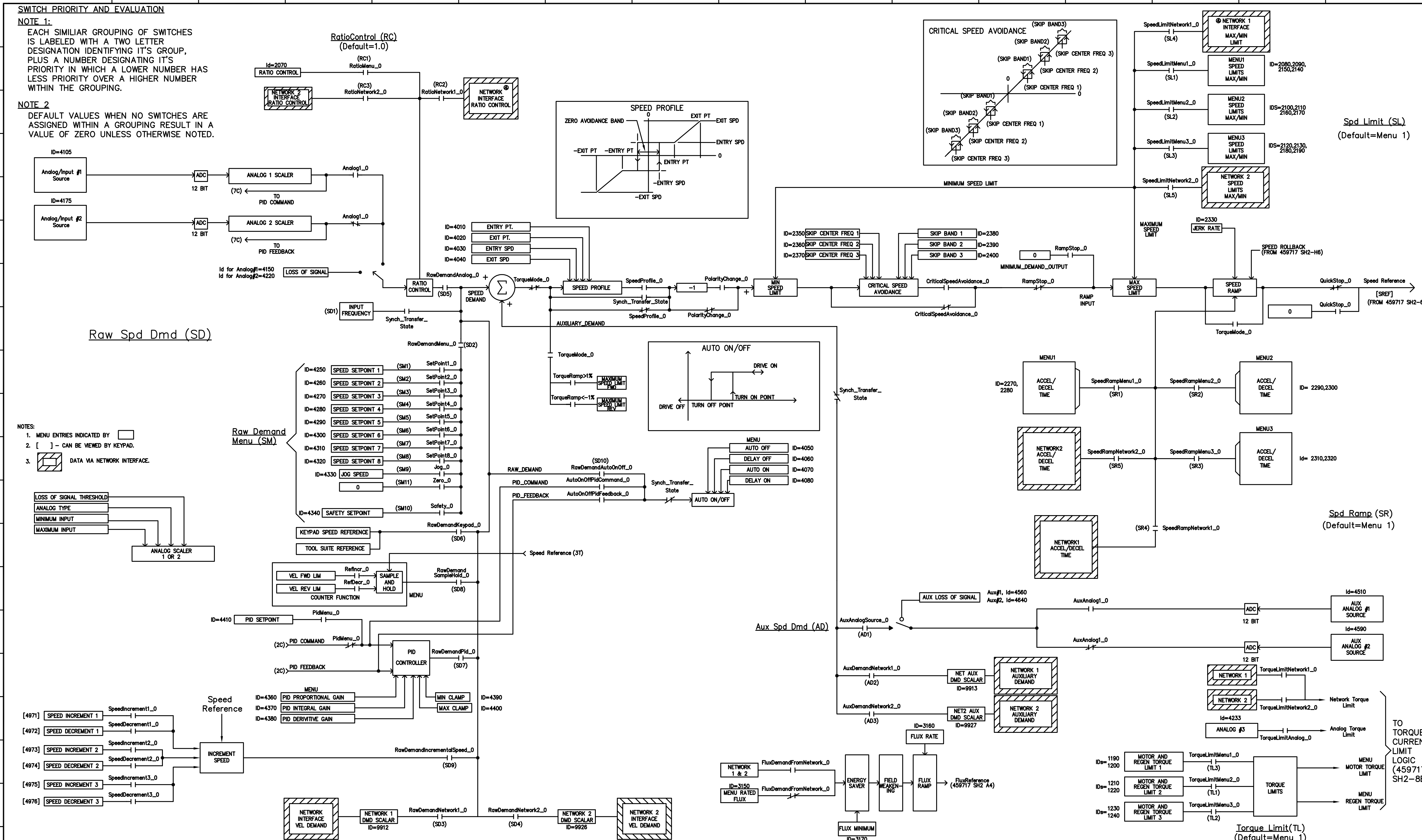
ID=2020 RATED INPUT CURRENT
ID=2030 RATED OUTPUT VOLTAGE
ID=2040 RATED OUTPUT CURRENT
ID=2530 INSTALLED CELLS/PHASE
ID=2540 MIN CELLS/PHASE COUNT
ID=2600 FAST BYPASS ENABLE/DISABLE
ID=3580 CARRIER FREQUENCY
CELL-CONTROL/STATUS FROM FIBER-OPTIC BOARDS
BYPASS SWITCH CONTROL FROM MV BYPASS BOARD
PERFECT HARMONY VFD
INPUT SOURCE
AC MOTOR
M
A1
A2
A8
B1
B2
B8
C1
C2
C8
INPUT CURRENTS
OUTPUT CURRENTS
INPUT VOLTAGES
OUTPUT VOLTAGES
HARDWARE SCALING & LOW-PASS FILTERS
CONDITIONING & INTERFACE BOARDS
ANALOG-TO-DIGITAL CONVERTERS
A/D BOARD
INPUT PROCESSING, OUTPUT PROCESSING & OUTPUT VOLTAGE REFERENCE CALCULATION
CONTROL PROCESSOR BOARD
SEE SHEETS A,B
ISA BUS
VOLTAGE REFERENCE
TRI-WAVE GEN.
MINIMUM ON-TIME
PWM
MODULATOR BOARD
CELL-STATUS MONITORING
CELL CONTROL
BYPASS CONTROL
MV BYPASS BOARD
TO BYPASS SWITCHES IN VFD
A1 B1 C1 B8 C8
FIBER-OPTIC BOARDS
CELL CONTROL/STATUS TO VFD
DFTG CODE NO.
REVISIONS
THIS DRAWING AND ALL INFORMATION CONTAINED HEREIN, IS THE PROPERTY OF ROBICON, AND MAY NOT BE COPIED, REPRODUCED, OR DIVULGED TO UNAUTHORIZED PERSONS WITHOUT THE EXPRESS WRITTEN CONSENT OF ROBICON. IT IS PROVIDED SOLELY FOR THE CONVENIENCE OF THE USER AND SHALL BE RETURNED UPON REQUEST. ©1997 ROBICON ALL RIGHTS RESERVED
UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS IN INCHES INTERPRET DRAWING PER ASME Y14.5M-1994
TOLERANCES: .XX ±.03 .XXX ±.015 ANGLES ±1°
THIRD ANGLE PROJECTION
SCALE 1:1
LAYER
DATE 05/08/01
DFTR A. RIBNICKY
ENGR J. BUCKEY
ROBICON
A SUBSIDIARY OF HIGH VOLTAGE ENGINEERING CORP 500 Hunt Valley Drive, New Kensington, PA 15068
CUSTOMER ROBICON
CUST ORDER NUMBER STD
TITLE CONTROL DIAGRAM
DWG NO 459712
REV -
CAD FILE 459712-1
SHEET NO 1 OF 1
DBORDF



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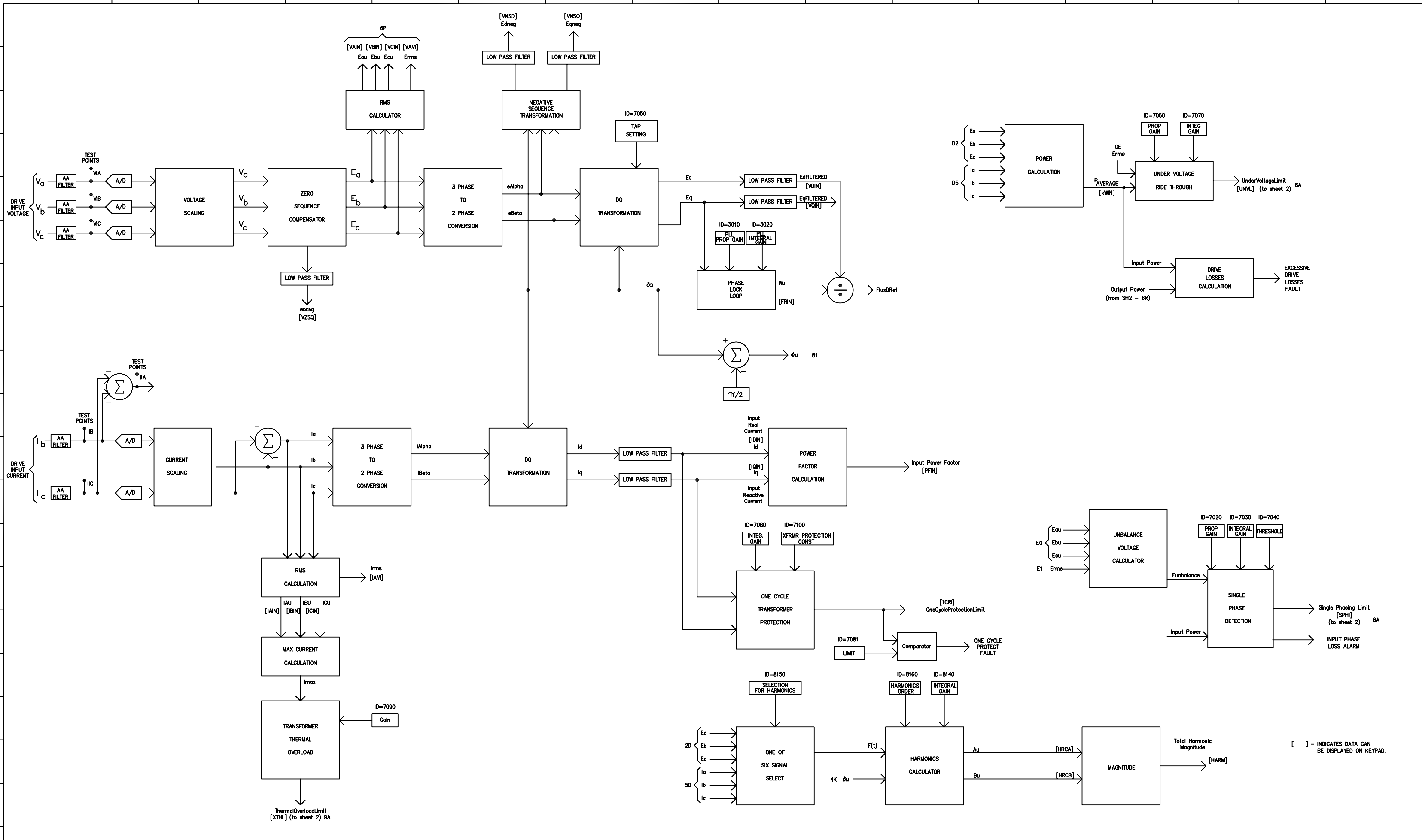
UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS IN INCHES INTERPRET DRAWING PER ASME Y14.5M-1994
TOLERANCES: .XX ± .03 .XXX ± .015 ANGLES ± 1°
THIRD ANGLE PROJECTION

SCALE 1:1
LAYER XXXX
DATE 05/08/01
DWGSZ D
DFTR A. RIBNICKY
ENGR J. BUCKEY

SIEMENS
Energy and Automation, Inc.
Large Drives - A

CUSTOMER SIEMENS
CUST ORDER NUMBER STD

TITLE COMMAND GENERATOR DIAGRAM
DWG NO A1A459713 REV BI
CAD FILE A5E01219450A
SHEET NO 1 OF 1
DBORDF



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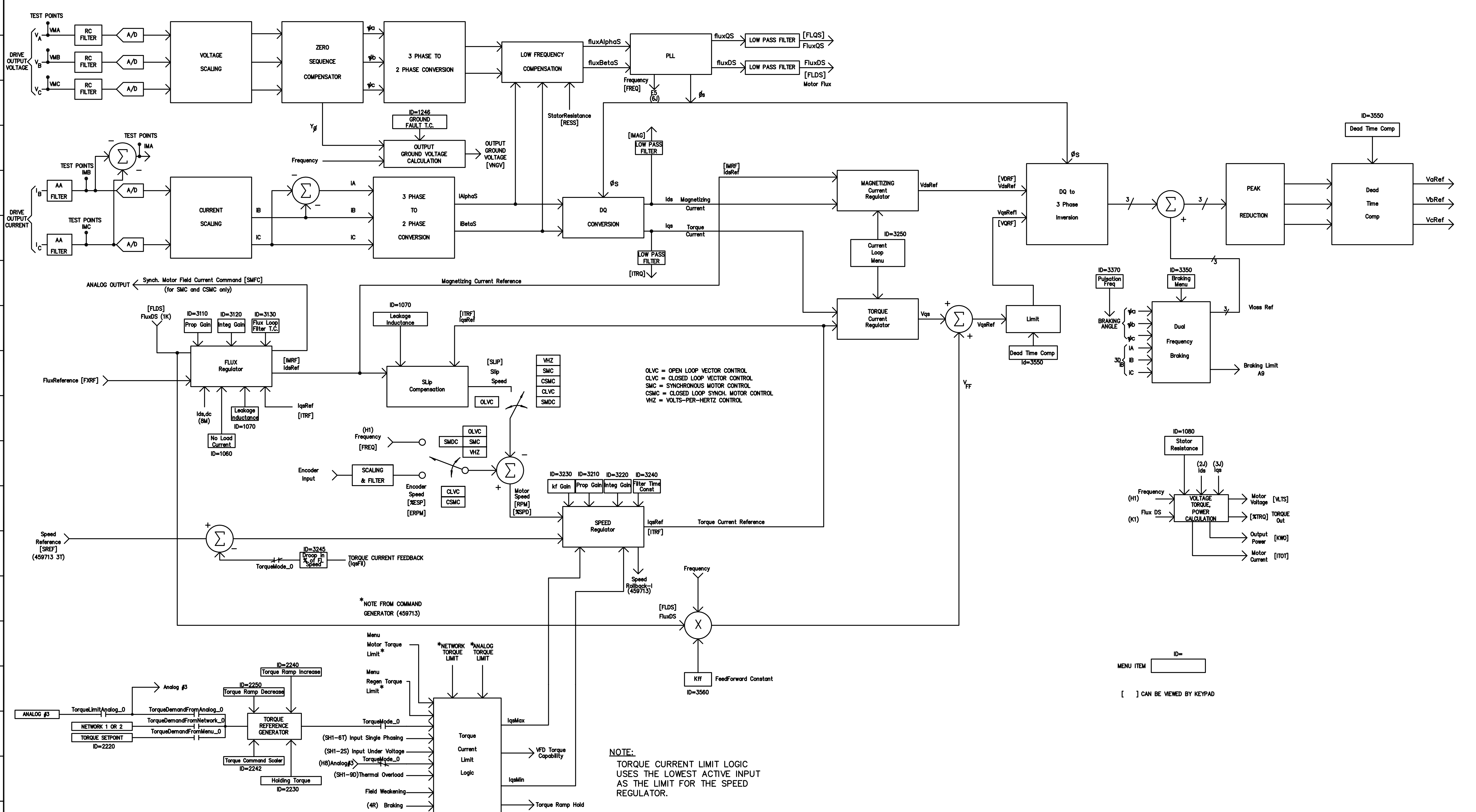
UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS IN INCHES INTERPRET DRAWING PER ASME Y14.5M-1994
TOLERANCES: .XX ± .03 .XXX ± .015 ANGLES ± 1°
THIRD ANGLE PROJECTION

SCALE 1:1
LAYER XXXX
DATE 05/15/01
DWGSZ D
DFTR A. RIBNICKY
ENGR J. BUCKEY

SIEMENS
Energy and Automation, Inc.
Large Drives - A
CUSTOMER SIEMENS
CUST ORDER NUMBER STD

TITLE INPUT PROCESS DIAGRAM
DWG NO A1A459717 REV BD
CAD FILE A5E01219451A
SHEET NO 1 OF 2
DBORDF



NOTE:
TORQUE CURRENT LIMIT LOGIC USES THE LOWEST ACTIVE INPUT AS THE LIMIT FOR THE SPEED REGULATOR.

DFTG CODE NO.

REVISIONS

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS IN INCHES INTERPRET DRAWING PER ASME Y14.5M-1994
TOLERANCES: .XX ± .03 .XXX ± .015 ANGLES ± 1°
THIRD ANGLE PROJECTION

SCALE	1:1
LAYER	XXXX
DATE	05/15/01
DWGSZ	D
DFTR	A. RIBNICKY
ENGR	J. BUCKEY

SIEMENS
Energy and Automation, Inc.
Large Drives - A

CUSTOMER SIEMENS
CUST ORDER NUMBER STD

TITLE OUTPUT PROCESS DIAGRAM

DWG NO A1A459717 REV BD
CAD FILE A5E01219451A SHEET NO 2 OF 2

DBORDF

APPENDIX

D Manual ID’s for Comparators

This appendix contains a list of Manual ID’s for Comparators.

Manual ID	Description	Units
2000	SpeedReference	1.0 = Rated
2010	SpeedReference	1.0 = Rated
2011	FluxReference	1.0 = Rated
2012	PowerFactor	1.0 = Rated
2013	Kvar	1.0 = Rated
2015	FluxDSFil	1.0 = Rated
2017	HotCellTemp	1.0 = Max Temp
2020	MotorSpeedFiltered	1.0 = Rated
2030	Frequency	1.0 = Rated
2040	SpeedDemand	1.0 = Rated
2050	SpeedDemand	1.0 = Rated
2060	RawSpeedDemand	1.0 = Rated
2070	RampOutput	1.0 = Rated
2080	IqsRefFiltered	1.0 = Rated
2090	IqsRefFiltered	1.0 = Rated
2100	MotorVoltage	1.0 = Rated
2110	MotorVoltage	1.0 = Rated
2120	Erms	1.0 = Rated
2130	Irms	1.0 = Rated
2140	Frequency	1.0 = Rated

D

Manual ID	Description	Units
2150	IqsFil	1.0 = Rated
2160	MotorTorque	1.0 = Rated
2161	DriveLosses	1.0 = Rated
2162	ExcessReactiveCurrent	1.0 = Rated
2163	Droop	1.0 = Rated
2164	SynchMotorFieldCurrent	1.0 = Rated
2168	Efficiency	1.0 = Rated
2170	IdsFil	1.0 = Rated
2180	IdsFil	1.0 = Rated
2230	AveragePower	1.0 = Rated
2240	AveragePower	1.0 = Rated
2250	AveragePower	1.0 = Rated
2260	AveragePower	1.0 = Rated
2270	E0Avg	1.0 = Rated
2280	E0Avg	1.0 = Rated
3600	AFEMinMaxStatusData.IdFilteredMin	1.0 = Rated
3601	AFEMinMaxStatusData.IdFilteredMax	1.0 = Rated
3602	AFEMinMaxStatusData.IdFilteredAvg	1.0 = Rated
3603	AFEMinMaxStatusData.IqFilteredMin	1.0 = Rated
3604	AFEMinMaxStatusData.IqFilteredMax	1.0 = Rated
3605	AFEMinMaxStatusData.IqFilteredAvg	1.0 = Rated
3606	AFEMinMaxStatusData.VdcMin	1.0 = Rated
3607	AFEMinMaxStatusData.VdcMax	1.0 = Rated

Manual ID	Description	Units
3608	AFEMinMaxStatusData.VdcAvg	1.0 = Rated
3609	AFEMinMaxStatusData.VdMin	1.0 = Rated
3610	AFEMinMaxStatusData.VdMax	1.0 = Rated
3611	AFEMinMaxStatusData.VdAvg	1.0 = Rated
3612	AFEMinMaxStatusData.OmegaMin	1.0 = Rated
3613	AFEMinMaxStatusData.OmegaMax	1.0 = Rated
3614	AFEMinMaxStatusData.OmegaAvg	1.0 = Rated
3615	AFEMinMaxStatusData.VdRefFilteredMin	1.0 = Rated
3616	AFEMinMaxStatusData.VdRefFilteredMax	1.0 = Rated
3617	AFEMinMaxStatusData.VdRefFilteredAvg	1.0 = Rated
3618	AFEMinMaxStatusData.VqRefFilteredMin	1.0 = Rated
3619	AFEMinMaxStatusData.VqRefFilteredMax	1.0 = Rated
3620	AFEMinMaxStatusData.VqRefFilteredAvg	1.0 = Rated
3621	AFEMinMaxStatusData.HighestTempMin	1.0 = 100°C
3622	AFEMinMaxStatusData.HighestTempMax	1.0 = 100°C
3623	AFEMinMaxStatusData.HighestTempAvg	1.0 = 100°C
3624	AFEMinMaxStatusData.DifferentialTempMin	1.0 = 100°C
3625	AFEMinMaxStatusData.DifferentialTempMax	1.0 = 100°C
3626	AFEMinMaxStatusData.DifferentialTempAvg	1.0 = 100°C
3627	AFEMinMaxStatusData.InputCurrentMin	1.0 = Rated
3628	AFEMinMaxStatusData.InputCurrentMax	1.0 = Rated
3629	AFEMinMaxStatusData.InputCurrentAvg	1.0 = Rated
3630	AFEMinMaxStatusData.MultiplexedDataMin	1.0 = Rated

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Manual ID	Description	Units
3631	AFEMinMaxStatusData.MultiplexedDataMax	1.0 = Rated
3632	AFEMinMaxStatusData.MultiplexedDataAvg	1.0 = Rated
3637	AFEMinMaxStatusData.FlowWaterMin	1.0 = Rated
3638	AFEMinMaxStatusData.FlowWaterMax	1.0 = Rated
3639	AFEMinMaxStatusData.FlowWaterAvg	1.0 = Rated
3640	AFEMinMaxStatusData.FlowWaterGlycolMin	1.0 = Rated
3641	AFEMinMaxStatusData.FlowWaterGlycolMax	1.0 = Rated
3642	AFEMinMaxStatusData.FlowWaterGlycolAvg	1.0 = Rated
3643	AFEMinMaxStatusData.NumberOfAFECells	1.0 = 24 cells
3644	AFEMinMaxStatusData.NumberOfAFECellsWithOpenSensors	1.0 = 24 cells

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APPENDIX

E Auto Resettable Faults

Table E-1: Fault Word 1

Fault Word 1	Bit number	ID number	Fault Text	Auto-resettable
OverSpeedAlarm	bit 0	1000	"Over Speed Alarm"	
OverSpeedFault	bit 1	1001	"Over Speed Fault"	Y
UnderLoadAlarm	bit 2	1002	"Under Load Alarm"	
UnderLoadFault	bit 3	1003	"Under Load Fault"	Y
MotorThermalOverLoad1	bit 4	1004	"Mtr Therm Over Load 1"	
MotorThermalOverLoad2	bit 5	1005	"Mtr Therm Over Load 2"	
MotorThermalOverLoadFault	bit 6	1006	"Mtr Therm Over Ld Fault"	
OutputPhaseImbalance	bit 7	1007	"Output Phase Imbal"	
OutputPhaseOpen	bit 8	1008	"Output Phase Open"	
OutputGroundFault	bit 9	1009	"Output Ground Fault"	Y
IOC	bit 10	1010	"IOC"	Y
MenuInit	bit 11	1011	"Menu Initialization"	Y
Cells	bit 12	1012	"Cell"	
InTorqueLimit	bit 13	1013	"In Torque Limit"	
InTorqueLimitRollback	bit 14	1014	"In Torq Limit Rollback"	
InputPhaseLoss	bit 15	1015	"Input Phase Loss"	
PhaseSequence	bit 16	1016	"Phase Sequence"	
CpuTempAlarm	bit 17	1017	"CPU Temperature Alarm"	
CpuTempFault	bit 18	1018	"CPU Temperature Fault"	
CellOverTemperatureAlarm	bit 19	1019	"Cell Over Temp Alarm"	

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Fault Word 1	Bit number	ID number	Fault Text	Auto-resettable
CellOverTemperatureFault	bit 20	1020	"Cell Over Temp Fault"	
ModulatorInitializationFault	bit 21	1021	"Modulator Configuration"	
CellCountMissMatch	bit 22	1022	"Cell Count Mismatch"	
PowerSupplyFault	bit 23	1023	"Power Supply"	
WagoCommunicationFault	bit 24	1024	"Wago CommunicationFault"	
WagoConfiguration	bit 25	1025	"Wago Configuration"	
CellBypassComFailure	bit 26	1026	"Cell Bypass COM Fail"	
CellBypassAckFailure	bit 27	1027	"Cell Bypass Acknowledge"	
CellBypassLinkFailure	bit 28	1028	"Cell Bypass Link"	
WeakBattery	bit 29	1029	"Modulator Battery Low"	
SystemProgram	bit 30	1030	"System Program"	
MediumVoltageLowAlarm1	bit 31	1031	"Medium voltage low 1"	
MediumVoltageLowAlarm2	bit 32	1032	"Medium voltage low 2"	
MediumVoltageLowFault	bit 33	1033	"Medium voltage low Flt"	Y
CellAlarm	bit 34	1034	"Cell alarm"	
LineOverVoltage1	bit 35	1035	"Line Over Voltage 1"	
LineOverVoltage2	bit 36	1036	"Line Over Voltage 2"	
LineOverVoltageFault	bit 37	1037	"Line Over Voltage Fault"	Y
InputPhaseImbalance	bit 38	1038	"Input Phase Imbal"	
InputOneCycle	bit 39	1039	"Input One Cycle"	
InputGroundFault	bit 40	1040	"Input Ground"	
EncoderLoss	bit 41	1041	"Encoder Loss"	Y
KeypadCommunication	bit 42	1042	"Keypad Communication"	Y

Fault Word 1	Bit number	ID number	Fault Text	Auto-resettable
Network1Communication	bit 43	1043	"Network 1 Communication"	Y
Network2Communication	bit 44	1044	"Network 2 Communication"	Y
MotorOverVoltageAlarm	bit 45	1045	"Motor Over Volt Alarm"	
MotorOverVoltageFault	bit 46	1046	"Motor Over Volt Fault"	Y
CellBypassComWarning	bit 47	1047	"Cell Bypass Com Alarm"	
CellBypassLinkWarning	bit 48	1048	"Cell Bypass Link Alarm"	
CellBypassFault	bit 49	1049	"Cell Bypass Fault"	
CellConfigurationFault	bit 50	1050	"Cell Config Fault"	
EffectiveSwitchFreqAlarm	bit 51	1051	"Carrier Frq Set Too Low"	
BackEmfTimeout	bit 52	1052	"Back EMF Timeout"	Y
HallEffectPowerSupplyFault	bit 53	1053	"Hall Effect Pwr Supply"	
UnknownModulatorFault	bit 54	1054	"Modulator Board Fault"	
Unused55	bit 55	1055	"Input Single Phase"	
ModulatorWatchdogTimeout	bit 56	1056	"Modulator Watchdog Flt"	
CellDcBusLowWarning	bit 57	1057	"Cell DC Bus Low"	
ToolCommunication	bit 58	1058	"Tool Communication"	
FailedToMagnetizeFault	bit 59	1059	"Failed To Magnetize"	Y
LossOfFieldFault	bit 60	1060	"Loss Of Field Current"	Y
LowMotorSpeedFault	bit 61	1061	"Minimum Speed Trip"	
ExcessiveDriveLosses	bit 62	1062	"Excessive Drive losses"	
WagoCommunicationAlarm	bit 63	1063	"Wago Communication Alarm"	

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Table E-2: Fault Word 2

Fault Word 2	Bit number	ID number	Fault Text	Auto-resettable
OneBlowerLost	bit 0	1064	"One Blower Not Avail"	
AllBlowersLost	bit 1	1065	"All Blowers Not Avail"	
CloggedFilters	bit 2	1066	"Clogged Filters"	
ReactorTemperature1	bit 3	1067	"Reactor OT Alarm"	
ReactorTemperature2	bit 4	1068	"Reactor OT Trip Alarm"	
ReactorTemperatureFault	bit 5	1069	"Reactor OT Fault"	
XformerOverTempAlarm1	bit 6	1070	"Xformer OT Alarm"	
XformerOverTempAlarm2	bit 7	1071	"Xformer OT Trip Alarm"	
XformerOverTempFault	bit 8	1072	"Xformer OT Fault"	
OnePumpFailure	bit 9	1073	"One Pump Not Available"	
AllPumpsFailure	bit 10	1074	"Both Pumps Not Available"	
CoolantConductivityAlarm	bit 11	1075	"Coolant Conduct > 3 uS"	
CoolantConductivityFault	bit 12	1076	"Coolant Conduct > 5 uS"	
InletWaterTempHigh	bit 13	1077	"Coolant Inlet Temp > 60c"	
InletWaterTempLow	bit 14	1078	"Coolant Inlet Temp < 22c"	
CellWaterTempHigh	bit 15	1079	"Cell Water Temp High"	
XformerWaterTempHigh	bit 16	1080	"Xfrm Cool OT Trip Alarm"	
LowWaterLevelAlarm	bit 17	1081	"Coolant Tank Level < 30"	
LowWaterLevelFault	bit 18	1082	"Coolant Tank Level < 20"	
LowWaterFlowAlarm	bit 19	1083	"Low Coolant Flow < 60%"	
LowWaterFlowFault	bit 20	1084	"Low Coolant Flow < 20%"	
LossOneHexFan	bit 21	1085	"Loss One HEX Fan"	

Fault Word 2	Bit number	ID number	Fault Text	Auto-resettable
LossAllHexFan	bit 22	1086	“Loss All HEX Fans”	
AllHexFansOn	bit 23	1087	“All HEX Fans On”	
LossOfDriveEnable	bit 24	1088	“Loss Of Drive Enable”	Y
UpTransferAlarm	bit 25	1089	“Up Transfer Failed”	
DownTransferAlarm	bit 26	1090	“Down Transfer Failed”	
AdcHardwareErrorAlarm	bit 27	1091	“A/D Hardware Alarm”	
AdcHardwareErrorFault	bit 28	1092	“A/D Hardware Fault”	
ConfigFileWriteAlarm	bit 29	1093	“Config File Write Alarm”	
ConfigFileReadFault	bit 30	1094	“Config File Read Error”	
WagoInternalErrorFault	bit 31	1095	“Wago Internal Fault”	
WagoCouplerErrorFault	bit 32	1096	“Wago Coupler Fault”	
WagoErrorAfterModuleFault	bit 33	1097	“Wago Flt After Module”	
WagoErrorAtModuleFault	bit 34	1098	“Wago Flt At Module”	
WagoInternalErrorAlarm	bit 35	1099	“Wago Internal Alarm”	
WagoCouplerErrorAlarm	bit 36	1100	“Wago Coupler Alarm”	
WagoErrorAfterModuleAlarm	bit 37	1101	“Wago Alm After Module”	
WagoErrorAtModuleAlarm	bit 38	1102	“Wago Alm At Module”	
LossOfSignalInternal	bit 39	1103	“Loss Of Signal Int”	Y
LossOfSignal1	bit 40	1104	“Loss Of Signal 1”	Y
LossOfSignal2	bit 41	1105	“Loss Of Signal 2”	Y
LossOfSignal3	bit 42	1106	“Loss Of Signal 3”	Y
LossOfSignal4	bit 43	1107	“Loss Of Signal 4”	Y
LossOfSignal5	bit 44	1108	“Loss Of Signal 5”	Y

Fault Word 2	Bit number	ID number	Fault Text	Auto-resettable
LossOfSignal6	bit 45	1109	“Loss Of Signal 6”	Y
LossOfSignal7	bit 46	1110	“Loss Of Signal 7”	Y
LossOfSignal8	bit 47	1111	“Loss Of Signal 8”	Y
LossOfSignal9	bit 48	1112	“Loss Of Signal 9”	Y
LossOfSignal10	bit 49	1113	“Loss Of Signal 10”	Y
LossOfSignal11	bit 50	1114	“Loss Of Signal 11”	Y
LossOfSignal12	bit 51	1115	“Loss Of Signal 12”	Y
LossOfSignal13	bit 52	1116	“Loss Of Signal 13”	Y
LossOfSignal14	bit 53	1117	“Loss Of Signal 14”	Y
LossOfSignal15	bit 54	1118	“Loss Of Signal 15”	Y
LossOfSignal16	bit 55	1119	“Loss Of Signal 16”	Y
LossOfSignal17	bit 56	1120	“Loss Of Signal 17”	Y
LossOfSignal18	bit 57	1121	“Loss Of Signal 18”	Y
LossOfSignal19	bit 58	1122	“Loss Of Signal 19”	Y
LossOfSignal20	bit 59	1123	“Loss Of Signal 20”	Y
LossOfSignal21	bit 60	1124	“Loss Of Signal 21”	Y
LossOfSignal22	bit 61	1125	“Loss Of Signal 22”	Y
LossOfSignal23	bit 62	1126	“Loss Of Signal 23”	Y
LossOfSignal24	bit 63	1127	“Loss Of Signal 24”	Y

Table E-3: Fault Word 4

Fault Word 4	Bit number	ID number	Fault Text	Auto-resettable
InternalLossOfSignal1	bit 0	1192	"Int AI1 Loss of Signal"	Y
InternalLossOfSignal2	bit 1	1193	"Int AI2 Loss of Signal"	Y
InternalLossOfSignal3	bit 2	1194	"Int AI3 Loss of Signal"	Y
PrechargeFault	bit 3	1195	"Precharge Fault"	
AfeCellDiffTempAlarm	bit 4	1196	"Cell Diff Temp Alarm"	
InputFrequencyAlarm	bit 8	1200	"Input Freq/Phasing"	
AfeCellDiffTempFault	bit 9	1201	"Cell Diff Temp Fault"	
FieldExciterFault	bit 10	1202	"Field Exciter Fault"	
SMDCStartupFault	bit 11	1203	"SMDC PLL Start-up Fault"	Y
PrechargeBreakerOpened	bit 12	1204	"Precharge Breaker Open"	
InputProtection	bit 13	1205	"Input Protection Fault"	
PoleSlip	bit 14	1206	"SM Pole Slip"	Y
MotorPullOut	bit 21	1213	"Motor Pull-out Fault"	Y

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