GenIII Harmony Product User Manual

Adjustable Speed AC Motor Drives with Next Generation Control

Manual Number: A5E03723047A
Version AB
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Version History

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Safety Precautions and Warnings

The Perfect Harmony™ Series is designed with considerable attention to personal safety. However, as with any piece of high power equipment, there are numerous internal connections that exhibit 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.

⚠ WARNING

Potential Arc Hazard

- Arcing can result in damage to property, serious injury, and even death.
- The equipment has not been tested for resistance to internal arcing.
- Avoiding arc hazard risks is dependent upon proper installation and maintenance. Incorrectly applied equipment; incorrectly selected, connected or unconnected cables; or the presence of foreign materials can cause arcing in the equipment.
- Follow all precautionary rules and guidelines used when working with medium voltage (MV) switch-gear.

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 and wear electrical safety gloves, safety shoes (composite or steel toe with an electrical hazard rating), and safety glasses.
- **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 (for example., meters, oscilloscopes, etc.) intended for high voltage measurements (isolation is provided inside the instrument and 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. There may also 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 ELV.
- **Never** connect any grounded (non-isolated) meters or oscilloscopes to the Perfect Harmony™ system.
- **Never** connect or disconnect any meters, wiring, or PCBs 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.).
- **Always** ensure the use of an even and flat truck bed to transport the Perfect Harmony™ drive system. Before unloading, be sure that the concrete pad is level for storage and permanent positioning.
- **Always** confirm proper tonnage ratings of cranes, cables, and hooks when lifting the drive system. Dropping the cabinet or lowering it too quickly could damage the unit.
- **Never** disconnect control power while MV is energized. This could cause severe system overheating and/or damage.
- **Never** store flammable material in, on, or near the drive enclosure. This includes equipment drawings and manuals.
- **Never** use fork trucks to lift cabinets that are not equipped with lifting tubes. Be sure that the fork truck tines fit the lifting tubes properly and are the appropriate length.
- **Always** confirm proper parameter settings. The drive will not work properly if relevant parameters are not set correctly.

ESD Sensitive Equipment!

Always be aware of electrostatic discharge (ESD) when working near or touching components inside the Perfect Harmony™ cabinet. PCBs contain components that are sensitive to static electricity. Handling and servicing 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.
- Always use either a metallic vacuum-style plunger or copper braid when desoldering.
- Make certain that anyone handling the Perfect Harmony™ PCBs 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 PCB, always hold the card by its edges.
- Do not slide PCBs across any surface (for example, a table or work bench). If possible, perform PCB maintenance at a workstation that has a conductive covering that is grounded through a 1 megohm resistor. If a conductive tabletop cover is unavailable, a clean steel or aluminum tabletop is an excellent substitute.
- Avoid plastic, Styrofoam™, vinyl and other non-conductive materials. They are excellent static generators and do not give up their charge easily.
- When returning components to Siemens LD A, always use static-safe packing. This limits any further component damage due to ESD.

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

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About This Manual

Separation of Manuals

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

- *GenIII Harmony Product User Manual* (A5E03723047A)
- *NXG ToolSuite Software User Manual* (A5E03086439)
- *NXG Communications Manual* (A5E02924901)
- *NXG Control Manual* (A5E02924900)

The *GenIII Harmony Product User Manual* (A5E03723047A) defines the configuration and capabilities of the Perfect Harmony family of Medium Voltage Variable Frequency Drives and specifically addresses the GenIII Harmony configuration. This manual also provides a detailed description of how the System is transported, installed, and maintained at the customer's site.

The *NXG ToolSuite Software User Manual* (A5E03086439) provides a detailed description of ToolSuite, a PC-based application that integrates various software tools used for NXG based Drives. The NXG ToolSuite is a high-level GUI that runs on a PC that is equipped with the Microsoft Windows operating system. The NXG Control and the PC running the NXG ToolSuite interface using Ethernet and TCP/IP protocol.

The *NXG Communications Manual* (A5E02924901) describes the NXG Control communication board, which enables network communication via a variety of protocols and enables modem connection.

The *NXG Control Manual* (A5E02924900) describes the NXG Control System. The Harmony family of drives is a collection of MV drives with different power topologies and cooling methods. The unifying factor with the drives is the NXG Control System--a second generation control for the Harmony line.

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

Reference Tools

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

- A thorough table of contents for locating particular sections or subsections
- Chapter number thumb nails in the outer margins for easy location of chapters
- Special text styles are applied to easily differentiate between chapters, sections, subsections, regular text, parameter names, software flags and variables, and test points.
- A comprehensive index.

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

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.

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

1.1 Purpose

This manual defines the configuration and capabilities of the Perfect Harmony™ family of MV VFD and specifically addresses the GenIII Perfect Harmony™ configuration. Detailed descriptions of the common features of the Perfect Harmony™ drive family are defined in the following manuals:

Companion Manuals:

- *NXG ToolSuite Software User Manual* (A5E03086439)
- *NXG Communications Manual* (A5E02924901)
- *NXG Control Manual* (A5E02924900)

1.2 Introduction

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

The Perfect Harmony™ series drives achieve this uncompromised performance by employing time-proven technology in a simple configuration. Figure "Perfect Harmony™ Typology" shows a typical power circuit topology for a 3364 volt Perfect Harmony™ series drive, using 630 VAC power cells. In this configuration, each motor phase is driven by 3 power cells connected in series. The groups of power cells are wye-connected with a floating neutral. Each cell is powered by an isolated secondary winding of an integral isolation transformer. The 9 secondaries are each rated for 630 VAC at one-ninth of the total power. The power cells and their associated transformer secondaries are insulated from each other and from ground for 7.2 kV class service or "according to the output voltage rating of the drive."

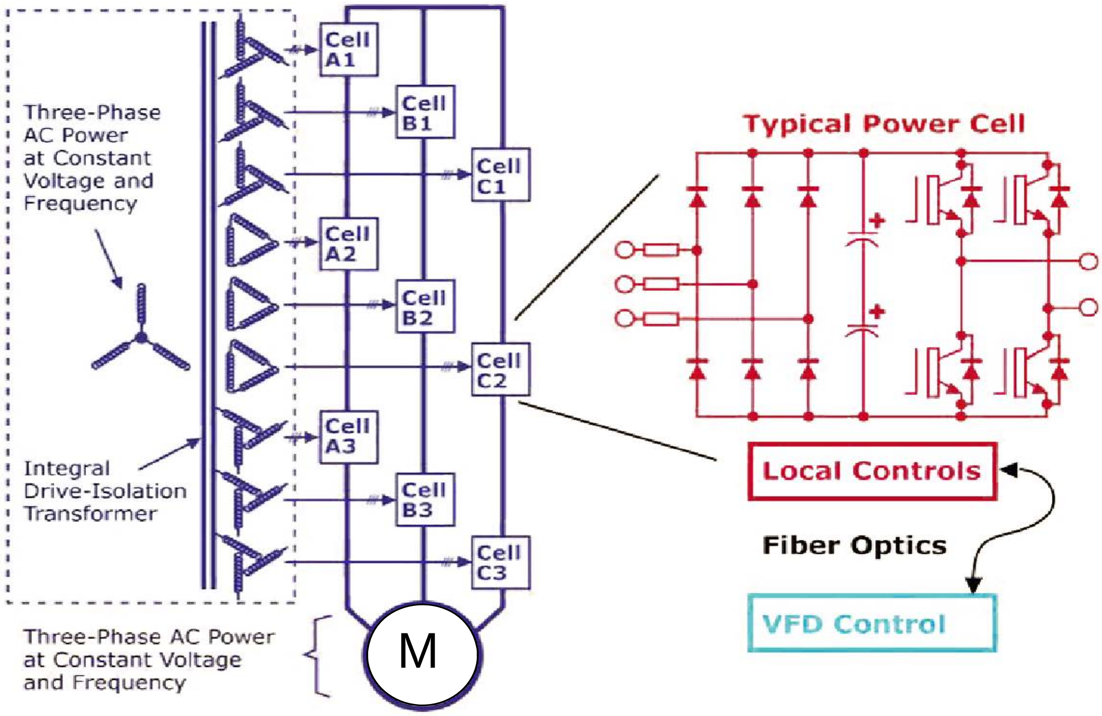

Figure 1-1: Perfect Harmony™ Topology

For higher output voltage capabilities, Figure “Perfect Harmony™ Typology” would be extended to have up to 6 power cells in series in each phase with additional secondary windings (number of secondaries equals number of power cells) on the integral isolation transformer.

Each power cell is simply a static power converter. It is capable of receiving input power at 630 VAC, 3-phase, 50/60 Hz and delivering that power to a single-phase load at a variable frequency from 0.5 to the maximum rated output frequency of the drive.

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1.2.1 Clean Power

Prior to the introduction of the Perfect Harmony™ drive, other solutions with variable frequency output power conversion created unwanted line disturbance. Refer to Figure “Harmonic Distortion Waveform Comparisons (6-pulse, 12-pulse, and Perfect Harmony™)” for 6-pulse and 12-pulse input waveforms.

The Perfect Harmony™ drive system mitigates power quality issues by

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

The Perfect Harmony™ drive series meets the most stringent IEEE 519-1992 requirements for voltage and current harmonic distortion, even if the source capacity is no larger than the drive rating. This series protects other online equipment (for example, 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 “Harmonic Distortion Wave Form Compensation (6-pulse, 12-pulse, and Perfect Harmony™)” illustrates harmonic distortion waveforms for a typical 6-pulse, a typical 12-pulse, and the Perfect Harmony™ series drive.

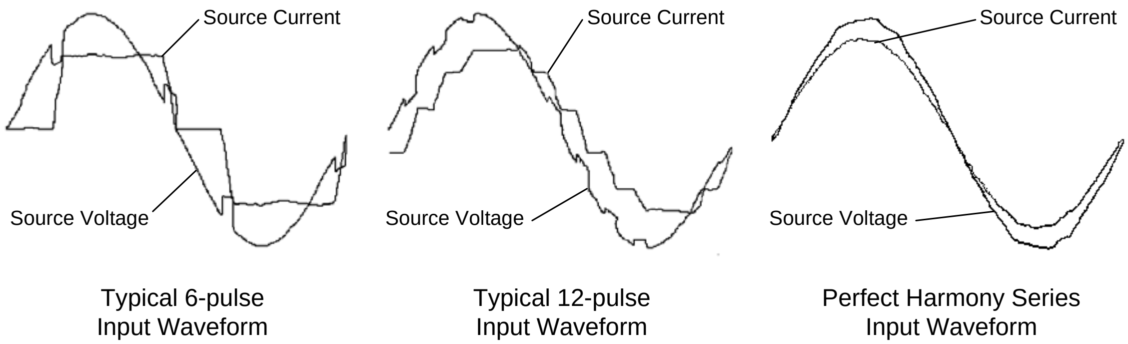

Figure 1-2: Harmonic Distortion Waveform Comparisons (6-pulse, 12-pulse, and Perfect Harmony™)

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 completed using a typical 1000 Hp current source drive (6-pulse and 12-pulse modes) and a Perfect Harmony™ series drive operating from an 1100 kVA, 5.75% impedance source.

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1.2.2 High Power Factor

Power factor is a measure of the fraction of current that produces real power to the load. Typically, power factor is given as a percentage. A high power factor VFD (for example, 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 (for example, 30%). VFDs having a low operating power factor often generate square-wave-shaped line currents. This can lead to harmonics and other associated resonance problems.

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

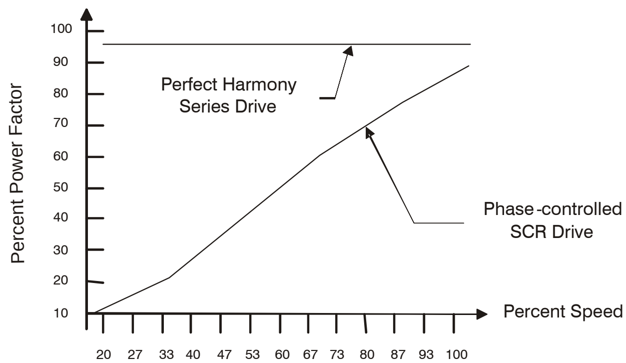

Figure 1-3: Comparison of Perfect Harmony™ and a Typical Phase-Controlled SCR Drive

1.2.3 Nearly Perfect Sinusoidal Output Voltages

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

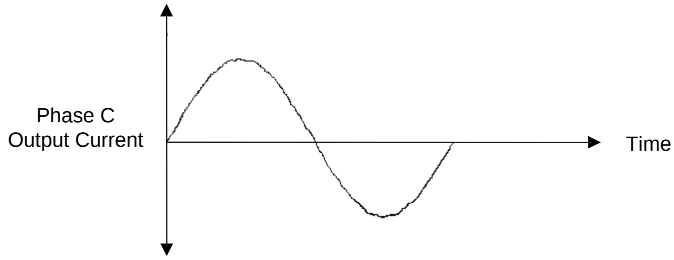

Figure 1-4: Nearly Sinusoidal Waveform of the Output Current from a Perfect Harmony™ Drive

Unlike standard PWM systems, the voltage applied to the motor leads is developed in many small steps instead of a few large steps. This provides 2 distinct advantages: the voltage stress on the motor leads is dramatically reduced, and the quality of the motor currents is dramatically increased.

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

1.3 Perfect Harmony™ Features

The features of the Perfect Harmony™ family of MV drives are summarized as follows:

- Truly scalable technology with modular construction
    - Air cooled: GenIV, GenIIIe, GenIII NBH
    - Liquid cooled: WCIII, High Voltage (HV)
- 200 to 40000 Hp (150 kW to 30 MW)
- Wide range of motor voltages supported
    - 2300 VAC through 13800 VAC
- Low harmonic input
- High efficiency and power factor
- Line disturbance immune
- Compatible with new or existing motors
- Power cell bypass with floating neutral point control
- Negligible torsion
- Wide range of connectivity to industrial Programmable Logic Controller (PLC) networks
- Parallel drive control
- Multi-motor control
- Long cable compatible
- Synchronous line/load transfer capability
- Inherent input/output metering
- Coordinated input protection scheme
- Dual frequency braking
- Process Tolerant Protection Strategy (ProToPS™)
- Partial or fully regenerative (4Q)

1.3.1 Perfect Harmony™ VFD Family Features

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

Note: The following ratings are subject to change.

GenIV:

Refer to *GenIV Product User Manual* (A5E01454341C) for full GenIV product range.

- 200 to 6000 Hp (150 to 4450 kW)
- 2.3 to 11 kV output
- 2.4 to 13.8 kVAC 50/60 Hz input
- Air cooled
- Power cell ratings:
  - 750 volts
  - 40, 70, 100, 140, 200 or 260 arms

GenIII:

- 200 to 3500 Hp (150 to 2610 kW)
- 2.3 to 6.6 kV output
- 2.4 to 13.8 kVAC 50/60 Hz input
- Air cooled
- Power cell ratings:
  - 630 volts
  - 70, 100, 140, 200, or 260 arms

GenIIIe:

Refer to *GenIIIe Product User Manual* (A5E02960987A) for full GenIIIe product range.

- 2000 to 9000 Hp (1.45 to 6.75 MW)
- 2.3 to 7.2 KV output
- 2.4 to 13.8 kVAC 50/60 Hz input
- Air cooled
- Power cell ratings:
  - 690 volts
  - 315, 375, 500, 660, or 720 arms

Note: For 720A cells, the cell voltage is 630V instead of 690V.

WCIII:

- 4000 to 19000 Hp (3 MW to 14.2 MW)
- 2.3 to 8.0 kV output
- 2.4 to 13.8 kVAC 50/60 Hz input
- Water cooled
- Power cell ratings:
  - 750 volts

- 880 or 1250 arms

HV:

- 10000 to 40000 Hp (7.5 MW to 30 MW)
- 7.2 to 13.8 kV output
- 2.4 to 13.8 kVAC 50/60 Hz input
- Water cooled
- Power cell ratings:
  - 1375 volts
  - 500, 800, or 1400 arms

1.3.2 VFD Scalability

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

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

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

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1.3.3 VFD Output Ratings

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

Output Voltage Capability, with All Cells Operating

The maximum output voltage of the drive in terms of the number of ranks and the secondary-side cell voltage is given as the following:

VAVAILABLE (volts) = 1.78 * #Cells * CellV * Vin / Vrated * TransformerTapSetting

Where:

1.78 = 3-phase factor times third harmonic injection factor

#Cells = Number series power cells per phase

CellV = Cell voltage (Vrms)

Vin = Measured line input voltage (Vrms)

Vrated = Rated VFD input voltage (Vrms)

TransformerTapSetting use: 0.95 when +5% tap on input transformer is used
1.00 when 0% tap on input transformer is used
1.05 when -5% tap on input transformer is used

Note: Drive voltage capability must be calculated based on worst-case line voltage (minimum value).

Table 1-1: Output Voltage Capability

Total Number Of Cells	Nominal Output Voltage Line-to-Line RMS			
	All Cells in Service	Vout 1 Cell Bypassed	Vout 2 Cells Bypassed	Vout 3 Cells Bypassed
9	3364	2804	2243	1682
12	4486	3925	3364	2804
15	5607	5046	4486	3925
18	6728	6168	5607	5046

Note: At least 1 cell must remain in service in each phase. The minimum cells per phase count cannot be 0. Systems with a total of 9 cells can have a maximum of 2 cells bypassed in a single phase.

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

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

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

After Cell Bypass

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 the following:

Vout_bypass = VAVAILABLE * {[(2 * N) - ***X***] / (2 * N)}

where VAVAILABLE is the maximum output voltage with all cells operating and can be calculated as shown above.

During Synchronous Transfer with Cell Bypass

When deciding on the feasibility of up/down transfer with cell-bypass, first calculate the maximum output voltage of the drive with all cells in operation (VAVAILABLE), as provided above.

If ***X*** is the largest number of cells in bypass in **two of the phases**, then calculate the drive output after bypass (Vout_bypass), as provided above. Assuming that Vin is the input voltage to which the drive has to synchronize, NXG software will allow up or down transfer only if Vout_bypass > Vin.

Example of Calculating Drive Output Voltage Capability

Consider a GenIIIe drive with 18 cells. The maximum output voltage that this drive can deliver on the +5% tap operating at rated input line voltage is the following:

VAVAILABLE = 1.78 * 630 * 6 * 0.95 * (1) = 6392 V

If after cell bypass, the drive has 6 cells operation 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 the following (with ***X*** = 1 + 2 = 3, where 2 cells in phase CD and 1 cell in phase B are bypassed):

Vout_bypass = 6392 * {[(2 * 6) - 3] / (2 * 6)} = 4694 V

1.3.4 Rectifier Configuration

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

Effective Rectifier Configuration is

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

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1.3.5 Power Cell Bypass Option

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

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

1.3.6 Transformer Winding Configuration

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

- Secondary windings experience higher harmonics
  - Plurality of phase staggered delta or extended delta reduces current
- Primary winding experiences low harmonics
  - Harmonics reflect multi-pulse secondary configuration

The Perfect Harmony™ transformers are applied to motor drives using the rule of 1 kVA per Hp (see below), resulting in a transformer utilization factor of 89%. The transformer is unusual in that the secondary windings carry 6-pulse currents, while the primary carries nearly perfect sine waves. The total VA of the secondary windings is greater than the VA of the primary windings.

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

With following assumptions used for sizing purpose:

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

Reducing this equation results in the following:

Rated input current (Amps) = [(kVA rating) ÷ (Rated primary voltage)] x 513.11

1.3.7 Control Overview

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

- Control sends message to each power cell control via dedicated fiber links
- Cell executes request by firing one switch pair:
  - Plus DC voltage
  - Minus DC voltage
  - Zero voltage
- Cell control confirms switch pair fired
- Control confirms firing from:
  - Output voltage divider
  - Output Hall Effect current transducer
- No two cells ever switch at the same time
- Cell switching rate is low compared to effective switching frequency of VFD:
  - Typically 600 Hz carrier frequency per pole results in 1200 Hz switching frequency per cell
- VFD effective switching frequency is simply the cell switching frequency times the number of cells per phase
- Switching rate is constant over the entire output frequency range
- Default control is an open flux vector control:
  - V/Hz and closed loop (encoder) control modes also available

1.4 Applications

- Oil and gas (including long cables)
- Municipal water
- Power generation
- HVAC
- Cement
- Chemicals
- Research

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1.5 Evolution

Historic Milestones:

1994: World's first fully integrated voltage source inverter (VSI) MV motor drive using Insulated Gate Bipolar Transistors (IGBT) that meet IEEE 519 for input current distortion and National Electrical Manufacturers Association (NEMA) / International Electrotechnical Commission (IEC) for motor Harmonic Voltage Factor (HVF) (without using output step-up transformers or line/load filters).

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

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

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

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

2000: First VSI drive to operate a MV synchronous motor.

2001: 1000th Perfect Harmony™ drive installed.

2002: 1500th Perfect Harmony™ drive installed.

2003: First high voltage 13.8 kV drive capable of operating motors from 4000 to 90000 Hp connected directly to 13.8 kV source.

2004: Built largest PWM drive, 80000 Hp.

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

1.6 Intellectual Property

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

5,625,545	6,236,580	6,417,644
5,986,909	6,262,555	6,762,947
6,014,323	6,301,130	7,554,804
6,166,513	6,313,600	
6,222,284	6,411,530	

1.7 CE Marking and Directives for Perfect Harmony™ Products

The Communaute Europeenne (CE) marking identifies products that are in compliance with EU product safety legislation. The CE marking is not a seal of quality. It was created to guarantee end users safe products in the free flow of goods within the European Economic Community (EEC) and the European Community (EC). By applying the CE marking the manufacturer acknowledges the product is in conformance with the applicable EU Directives and the product complies with the "essential requirements" defined in these directives.

1.7.1 Directives that Apply to Perfect Harmony™ Products

- **LVD** (Low Voltage Directive): 2006/95/EEC (formerly 72/23/EEC).
- **EMC** (EMC Directive): 2004/108/EEC (formerly 89/36/EEC).

1.7.2 Directives that Do Not Directly Apply to Perfect Harmony™ Products

- **MD** (Machinery Directive): 98/37/EEC until 29 Dec. 2009, then 2006/42/EEC becomes effective.
- **PED** (Pressure Equipment Directive): 97/23EC. Liquid-cooled Siemens Industry, Inc. I DT LD A Perfect Harmony™ designs are exempt since they operate at pressures less than 10 bars.
- **ATEX B** (Explosive Atmospheres): 94/9/EC – Does not apply to Siemens Industry, Inc. I DT LD A Perfect Harmony™ designs that are installed in ordinary (non-explosive) atmospheres. May apply to a motor if the "Ex" option for the motor is specified by the purchaser.

1.7.3 EU Norms

- **LVD**: Siemens Industry, Inc. I DT LD A Perfect Harmony™ designs comply with IEC61800-5-1 (2007) "Adjustable Speed Electrical Power Drive Systems," Part 5-1 "Safety Requirements – Electrical, Thermal and Energy."
- **EMC**: Siemens Industry, Inc. I DT LD A Perfect Harmony™ designs comply with IEC 61800-3 (2004) "Adjustable Speed Electrical Power Drive Systems", Part 3 "EMC Requirements and specific test methods." Reference Section 6.10 "EMC Installation Guidelines for Perfect Harmony™" in Siemens Industry, Inc. I DT LD A document A5E03723047A (this document).
- **MD**: Siemens Industry, Inc. I DT LD A Perfect Harmony™ designs comply with:
  - o IEC 60204-1 (2005) "Safety of machinery – Electrical equipment of machines – Part 1."
  - o IEC 60204-11 (2000) "Safety of machinery – Electrical equipment of machines – Requirements for HV equipment to 35KVAC."
  - o IEC61800-5-1 (2007) "Adjustable Speed Electrical Power Drive Systems," Part 5-1 "Safety Requirements – Electrical, Thermal and Energy."

1.7.4 CE Marking

Conformity with the directives (or with the relevant national law) is expressed by the CE mark.

The CE marking is required for all products which fall in the scope of a European Directive (which foresees the CE marking for those products) which are placed on the market in the European Economic Area.

Note: "CE Marking and Technical Standardization – Guidelines for Application to Electrical Power Drive Systems" Edition 3.0 may be accessed at: Gambica Technical

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1.7.5 CE Marking on Power Drive Systems

The concept of a Power Drive System (PDS) is used to describe an electric motor drive system within an overall installation. The terminology is used throughout IEC and EN standards relating to electrical variable speed drives to describe a combination of components, including a power converter and motor. IEC series 61800 covers “Adjustable Speed Electrical Power Drive Systems.”

Siemens Industry, Inc. I DT LD A Perfect Harmony™ designs always include the Basic Drive Module (BDM), consisting of a Perfect Harmony™ transformer, a converter/inverter (power cell) section, and a control section. Depending on the Siemens Industry, Inc. I DT LD A scope of supply, the Perfect Harmony™ Complete Drive Module (CDM) may include optional components such as a motor excitation unit, output line filter, output line reactor, or earthing switches. The Siemens Industry, Inc. I DT LD A scope of supply may include a motor.

The components of the machinery, including gear boxes and the driven equipment is the end user’s responsibility and outside the scope of Siemens Industry, Inc. I DT LD A’s responsibility from a MD standpoint.

The conventional illustration of a PDS and its component parts is shown in Figure “The Power Drive System.”

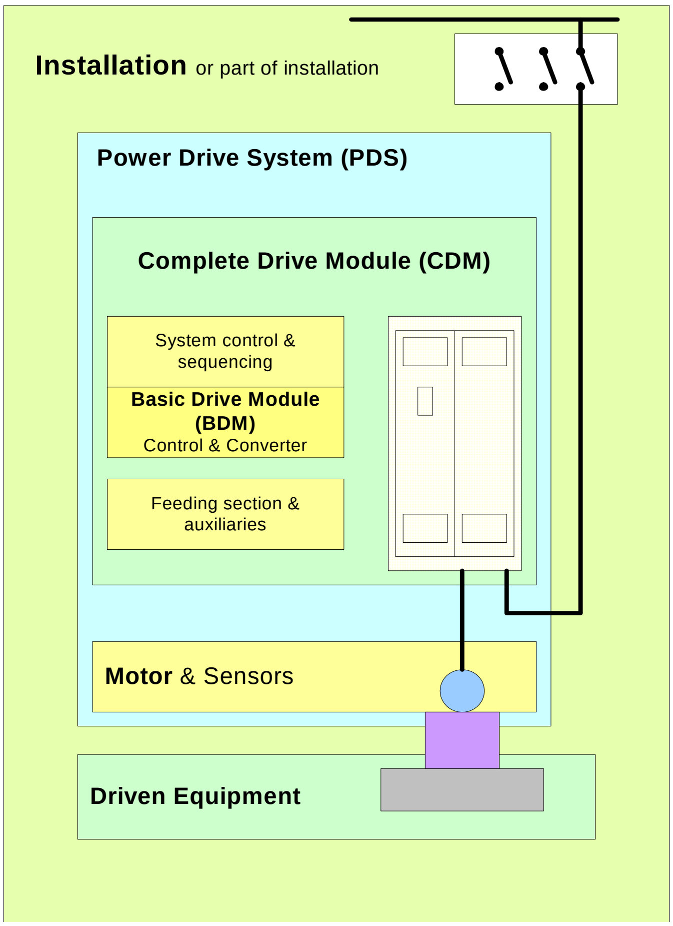


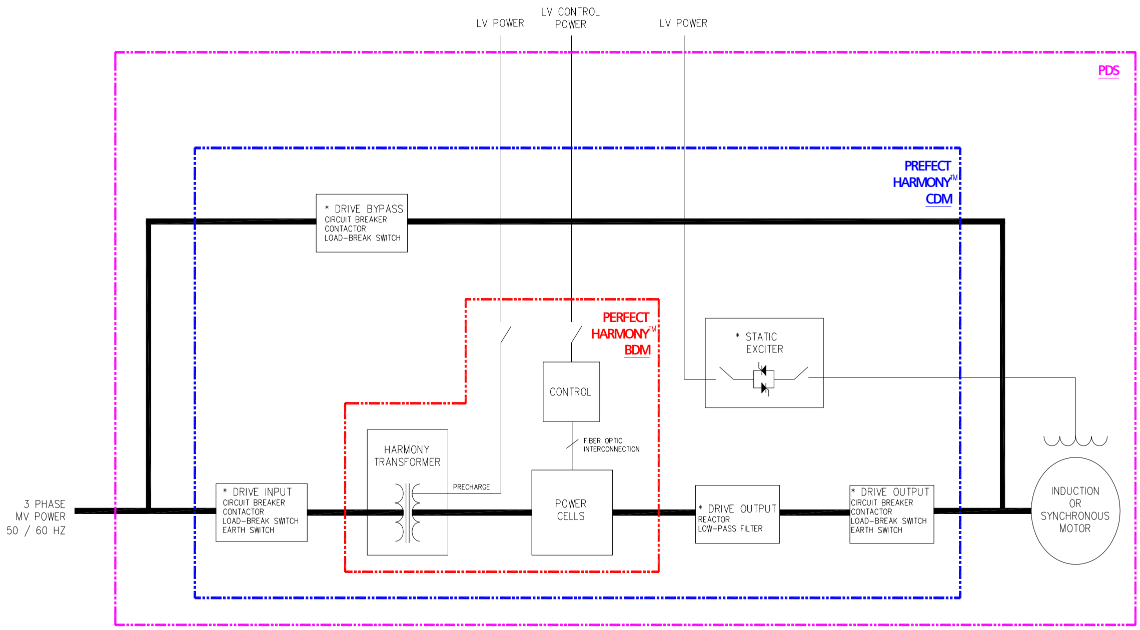
Figure 1-5: The Power Drive System

BDM: Basic drive module consisting of power input, control, and power output sections.

CDM: Complete drive module consisting of BDM and auxiliary sections, including devices such as incoming switches, input and output transformers, and filters, etc. but excluding the motor, cables, and motor-coupled sensors.

PDS: PDS consisting of CDM, motor, and sensors, excluding the driven equipment and sensors.

1.7.6 Overview of PDS Containing the Perfect Harmony™ BDM and CDM



*Optional Components in Perfect Harmony™ CDM
May not be in Siemens Industry, Inc. I DT LD A scope of supply.
May be housed separately in own stand-alone enclosure.

The machinery includes the drive shaft, gear box, and the driven equipment (not shown). As stated previously, the components of the machinery, including gear boxes and the driven equipment, is the end user's responsibility and outside the scope of Siemens Industry, Inc. I DT LD A's responsibility from a MD standpoint.

MD 2006/42/EEC

In the case of the MD (and also the EMC Directive), no EC Declaration of Conformance or CE mark can be issued for the product itself. The reason for this is conformance can only be evaluated within the scope of the complete plant or system. The conformance of the product, exclusively relating to the MD (or EMC Directive), is acknowledged and confirmed in the factory certificate or EU Manufacturer's Declaration.

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EC Declaration of Conformity and Declaration of Incorporation

There are three categories that require consideration:

- **Partly completed machinery**
  Such equipment (as defined in Article 2(g) of Directive 2006/42/EC) requires a "Declaration of Incorporation" but no CE marking for conformity to Directive 2006/42/EC. In practice this may be a PDS which has specific functionality, but not a BDM or CDM.
- **Application independent equipment**
  This category typically relates to a general purpose BDM or CDM, which is application independent. Such equipment does not require a Declaration of Incorporation or Declaration of Conformity and does not require a CE mark for conformity to Directive 2006/42/EC.
- **Safety components**
  A safety component could be a particular BDM, CDM, or PDS provided it meets the following definition as given in Article 2(c) of Directive 2006/42/EC: "...which serves to fulfill a safety function, which is independently placed on the market, the failure and/or malfunction of which endangers the safety of persons, and which is not necessary in order for the machinery to function, or for which normal components may be substituted in order for the machinery to function." Such equipment requires both a Declaration of Conformity and a CE mark for conformity to Directive 2006/42/EC.

EU Directives and Norms can be accessed at the following link:
Europa.eu/enterprise/newapproach/standardization/harmstds

The above site gives access to all European Directives and the appropriate standards according to each manufacturer's specific products.

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CHAPTER

2 Theory

2.1 Introduction

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

- The Perfect Harmony™ series drives do not inject significant harmonic distortion into the plant's distribution system. Power filters are not required. Interference to sensitive equipment or resonance problems with power factor capacitors will not occur.
- The Perfect Harmony™ series drives present a high power factor to the utility at typically 95% or better throughout the speed range. No power factor correction is required.
- The Perfect Harmony™ series drives do not require any derating of the motor due to output harmonics. Additional motor heating is not produced, versus operation directly from the utility.
- The Perfect Harmony™ series drives, when set up properly, do not produce torque pulsations that can excite mechanical resonance.
- The Perfect Harmony™ series drives do not cause a noticeable increase in acoustic noise from the motor, versus operation directly from the utility.
- The Perfect Harmony™ series drives do not cause an appreciable additional stress to the motor insulation, versus operation directly from the utility.
- The Perfect Harmony™ series drives allow unrestricted use of rated motor torque throughout the speed range, subject only to the thermal limitations of the motor.
- The Perfect Harmony™ series drives are virtually silent in operation, if liquid-cooled, so that normal conversation is possible next to drives running at full power.
- The Perfect Harmony™ series drives are completely modular in construction, so that if necessary, a defective module can be replaced in minutes. Sophisticated microprocessor-based diagnostics pinpoint the location of any defects.

2.2 The Power Circuitry

Note: The examples used in this section refer to drives having 690V cells. High voltage cell systems (1375V), GenIV and Water Cooled III cell systems (750V), and GenIII cell systems (630V) will have different values.

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

Figure "Typology of Perfect Harmony™ VFD (3 Cells per Phase)" shows a typical power circuit topology for a 3685-volt Perfect Harmony™ series drive using 690 VAC cells. Each motor phase is driven by 3 power cells connected in series. The groups of power cells are wye-connected with a floating neutral. Each cell is powered by an isolated secondary winding of an integral isolation transformer. The 9 secondaries are each rated for 690 VAC at one-ninth of the total power. The power cells and their secondaries are insulated from each other and from ground for full output voltage rating.

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

Each cell is a static power converter. It is capable of receiving input power at 690 VAC 3-phase, 50/60 Hz and delivering that power to a single-phase load at any voltage up to 690 VAC and at any frequency up to the rated maximum frequency defined in Chapter 3.

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

With 3 690 VAC power cells in series per phase, a Perfect Harmony™ series drive can produce as much as 2127 VAC line-to-neutral or a maximum VAVAILABLE of 3685 volts.

It should be noted that it is possible to connect as many as 8 power cells in series using the Perfect Harmony™ Control. VAVAILABLE determines the maximum voltage that can be delivered from the VFD output. The actual voltage delivered is fully adjustable. As the Perfect Harmony™ VFD topology is based on multi-level output capabilities, the result is true adjusted voltage. The advantages of utilizing the VAVAILABLE capability of the VFD become apparent when the patented advanced cell bypass option is applied for high availability or redundant applications.

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

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

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

The schematic of a typical power cell is shown in Figure “Schematic of a Typical Power Cell.” In this example, a 3-phase diode rectifier, fed by the 690 VAC secondary, charges a DC capacitor bank to about 931 VDC. The DC voltage feeds a single-phase H-bridge of Insulated Gate Bipolar Transistors (IGBT).

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

With 3 power cells per phase, the circuit can produce 7 distinct line-to-neutral voltage levels (±2793, ±1862, ±931, or 0 volts). With N cells per phase, (N*2)+1 distinct voltage levels are available, where N is a maximum of 8. The ability to generate many different voltage levels allows the Perfect Harmony™ series drives to produce a very accurate approximation to a sinusoidal output waveform.

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

Phase shift between carriers in each phase is computed based on the following equation:

Carrier phase shift (same phase) = 180 degrees / # cells per phase

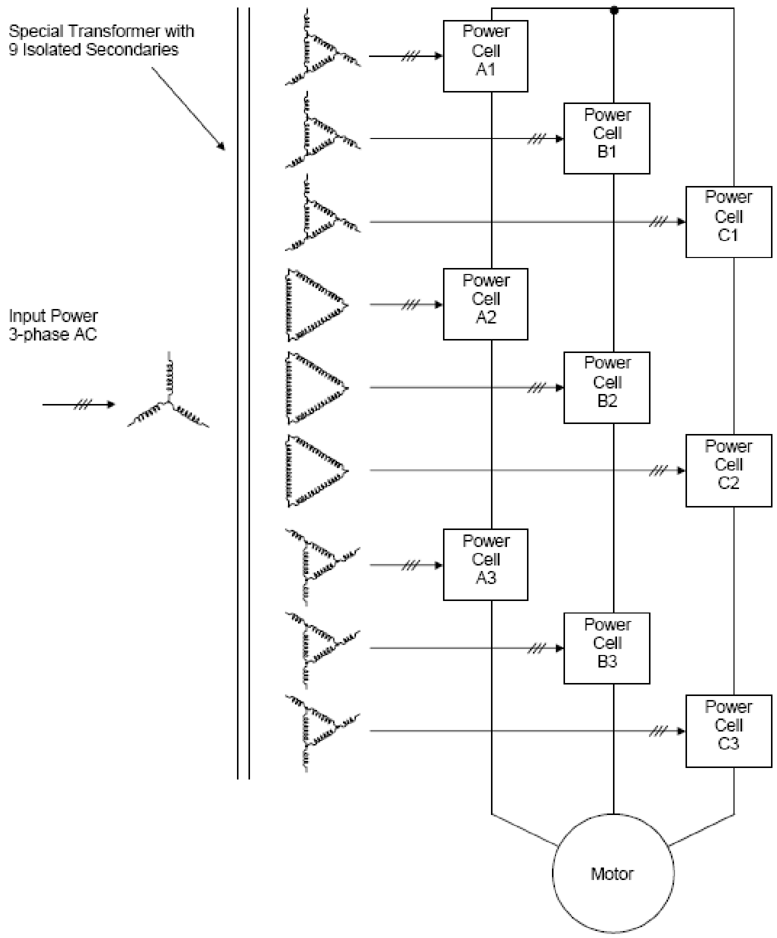

Figure 2-1: Topology of Perfect Harmony™ VFD (3 Cells Per Phase)

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

The difference between **L1** and **R1** gives the output waveform of cell **A1**, shown in Figure “Waveforms for Phase A” for Phase A as **A1**.

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

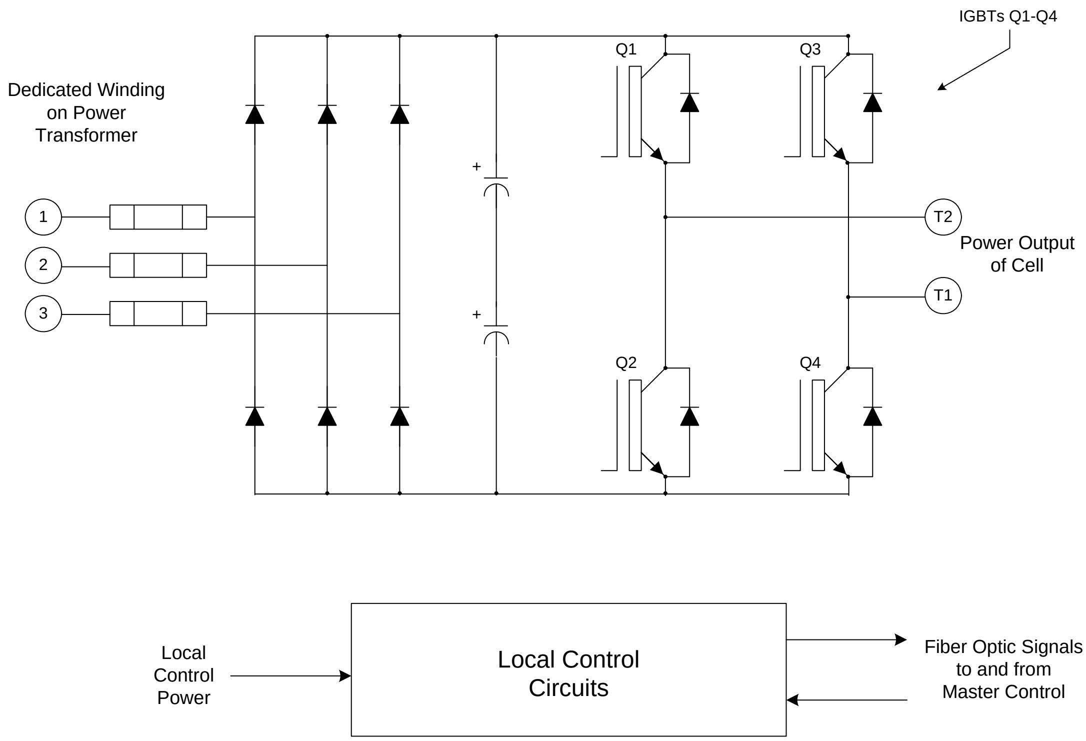

Figure 2-2: Schematic of a Typical Power Cell

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

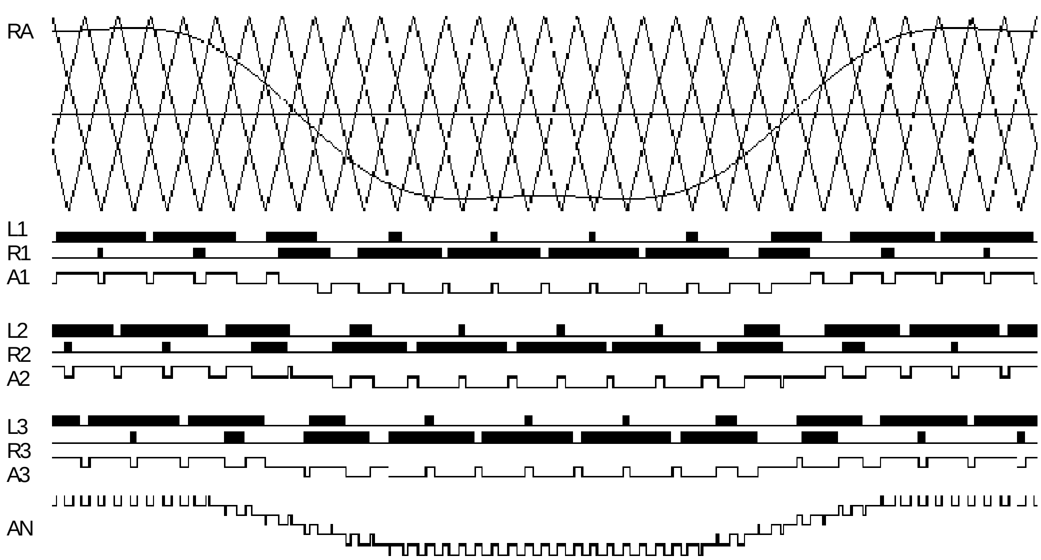

Figure 2-3: Waveforms for Phase A

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

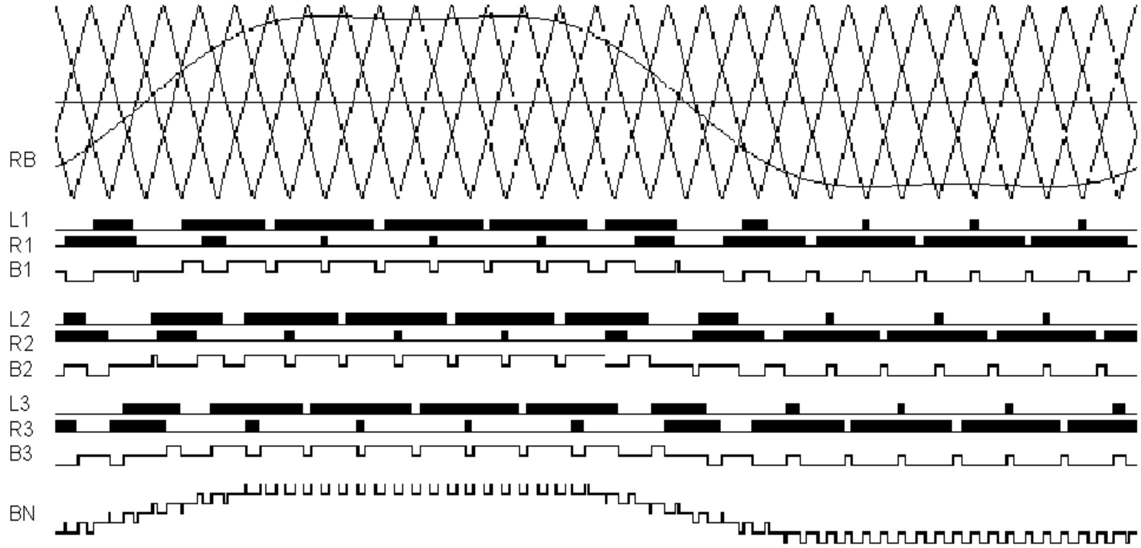

Figure 2-4: Waveforms for Phase B

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

The sum of the output voltages from cells **B1**, **B2,** and **B3** produces the B-to-neutral output voltage of the drive, as shown in Figure “Waveforms for Phase B” as **BN**.

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

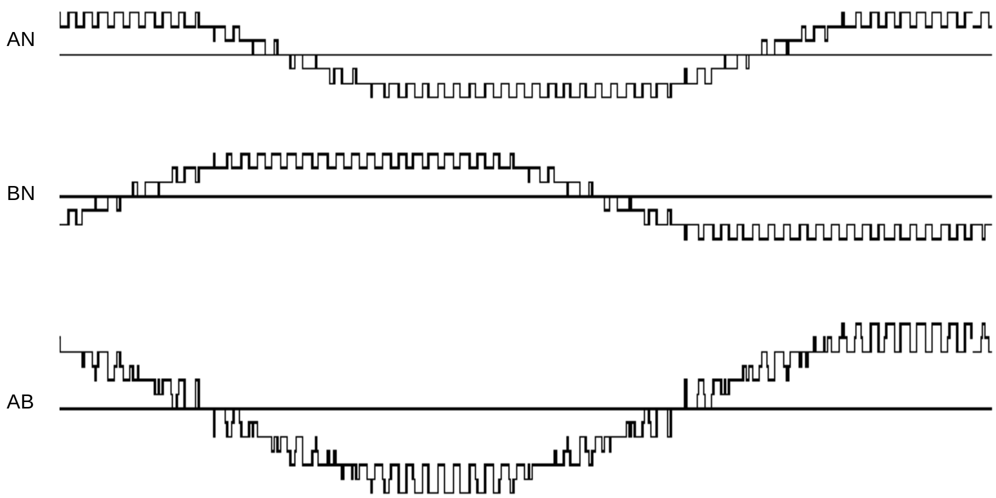

Figure 2-5: Waveforms for Line-to-Line Voltage

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

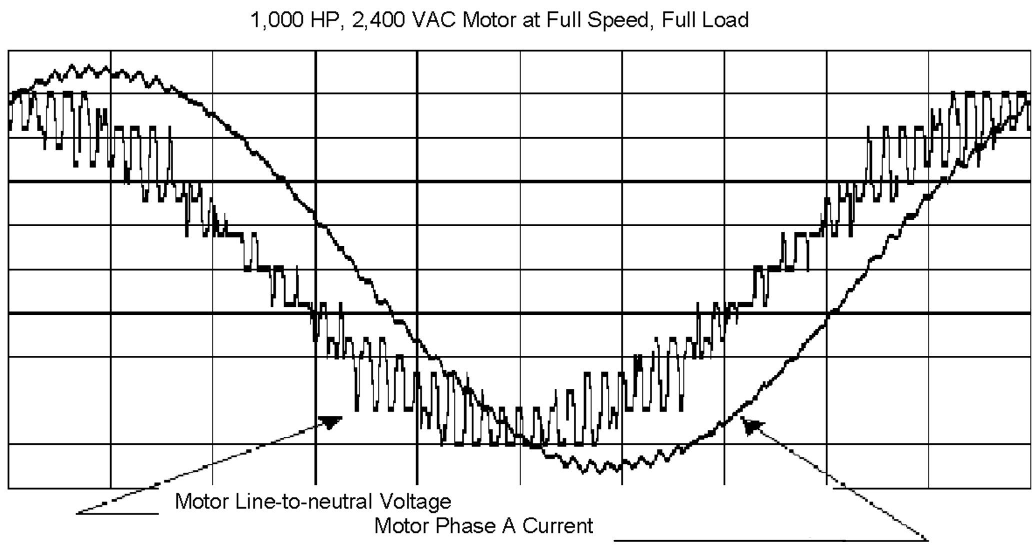

Figure 2-6: Perfect Harmony™ Output Waveforms, 2400 Volt Drive at Full Load

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

Figure “Perfect Harmony™ Input Waveforms for a Drive at Full Load” shows the input voltage and current waveforms for the same drive as shown in Figure “Perfect Harmony™ Output Waveforms, 2400 Volt Drive at Full Load” under the same conditions. The perfect sine wave in Figure “Perfect Harmony™ Input Waveforms for a Drive at Full Load” is the voltage into the special input transformer, measured between Phase A and the neutral of the wye-connected primary. The other waveform is the current into Phase A of the same winding.

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

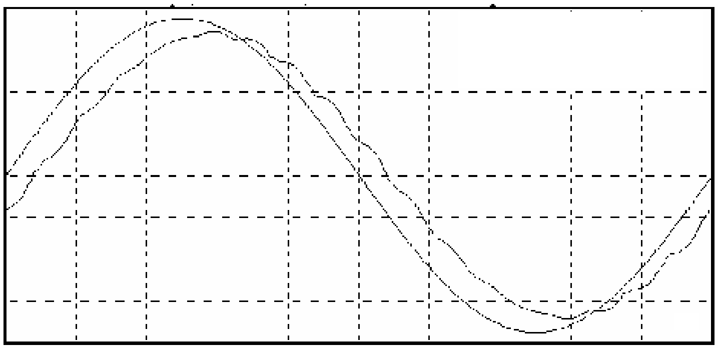

Figure 2-7: Perfect Harmony™ Input Waveforms for a Drive at Full Load

Note in Figure "Perfect Harmony™ Input Waveforms for a Drive at Full Load" that the input current lags behind the input voltage by less than 15 degrees at full load. This represents a power factor better than 96%. Perfect Harmony™ series drives always maintain a high power factor at typically better than 95% throughout the speed and load range.

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

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

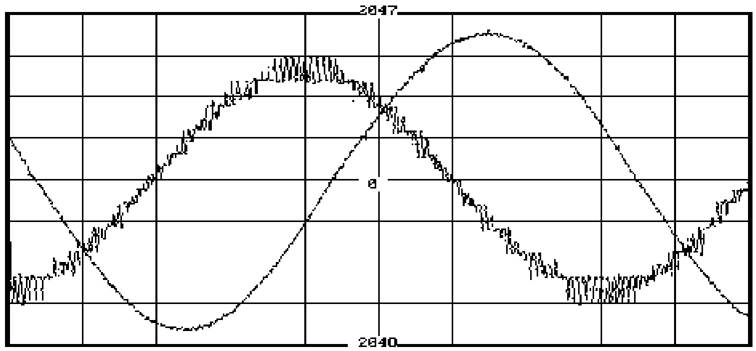

Figure 2-8: Motor A-B Voltage and Current in Phase C at Full Load for a Perfect Harmony™ Drive

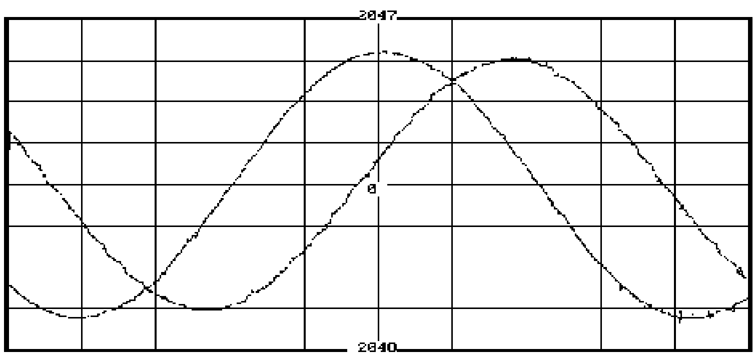

Figure 2-9: Input A-B Voltage and Current in Phase C at Full Load for a Perfect Harmony™ Drive

2.3 The Control System

The block diagram in Figure “Block Diagram of Perfect Harmony™ Control Structure” shows the implementation of the Perfect Harmony™ Control System. The Control System consists of the following functional blocks: signal interface and conditioning, an A/D converter, a processor, a digital modulator, and fiber optic interfaces.

The signal interface processes the feedback signals collected from the drive. These circuits scale and filter the feedback signals before passing them along to the A/D converter. Provisions are included to interface to an E-Stop signal.

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

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

The processor performs all of the functions for motor control and generates 3-phase voltage commands for the digital modulator. In addition, it monitors the input voltages and currents to provide metering functions (for example, power factor, input power, and harmonic calculation), input protection (for example, excessive losses, excessive reactive current, under-voltage, and single-phasing), and input voltage magnitude, frequency, and phase angle for synchronous transfer.

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

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

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

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

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

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

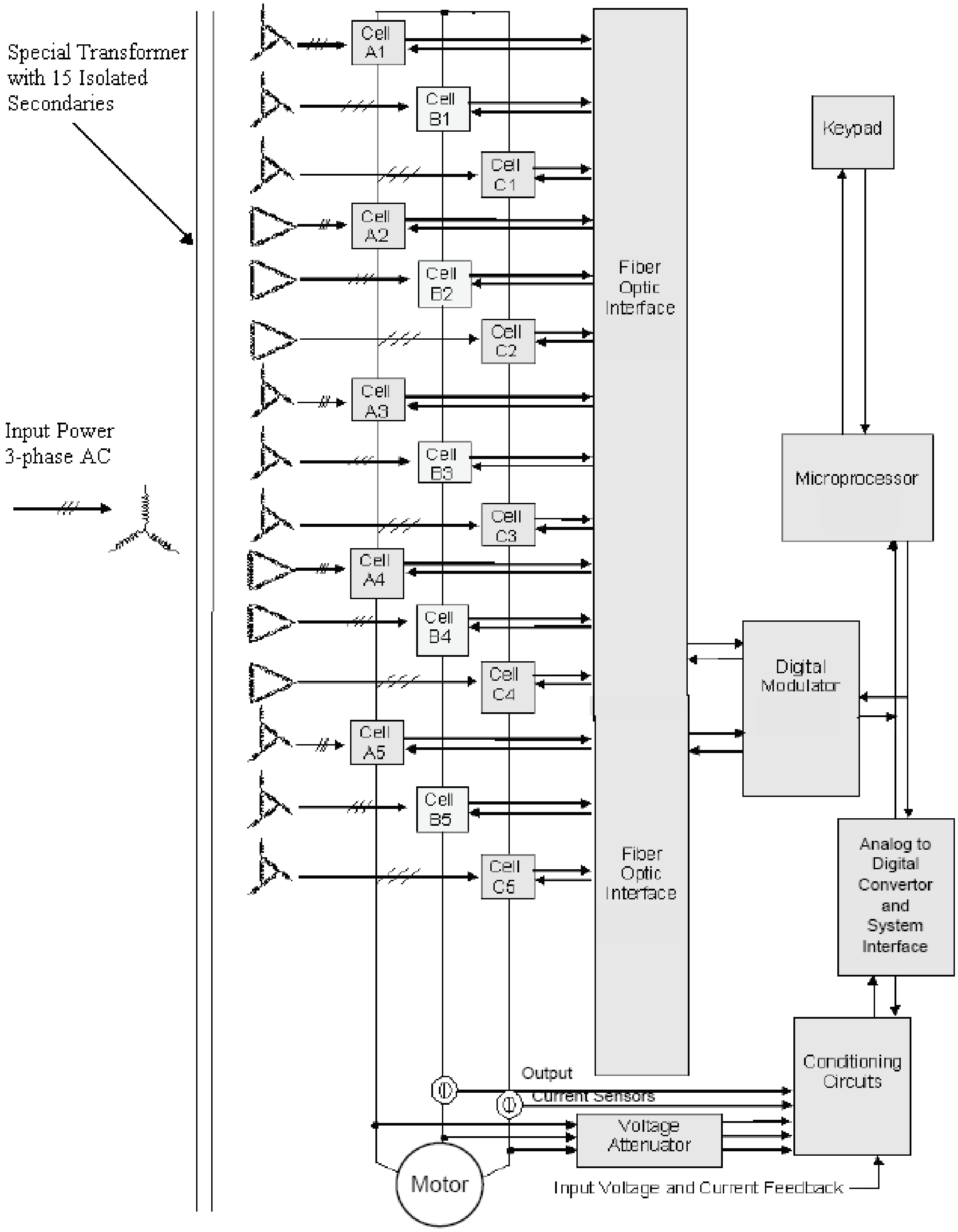

Figure 2-10: Block Diagram of Perfect Harmony™ Control Structure

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CHAPTER

3 GenIII Technical Specifications

3.1 GenIII Technical Specifications

Table 3-1: GenIII Perfect Harmony Specifications

Parameter	Rating
Input Line Voltages	2400 to 13800V; 3-phase; +10%, -5%
Input Frequency	50 or 60 Hz ± 5%
Input Power Factor	>0.95 above 10% load
Input Current Harmonics	≤ 5% Total Demand Distortion (Meets TDD requirements from IEEE 519)
Output Power	300 to 3500 Hp (0.22 to 2.6 MW)
Output Voltage	0 to 6728V RMS
Output Frequency & Drift	0.5 to 330 Hz ± 0.5% (motor dependent)
Harmonic Voltage Factor	< 0.03
Output Torque	10 to 167 Hz rated torque (2 quadrant)
Acceleration/Deceleration Time Range	0.5 to 3200 seconds (load dependent)
Cell Frame Sizes	70, 100, 140, 200, and 260 Amp
Overload Capability	Refer to Section “Power Cell Specifications”
Efficiency	Transformer 98.5%, Converter 99.0%, Total VFD > 96.5%
Enclosure Type	NEMA 1 ventilated
Enclosure Degree of Protection	IP 21 standard IP 42 optional
Ambient Temperature	0 to 40°C; (maximum 50°C; derate starts from 40°C on)
Altitude	Up to 3300 feet. Above 3300 feet requires derating.
Cooling	Ventilated, forced air-cooled with integrated fans
Dust Contamination	See Appendix A for more information
Gas Contamination	See Appendix A for more information

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3.2 General Ambient Conditions for Storage, Transport, and Operation

Table 3-2: General Ambient Conditions Table

General Ambient Conditions			
	Storage	**Transport**	**Operation**
Climatic Ambient Conditions			
Ambient temperature	+5°C to +40°C	–25°C to +60°C	+5°C to +40°C
Relative air humidity	< 95**%** (converter must be completely dry before com-missioning)	< 95**%** (converter must be completely dry before com-missioning)	< 95**%** (condensation not permitted)
Other climatic conditions in accordance with class	1K3, 1Z2 in accordance with IEC 60721-3-1	2K2 in accordance with IEC 60721-3-2	3K3 in accordance with IEC 60721-3-3
Degree of pollution	2 without conductive pollution in accordance with IEC 61800-5	2 without conductive pollution in accordance. with IEC 61800-5	2 without conductive pollution in accordance with IEC 61800-5
Mechanical Ambient Conditions			
Stationary vibration, sinusoidal			
Displacement	1,5 mm (2 to 9 Hz)	3,5 mm (2 to 9 Hz)	0,3 mm (2 to 9 Hz)
Acceleration	5 m/s2 (9 to 200 Hz)	10 m/s2 (9 to 200 Hz) 15 m/s2 (200 to 500 Hz)	1 m/s2 (9 to 200 Hz)
Other mechanical conditions in accordance with class	1M2 in accordance with IEC 60721-3-1	2M1 in accordance with IEC 60721-3-2	3M1 in accordance with IEC 60721-3-3
Other Ambient Conditions			
Biological ambient conditions in accordance with class	1B1 in accordance with IEC 60721-3-1	2B1 in accordance with IEC 60721-3-2	3B1 in accordance with IEC 60721-3-3
Chemical active substances in accordance with class	1C1 in accordance with IEC 60721-3-1	2C1 in accordance with IEC 60721-3-2	3C1 in accordance with IEC 60721-3-3
Mechanical active substances in accordance with class	1S1 in accordance with IEC 60721-3-1	2S1 in accordance with IEC 60721-3-2	3S1 (standard) in accordance with IEC 60721-3-3 with addition of sand con-tent of 0.01 mg / m “ 3

3.3 Power Cell Specifications

Table 3-3: Power Cell Specifications

Power Cell Specifications	70A	100A	140A	200A	260A
Input Voltage	630V ± 10%, 3-phase, 50 or 60 Hz				
Input Current	48A	69A	96A	137A	179A
Cell Efficiency	98.8%				
Overload Capabilities	No overload capability has been built into these cells; therefore, rated cell current will correspond to the torque limit set for the application.				
Electrical Connections	Front access connection via power plugs.				
Storage Temperature	-13°F (-25°C) to 104°F (40°C)				
Forced Air Cooling	>180 CFM	>180 CFM	>180 CFM	>300 CFM	>300 CFM
Dimensions and Weights	**70A**	**100A**	**140A**	**200A**	**260A**
Power Cell Height	19.33 inches 490.98 mm	19.33 inches 490.98 mm	19.85 inches 504.19 mm	21.37 inches 542.80 mm	12.37 inches 542.80 mm
Power Cell Width	8.91 inches 226.19 mm	8.91 inches 226.19 mm	8.90 inches 226.06 mm	12.11 inches 307.62 mm	12.11 inches 307.62 mm
Power Cell Depth	16.15 inches 410.21 mm	16.15 inches 410.21 mm	16.15 inches 410.21 mm	17.71 inches 449.78 mm	17.71 inches 449.78 mm
Power Cell Weight	57.43 lbs 26.05 kg	63.80 lbs 28.94 kg	70.20 lbs 31.84 kg	118.39 lbs 53.70 kg	128.31 lbs 58.20 kg

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Power Cell Output Current Rating Deration

Power Cell Output Current Rating Deration for Drive Maximum Output Frequency (f_o)

- If $330 \geq f_o \geq 10$ Hz → Cell Output Current Rating = I_o (from Table 3-3)
- If $0.5 \leq f_o < 10$ Hz → Cell Output Current Rating = I_o x [0.5 + (f_o / 20)]

Power Cell Output Current Rating Deration for Cell Carrier Frequency (f_c)

- f_c can be assigned any value from 300 to 1200 Hz provided [f_c > (3.6 x f_o) Hz]
- For (f_o < 167 Hz), the default value (f_c = 600 Hz) is typically adequate.
  A smaller value of f_c can be chosen provided [300 Hz < f_c > (3.6 x f_o) Hz]
- For (f_o = 167 Hz → 330 Hz), select carrier using [1200 Hz > f_c > (3.6 x f_o) Hz]
- If $300 \leq f_c \leq 600$ Hz → Cell Output Current Rating = I_o (from Table 3-3)
- If $600 < f_c \leq 1200$ Hz → Cell Output Current Rating = I_o x {1 - {[(f_c - 600) / 600] x 0.20}}

Power Cell Output Current Rating Deration for Drive Altitude Above Mean Sea Level

- If Altitude ≤ 3300 feet (1006 meters) → Cell Output Current Rating = I_o (from Table 3-3)
- If 3300 feet (1006 meters) < Altitude ≤ 20000 feet (6096 meters) →
  Cell Output Current Rating = I_o x { 1 - { [0.5 x (Alt - 3300)] / 20000 }} — Altitude in feet
  Cell Output Current Rating = I_o x { 1 - { [0.5 x (Alt - 1006)] / 6096 }} — Altitude in meters

Power Cell Output Current Rating Deration for Drive Maximum Ambient Temperature

- If Ambient Temperature ≤ 104°F (40°C) → Cell Output Current Rating = I_o (from Table 3-3)
- If 104°F (40°C) < Ambient Temperature ≤ 122°F (50°C) →
  Cell Output Current Rating = I_o x ((60°C - Tambient) / 20°C)^0.67 — Ambient Temperature in °C
  Cell Output Current Rating = I_o x ((140°F - Tambient) / 36°F)^0.67 — Ambient Temperature in °F

3.4 System Air Flow Requirements

Table 3-4: Air Flow Requirements

System Air Flow Requirements		70A	100A	140A	200A	260A
Cooling Air Requirement	m^3/s	2.08	2.08	2.08	4.15	4.15
	CFM	4400	4400	4400	8800	8800

3.5 System Dimensions and Weights

Table 3-5: Cabinet Dimensions and Weight

# of Cells	Trans. rating (kVA)	Input Volt.	Transformer Cabinet			Output Curr.	Cell Dimensions			System Weight lbs kg
			Length in. mm	Height in. mm	Depth in. mm		Length mm in.	Height mm in.	Depth mm in.	
9	0 to 600	0 to 4160	46 1168.4	91.5* 2324.1*	42	70, 100, 140	54 1371.6	91.5* 2324.1*	42 1066.8	7500 3402
		4800 to 13800	60** 1524	91.5* 2324.1*	42		77 1955.8	91.5* 2324.1*	42 1066.8	
	1000 to 1750	4800 to 13800	60 1524	91.5 2324.1	42	200, 260	77 1955.8	91.5 2324.1	42 1066.8	9000 4082
12	0 to 560	0 to 4160	46 1168.4	91.5 2324.1	42	70, 100, 140	54 1371.6	91.5 2324.1	42 1066.8	7700 3493
		4160 to 13800	60** 1524	91.5 2324.1	42	200, 260	77 1955.8	91.5* 2324.1*	42 1066.8	11000 4990
	640 to 1000	4160 to 13800	60 1524	91.5 2324.1	42	70, 100, 140	77 1955.8	91.5* 2324.1*	42 1066.8	11000 4990
	1120 to 2250		80*** 2032	91.5 2324.1	42	200, 260	112 2844.8	91.5* 2324.1*	42 1066.8	14000 6350
15, 18	0 to 1250	0 to 4160	60 1524	91.5* 2324.1*	42	70, 100, 140	77 1955.8	91.5* 2324.1*	42 1066.8	13200 5988
		4160 to 13800	80 2032	91.5* 2324.1	48	200, 260	112 2844.8	91.5* 2324.1*	42 1066.8	
	1500 to 3500	4800 to 13800	60 120	91.5* 2324.1*	42	70, 100, 140	77 1955.8	91.5* 2324.1*	48 1219.2	17800 8074
			80*** 128	91.5* 2324.1*	48	200, 260	112 2844.8	91.5* 2324.1*	48 1219.2	

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# of Cells	Trans. rating (kVA)	Input Volt.	Transformer Cabinet			Output Curr.	Cell Dimensions			System Weight lbs kg
			Length in. mm	Height in. mm	Depth in. mm		Length mm in.	Height mm in.	Depth mm in.	

*Cabinet height without blowers Blower heights listed below:

Single Blower (for transformer) = 12.62 in., 447.55 mm

Single Blower (for cell cabinet) = 23.38 in., 593.85 mm

Redundant Blower: 25.32 in., 643.13 mm

Dual Blowers (double) = 25.32 in., 643.13 mm

**Only if redundant blower is required.

***An 80-inch cabinet is needed if input voltage exceeds 9900V.

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CHAPTER

4 Product Description

4.1 Description of Drive Family

GenIIIe is the third generation of forced air-cooled medium voltage Pulse Width Modulated Variable Frequency Motor Drives, offered in the patented Perfect Harmony power topology in concert with proprietary NXGII hardware control platform and embedded Eagle software. GenIIIe is an extension of the GenIII series offering a higher current rating.

The GenIIIe is a series of adjustable speed AC motor drives presently available in an output voltage range from 2.3kV to 7.2kV, and loads ranging from 2000 - 9000 Hp. Five power cell amperage types are available: 315, 375, 500, 660 and 720 A.

4.2 Cabinet Description

Figure 4-1 depicts a typical GenIIIe Perfect Harmony Drive configuration consisting of a Transformer Cabinet and a Cell/Control Cabinet.

The GenIIIe Drive is usually shipped so that the Transformer and Cell Cabinets are separated. In these systems, the Output section is located on the left side of the Cell Cabinet (behind the Control Panel) and the Input Section is located in the Transformer Cabinet. The Control Section is a swinging panel located in the left side of the Cell Cabinet.

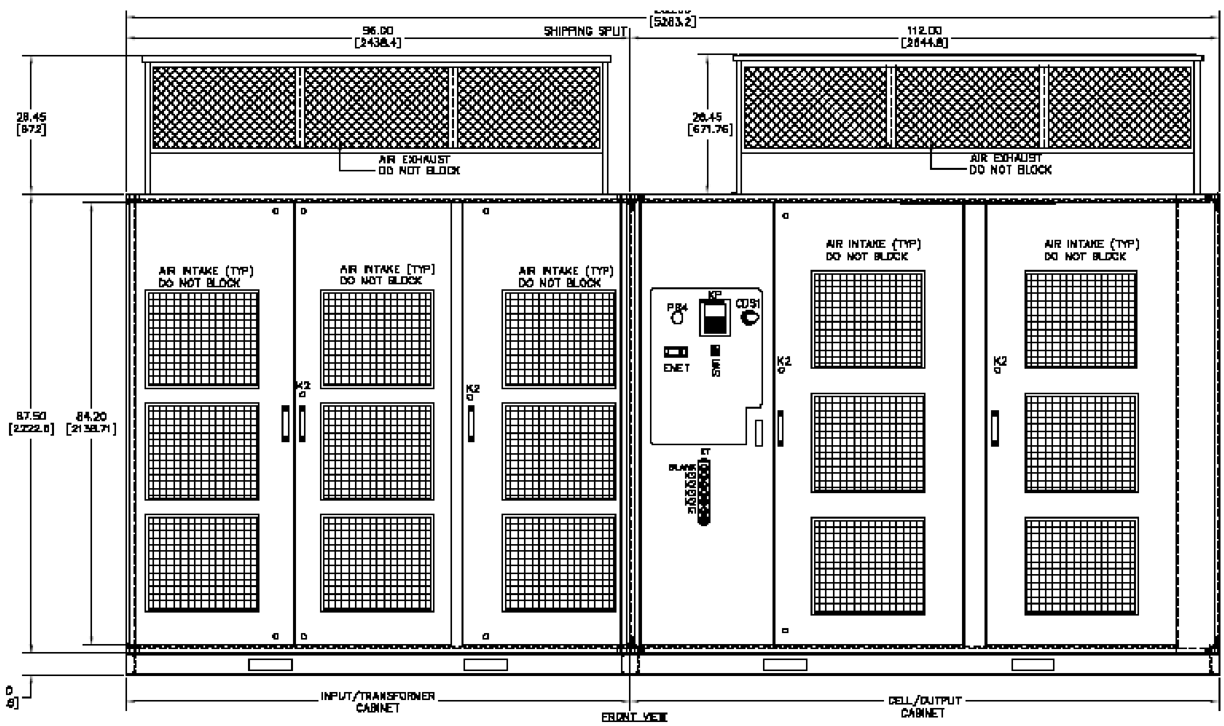

Figure 4-1: GenIIIe Typical Layout

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4.2.1 Input/Transformer Cabinet

The standard Input/Transformer Cabinet is NEMA 1 Ventilated (IP 21 degree of protection) and is provided with top and bottom cable access plates. The doors are hinged and mechanical key interlock provisions are provided. This cabinet has two sections; the Transformer Section and the Input Section. Figure 4-2 shows the major components of the Input/Transformer Section.

The Transformer Section houses the following standard components:

- Perfect Harmony multi-winding power transformer. The transformer is a dry type forced air cooled unit, and poly-glass air baffles are used to direct air movement across the coils. The transformer is wound with 180° or 220°C winding insulation and the BIL level depends on the input voltage rating. The transformer primary and secondary windings are built using copper or aluminum. The ratings of this transformer vary, based upon individual customer input supply frequency and voltage, drive power cell redundancy requirements, and motor requirements. The transformer is optionally available with an electrostatic shield and/or primary distribution class surge arresters.
- Blowers to remove heat rejected within the cabinet by the transformer and associated power cable.

The Input Power Section contains the following standard components:

- Customer input medium voltage line terminals (L1, L2, L3).
- Input line current transformers (CT1, CT2), which provide scaled analog current signals to NXGII Control and optional input power quality meter.
- Input line voltage attenuator resistors (RA1, RA2, RB1, RB2, RC1, RC2) which provide scaled analog voltage signals to NXGII Control.

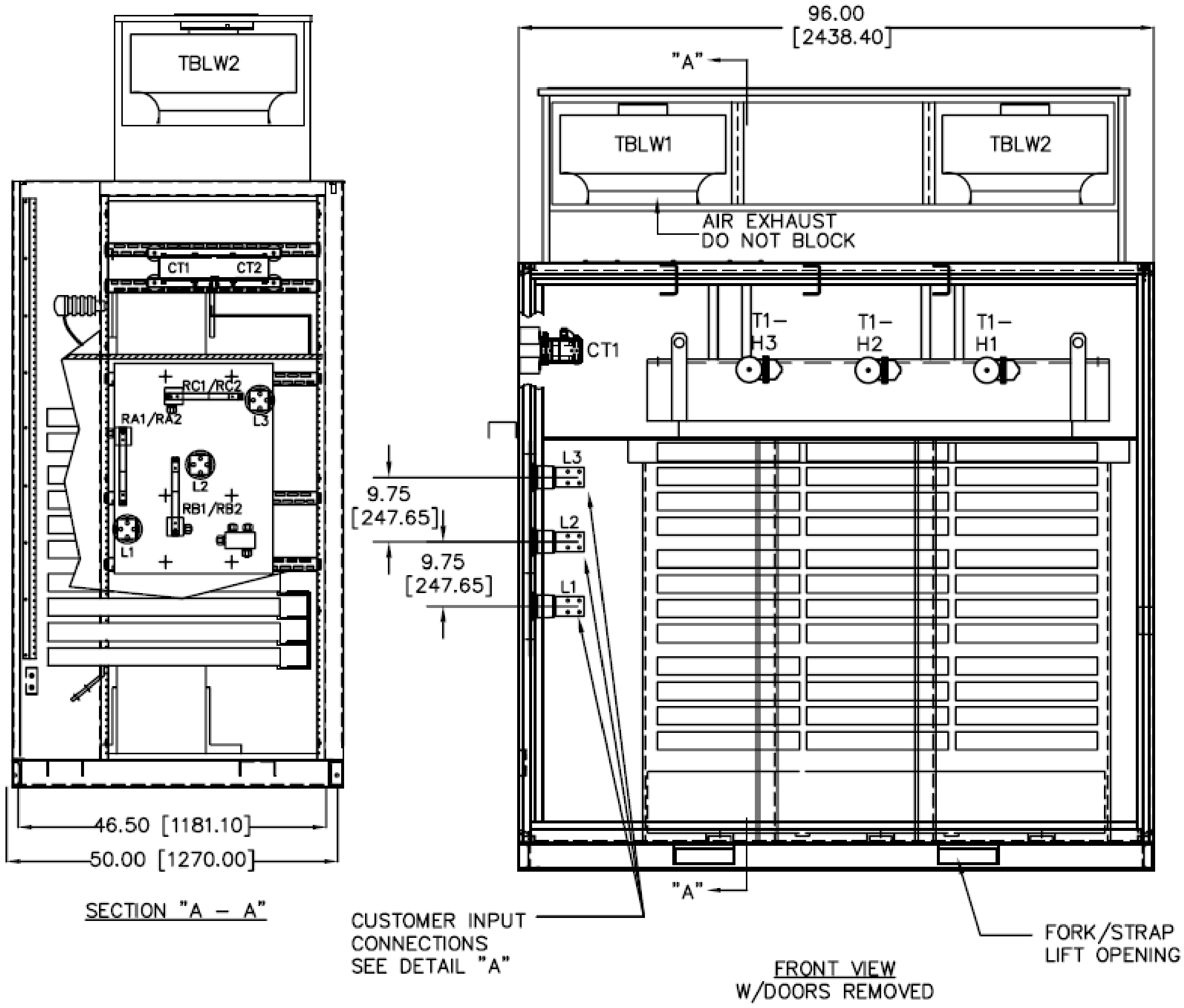

Figure 4-2: Typical GenIIIe Input/Transformer Cabinet (Width 96”, Height 118”, Depth 50.0")

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4.2.2 Cell/Output Cabinet

The standard Cell/Output Cabinet is NEMA 1 Ventilated (IP 21 degree of protection) and is provided with top and bottom cable access plates. The doors are hinged and mechanical key interlock provisions are provided. This cabinet has three sections; the Cell Section, the Control Section and the Output Section. Figure 4-3 shows the major components of the Cell/Output Section.

The Cell Section houses the following standard components:

- Power cells A1/ B1/ C1 … A6/ B6/ C6. The total number of power cells varies based upon individual customer cell redundancy and motor requirements.
- Cell Cabinet cooling blowers BLWR1, BLWR2, BLWR3, and BLWR4. The total number of these blowers varies, based on the total number of power cells.
- Blowers to remove heat rejected within the cabinet by the cells and associated power bus.

The Cell Section houses the following optional components:

- Power cell bypass contactors BPKA1/ BPKB1/ BPKC1 … BPKA6/ BPKB6/ BPKC6. There is one bypass contactor for each power cell.
- Bypass Control Circuit (BCC) and Bypass Power Supply (BPPS) providing control interface for optional power cell bypass.

The Control Section houses the following standard components:

- The following standard components are mounted on the front cover:
  - o NXGII Control HMI keypad.
  - o Emergency Stop pushbutton.
  - o Speed Demand Mode selector switch [Local-Remote or Off-Local-Remote].
  - o RJ45 Ethernet port [temporary connection for walk-up communication with drive via Ethernet Modbus™ or Siemens LDA ToolSuite].
- The following optional components are mounted on the front cover:
  - o GE Multilin 469 motor protection relay.
- The following standard components are mounted inside the Control Section:
  - o Circuit breaker CB1, CB2, which sources customer-supplied single phase 120 VAC control power.
  - o Customer control signal terminal strips TB2 and TB2ELV.
  - o NXGII Digital Card Rack (DCR) which contains the following:
    - Slot 1: Keypad Interface Board
    - Slot 2: Single Board Computer
    - Slot 3: BGA Modulator with 12 Fiber Optic Ports
    - Slot 4: Reserved
    - Slot 5: Analog I/O Cable Assembly
    - Slot 6: System I/O Board
    - Slot 7: Digital I/O Cable Assembly
    - Slot 8: Communications Board
  - o NXGII Control Power Supply (CPS).

o NXGII Signal Conditioning Board (SCB).

o NXGII I/O Breakout Board (IOB), which provides interface for critical customer remote hardwired analog and digital control signals via terminal strips TB2 and TB2ELV.

o Latch Fault relay (LFR) to lock-out drive in IDLE state if a medium voltage power circuit fault occurs within the drive.

o Key Reset (KR) switch resets drive to resume operation after fault has been cleared.

o Auxiliary Voltage Control Transformer (T5)

o Blower Circuit Breaker (TBM1,TBM2, TBM3, CBM1,CBM2, CBM3)

o Wago 750 Series Fieldbus. Provides interface for non-critical customer remote hardwired analog and digital control signals via terminal strips TB2 and TB2ELV.

o Fuses, control power fuses, blower fuses.

o Control disconnect switch (CDS1)

o Network switch (NSW)

o EMC Filter for Auxiliary Control Voltage (FLTR1, FLTR2) optional

o Encoder Power Supply (EPS) optional

o Voltage Monitoring Relay (VMR)

The Output Section houses the following standard components:

- Customer output medium voltage line terminals T1, T2, T3.
- Output line voltage attenuator resistors (RA3, RA4, RB3, RB4, RC3, RC4) which provide scaled analog voltage signals to NXGII Control.
- Output line Hall Effect current transducers (HEB, HEBC), which provide scaled analog current signals to NXGII Control. In some units Hall Effect current transducers can be located in the cell section.
- Power cell input line fuses.

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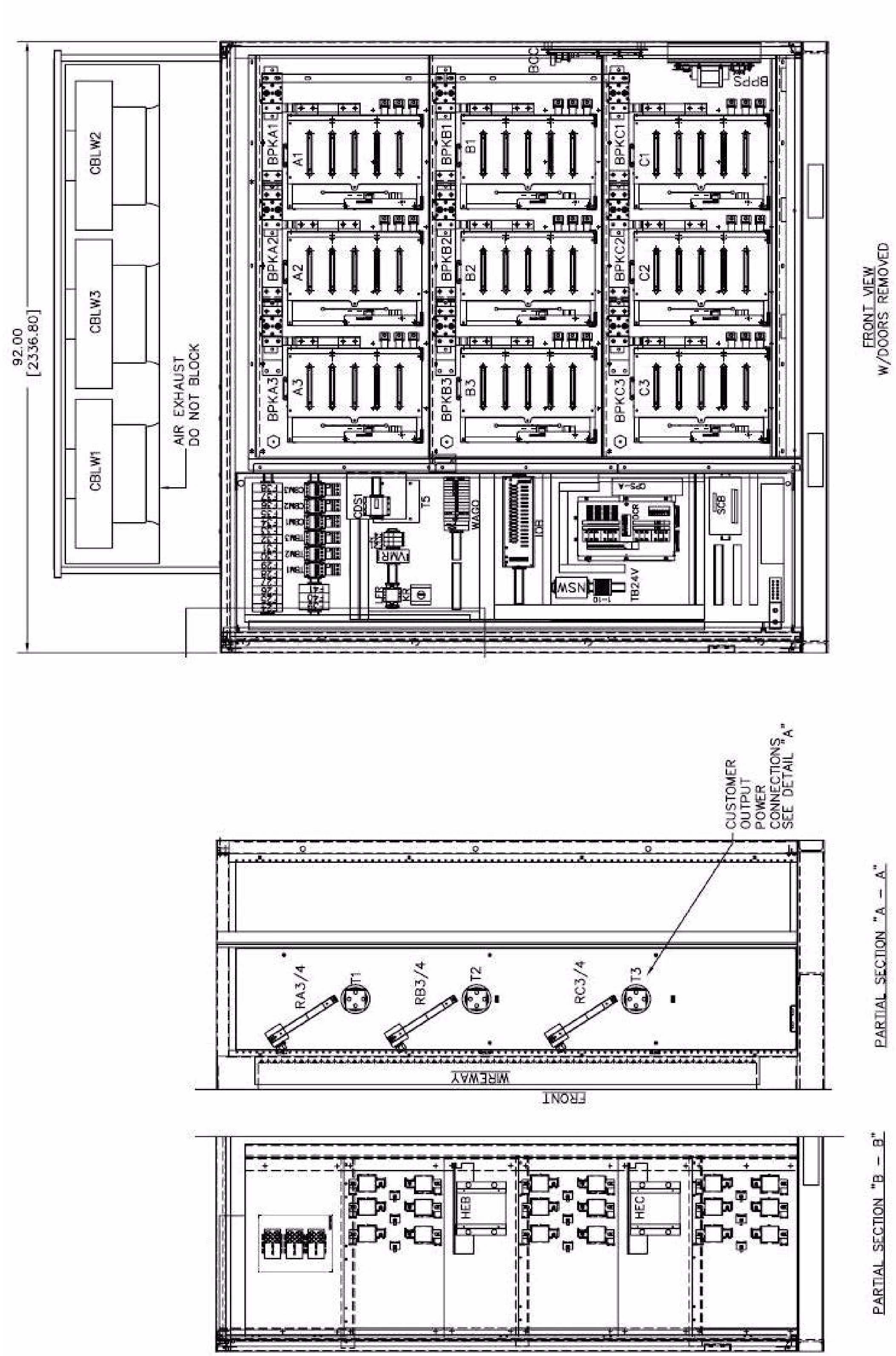

Figure 4-3: Typical GenIIIe Input/Transformer Cabinet (Width 92”, Height 118”, Depth 50.0")

4.3 Coordinated Input Protection Scheme

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

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

Danger!

This contact MUST be integrated with input switchgear to deactivate the drive input medium voltage upon the rare event of a secondary circuit fault.

This scheme is active on all GenIIIe drives. Therefore, a medium voltage input circuit breaking device is required. The Drive Control continuously meters the input power, and if the drive exhibits excessive losses or reactive power, then a dedicated NXGII I/O digital output (IDO-15) is closed as a one-shot pulse latches the LFR coil. This causes the normally-closed LFR contact to OPEN, and the NXGII I/O digital output IDO-14 also opens.

As shown in Figure 4-4, if the contacts looking into the drive are closed, the user is permitted to close the incoming breaker, hence the signal name “MV IP Breaker Enable”. However, if the contacts are open, then the input breaker must also be immediately opened.

To reset the protection scheme, the LFR must be reset using KR (located in the Control Tub), which immediately recloses the normally-closed LFR contacts, and then a Drive Fault Reset must be initiated (NXGII Control will not re-close IDO-14 if the FAULT conditions still exist).

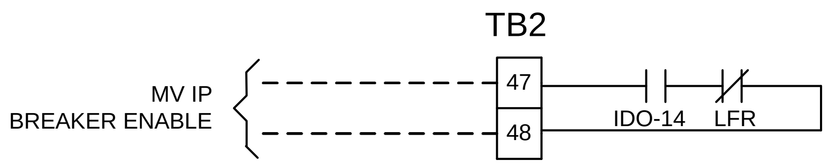

Figure 4-4: Input Protection Scheme

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CHAPTER

5 Application Specific Features

5.1 Control Mode Summary

The NXGII Control provides 6 control modes for the Perfect Harmony™ drive family. These modes are described as follows:

- CLVC (Closed Loop Vector Control) CLVC provides flux vector control for an induction machine utilizing an encoder for speed feedback.
- CSMC (Closed Loop Synchronous Machine Control) CSMC is a flux vector control for a synchronous machine utilizing an encoder for speed feedback and providing a field excitation command for use by an external field exciter.
- OLTM (Open Loop Test Mode) OLTM is intended for running the drive with no load attached to permit verifying the output voltage waveforms.

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

- OLVC (Open Loop Vector Control, also known as Encoderless Vector Control) OLVC is a flux vector control for induction machines that computes the rotational speed of the rotor based on measured output currents from the drive and uses this computed speed as the speed feedback.
- SMC (Synchronous Motor Control) SMC computes the rotational speed similarly to OLVC and controls the field reference or the synchronous motor as in CSMC. The field reference is controlled to achieve unity power factor.
- V/Hz (Volts per Hertz Control) V/Hz is intended to be used when multiple induction motors are connected in parallel to the output of the drive. V/Hz operates similarly to OLVC with de-tuned current regulators.

Note: Spinning load and fast bypass are not available in V/Hz control mode**.**

5.2 Control Loops

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

5.2.1 Current Loop

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

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

5.2.2 Speed Loop

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

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

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

5.2.3 Flux Loop

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

5.3 System Program

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

> **Note:** Internal drive-generated faults defined for drive protection cannot be modified by the System Operating Program (SOP).

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

5.4 Speed Droop

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

However, in some applications, droop is needed. For example, in a multiple motor application, such as 2 motors mechanically connected to a common load, there are inherent differences between the motors. In the case of a torque current increase, these differences may allow one motor to attempt to run faster, causing that motor to bear a greater portion of the load.

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

5.5 Long Cable Applications

When a step of voltage from a drive is applied to one end of a transmission line, it causes a traveling wave to be propagated toward the opposite (or motor) end of the transmission line. When the traveling wave reaches the motor end of the cable, the motor leakage reactance is so high that the line behaves as if it were open-circuited. A reflection wave begins to travel back toward the drive end. The total voltage at any point is the sum of all waves present, in this case the forward wave and the reflected wave. The reflection at an open circuit is such that the reflected voltage wave has the same polarity as the forward voltage wave. At the motor end, the reflected wave appears at the same instant as the forward wave arrives, so that the effective voltage step is doubled. At other points, there is a delay from the time that the forward wave passes until the reflected wave passes, so that two separate steps appear and each are equal to the original.

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

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

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

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

For a Perfect Harmony™ drive, the critical length is a function of the number of power cells per phase and the effective switching frequency of the drive. If the cable length exceeds a critical length, an output filter is included with the drive.

5.6 Output Filters

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

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

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

5.7 Synchronous Transfer

5.7.1 Introduction

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

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

- “Up Transfer: The process of transferring a VFD-controlled motor to the line, and then decoupling the motor from the drive.
- Down Transfer: The process of transferring a line-energized motor to VFD control, and then decoupling the motor from the line.

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

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

Note: Synchronous up/down transfer is not available in V/Hz or OLTM control modes.

WARNING!

Improper phase sequence may result in a synchronous transfer related VFD fault.

5.7.2 VFD Synchronous Transfer Implementation

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

VFD Transfer Permissive

WARNING!

The VFD output contactor and motor line contactors should never be simultaneously closed if the digital output signal "VFD Transfer Permissive" is low or when the VFD input is not energized. Failure to ensure that this condition **does not** occur could result in severe damage to the VFD power cells.

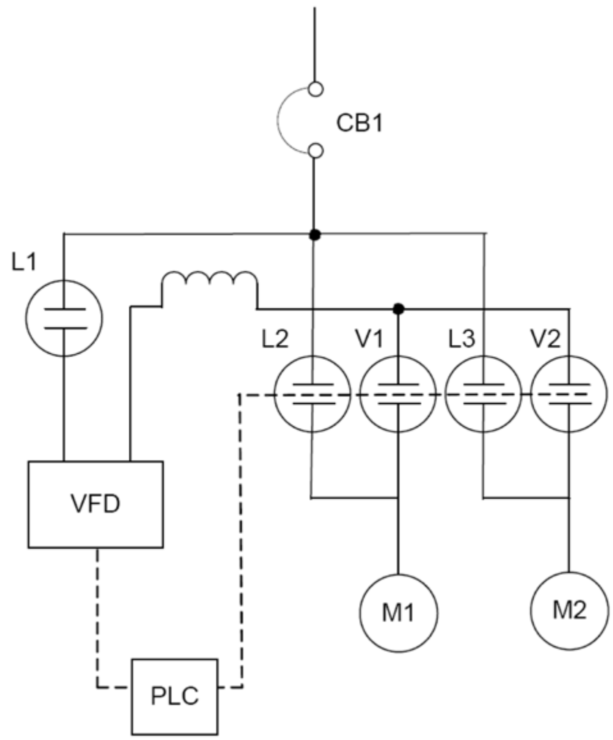

Figure 5-1: Multi-Motor, Synchronous Transfer

Figure "Multi-Motor, Synchronous Transfer" provides a block diagram showing the VFD configuration for synchronous transfer for a 2 motor implementation.

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

Note: It is not required that all motors connected to a drive configured for synchronous transfer have matching ratings. If mis-matched motors are implemented, the drive must be sized for the worst case load. Smaller motor loads can be mechanized via parameter read/write functionality or the NXGII Control Multiple Configuration File capability, as described in *NXG Communications Manual* (A5E02924901) and *NXG Control Manual* (A5E02924900), respectively. As a rule, the smallest motor rating should be greater than 50% of the ratings of the largest motor to ensure feedback signal integrity. When mismatched motors are used, the proper configuration file should be active for the subject motor.

Controller Implementation

Refer to the *NXG Control Manual* (A5E02924900) for a detailed description of NXGII Control configuration required for synchronous transfer.

5.7.3 Input/Output Signals for Synchronous Transfer

Excluding standard run, stop, and speed reference inputs, synchronous transfer requires 4 dedicated input signals and 6 dedicated output signals to be implemented. These signals can either be hardwired or implemented as digital control bits over one of the NXG-supported PLC communication links.

Input Signals to the VFD:

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

Output Signals from the VFD:

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

5.7.4 Up Transfer Implementation

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

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

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

A typical up transfer sequence is summarized as follows:

1. Start the VFD as a normal running drive with desired speed command. The drive must be in the RUN state to initiate transfer, and the VFD Transfer Permissive Signal must be set true. In addition, the digital input flag VFD Output Contactor Status must be set true.
2. Initiate the transfer with the Up Transfer Request digital input when an up transfer is desired. A timer should be used to establish a maximum time period for the transfer to complete. Transfer timeouts are rarely encountered and are usually due to an unstable source, a varying load, or improperly tuned drive.

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

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

Note: The VFD will automatically ramp the output to rated frequency upon initiating the up transfer sequence. There is no need to change the speed reference prior to issuing an Up Transfer Request.

4. The VFD ramps to line frequency and phase-locks for a minimum a 5 seconds. Note that the NXGII Control includes provisions for offsetting the phase should a configuration exist where the VFD medium voltage input is not the same phase as the line voltage to be used at the motor.
5. Once synchronized, the VFD issues a permit signal, Up Transfer Permit, indicating that the motor line contactor can be closed (VFD output contactor also remains closed during this stage).
6. Once the motor line contactor is closed and acknowledged at the VFD, the VFD will disable its output.
7. Once the VFD output is disabled, the run request should be removed and the VFD output contactor must be opened. This completes the up transfer process, and the Up Transfer Request digital input can be removed.

5.7.5 Down Transfer Implementation

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

A typical down transfer sequence is summarized as follows:

1. The motor is running directly from the line, VFD is idle, the VFD output contactor must be open, and the external speed reference must be set to the speed desired upon completion of the down transfer. Remember to account for motor slip, if bumpless down transfer is desired.
2. If the VFD indicates that it is capable of performing a down transfer (sufficient output voltage available and drive is energized and ready to run), the down transfer request is issued to the VFD.
3. Once the drive acknowledges the down request, the VFD output contactor is closed, and the VFD run request must be set.

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

4. Once the VFD PLL maintains phase/frequency and voltage lock (typically 5 to 10 seconds), the VFD output is automatically enabled with a small frequency offset to ensure that current flows from the VFD to the line/motor.
5. Once the output current from the VFD reaches a predetermined level, the VFD signals that the line contactor can be opened. The output current will be limited to the maximum torque limit set in the NXGII Control.

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

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

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

5.8 Parallel Control

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

5.9 Communication Interfaces

The NXGII Control provides a means for the Perfect Harmony™ series of drives to be directly connected to several industry standard PLC communication networks, which provides the capability to control and/or monitor the VFD over these networks. A detailed description of the network capabilities is defined in the *NXG Control Manual* (A5E02924900) and the *NXG Communications Manual* (A5E02924901). A brief summary of the networks and their associated capabilities are provided in the following subsections.

5.9.1 Available Networks

At present, the NXGII Control supports the following industry standard PLC networks:

- Modbus™ RTU
- Modbus™ Ethernet
- Profibus™ DP
- ControlNet™
- DeviceNet™

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

5.9.2 Multiple Networks

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

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

5

5.10 Process Availability - The Perfect Harmony™ Advantage

Process availability is the primary prerequisite for applying a MV VFD system in a process critical application. By combining the capabilities of Perfect Harmony™'s unique distributed power architecture with the power of the NXGII Control and the patented power cell bypass feature, it is possible to deliver unparalleled opportunities for improved process availability. It is also essential that the process operator receive complete and accurate information on VFD status to allow for process adjustments that can preclude process trips and disruptions in process capability.

5.10.1 What is ProToPS™?

Process Tolerant Protection Strategy (ProToPS™) is a standard implementation of the VFD SOP. 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 to provide advance indication of a pending VFD trip. ProToPS™ allows the process operator to make process corrections to maintain the VFD in service, or adjust the process to address a pending VFD trip.

With ProToPS™, 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?

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 WCIII cell bypass.

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

5.10.3 ProToPS™ Implementation

With ProToPS™, the 4 indication categories are provided as separate digital output signals (alarm, process alarm, trip alarm, trip). The concept is to provide the operator or the process program with a clear message to indicate a status change in the VFD.

The specific information on the VFD parameter change is indicated (along with the general category information) across a serial communications interface. Any serial communications protocol supported by the VFD product can be supported in the ProToPS™ 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 4 defined outputs must be present as digital outputs 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 NXGII Control, the need for the designation Transient Alarm has disappeared as all bypassable faults become process transparent.

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

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CHAPTER
6 Installation

6.1 Introduction

When installing Perfect Harmony™ drives, it is essential to understand the proper techniques associated with the following procedures:

- Receiving
- Shipping splits
- Off-loading
- Weight estimates
- Handling
- Placement and storage
- Anchoring
- Reconnecting wiring

Each of these procedures is discussed in this and the next chapter.

6.2 Receiving

The proper receiving procedure consists of the following steps:

- Verify that the proper items have been shipped.
- Inspect all shipments for damage that may have occurred during shipping.
- File a claim with the shipping carrier if any damage is present.

6.3 Shipping Splits

The GenIII units, depending on size, may be shipped self-contained or in two sections (Input/Transformer Section and Output/Cell-Control Section). Standard drives are shipped as 1 unit.

Note: The blower assembly is shipped on a pallet and includes eyebolts for lifting and installation.

Note: Cells may ship separately in some instances.

Once the support box is removed and the secondary wires are exposed, the transformer secondary wires are to be bolted to the cell bus.

6.4 Off-loading

Due to the size and weight of Perfect Harmony™ components, it is important to carefully plan all handling operations. Off-loading from the truck is often the most critical operation because of the limited access. Advance planning and coordination among the manufacturer, the carrier, the installation contractor, and the owner are vital. Prior considerations should be made for ceiling heights, door widths, and ease of installation.

Warning!

Never use eye bolts for lifting any of the Perfect Harmony™ cabinets. Eye bolts are used at the beginning of the manufacturing process when the cabinets weigh much less. Drives may be shipped with the eye bolts removed from certain cabinets.

Prior to moving the unit, ensure that

- The unit doors are closed
- The unit is in an upright position
- The unit is stabilized to prevent tilting
- Each cell's locking latches are tie-wrapped in an upright position

6.5 Weight Estimates

Refer toTable "Power Cell Specifications" in Chapter 3 for information.

6.6 Handling

There are 5 possible methods of handling cabinets:

- Strap and cradle
- Overhead crane lifting
- Fork lift truck lifting
- Pipe rollers

- Roller dollies

Note: The Perfect Harmony™ drive contains many cable entry and exit locations. For complete details, please refer to the system drawings supplied with the drive.

IMPORTANT!

Though lifting options are presented, the final lifting is the liability of those lifting the structures. Care and attention should be used while lifting to monitor the condition of the lift at all times. Low lifting heights and slow movements should be made where possible.

The actual lifting process must be monitored continuously. In addition, the equipment used must be sized appropriately according to forces to which they will be subjected. This analysis has been prepared without knowing any of the available on site equipment, therefore tailored lifting descriptions cannot be made.

6.6.1 Strap and Cradle Method of Lifting

The preferred lifting method is Strap and Cradle using fabric slings. The length and strength of the slings are very important. To prevent buckling of the drive cabinets, the slings must be long enough for the crane hook to be at least 4 feet above the top of the enclosure. If this distance cannot be maintained, spreader bars of appropriate strength must be used. The strength of the slings must be adequate for the weight given in the drawings.

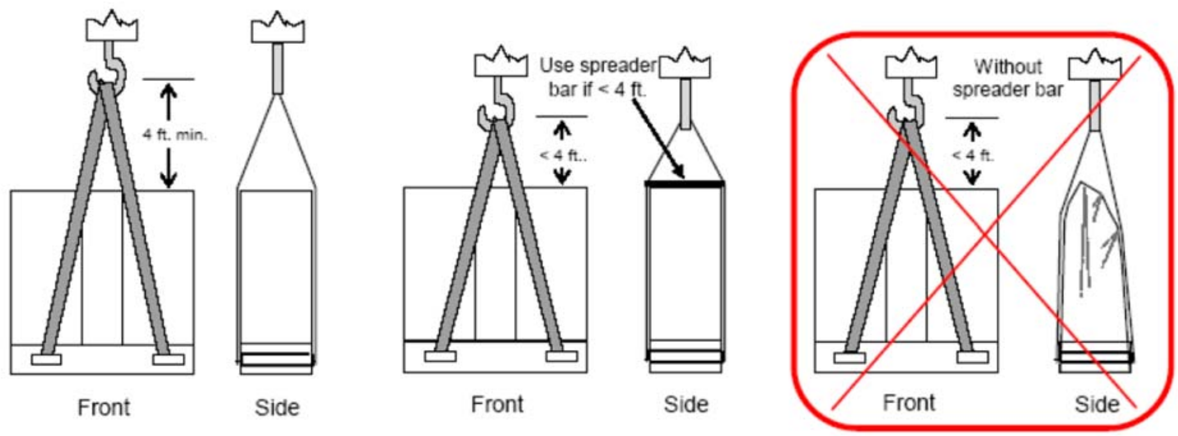

Figure 6-1: Strap and Cradle Method of Lifting

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6.6.2 Forklift Truck

A properly sized forklift truck may be used to lift the Input/Transformer Cabinet and Output/Cell Cabinet. These enclosures have heavy duty base structures that will accept forklift tines. Be careful that the forklift does not damage the surface of the enclosure. It is a good idea to place a wooden stop block in the corner of the tines as shown in Figure "Proper Handling of Transformer or Cell Cabinet Using a Fork Lift Truck.".

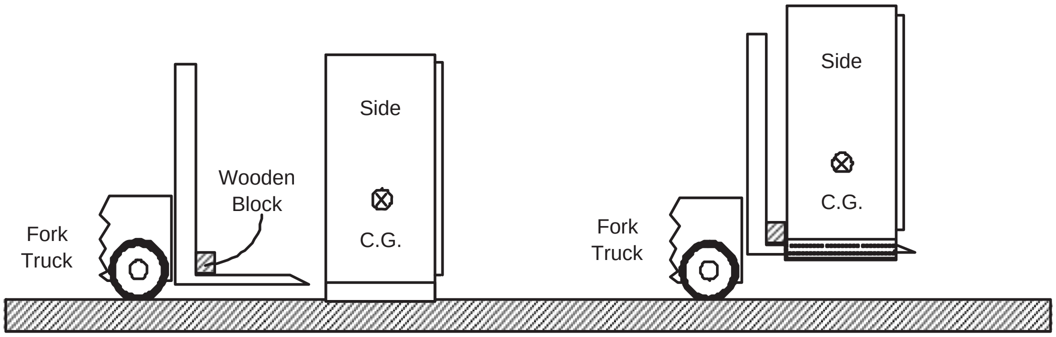

Figure 6-2: Proper Handling of Transformer or Cell Cabinet Using a Fork Lift Truck

6.6.3 Pipe Rollers

The use of pipe rollers is the least preferred method of handling. However, it is possible to set the enclosure on many parallel pipe sections placed on the floor and move it by rolling. The pipes must be no less than 2 feet in diameter and at least 6 feet longer than the width of the cabinet (3 feet on each side). The pipes must be spaced no more than 18 feet apart. Refer to Figure "Proper Use of Pipe Rollers in Handling Perfect Harmony™ Cabinets."

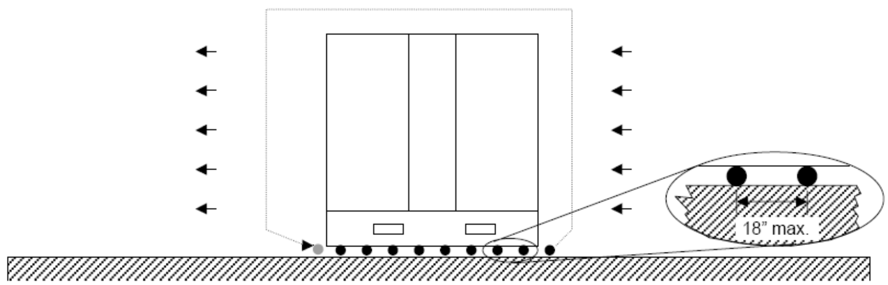

Figure 6-3: Proper Use of Pipe Rollers in Handling Perfect Harmony™ Cabinets

6.6.4 Roller Dollies

If roller dollies are used, they should be placed under the front and rear channels of the base, just outside the fork tubes as shown in Figure "Proper Placement of Roller Dollies."

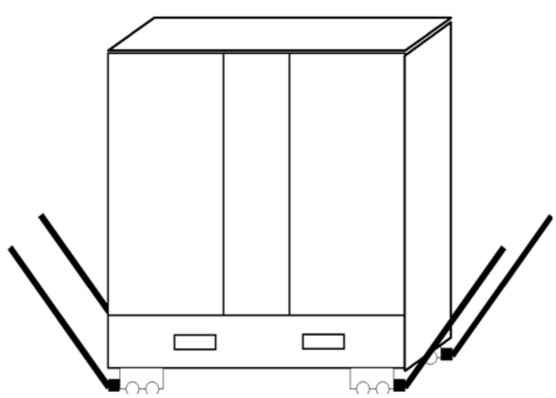

Figure 6-4: Proper Placement of Roller Dollies

6.7 Placement Location and Storage

Important!

Intake cooling air enters the drive through front-mounted ventilation grilles, and is exhausted through the cage mounted on top of the enclosure. Do not place the drive where the intake/exhaust paths could be blocked.

Place the drive in a location where the removable access plates interface with the cable entry to the drive.

After final inspection, move the drive promptly to its final position or dry indoor storage area. When choosing the location for the Perfect Harmony™ drive, be sure the area is clean, flat, dry, and the front of the drive is easily accessible with the drive doors open. Shims may be necessary to level the cabinet on uneven floors. Avoid extreme temperatures (below -5°C or above 45°C). If it is necessary to temporarily store the drive in an outdoor area, heaters may be placed in the drive and operated to prevent moisture accumulation. A protective cover such as plastic or a tarp should be placed over the drive to reduce any problems due to the outside elements. This is especially important if the storage is for more than a few days.

Warning!

If the mounting surface is not flat, the metal cabinets of the Perfect Harmony™ drive may buckle, causing the cabinet doors to be misaligned and/or not open and close properly. Shims may be necessary to level the drive for proper door operation.

Warning!

If a drive is de-energized (or in storage) for 6 months or more, the Perfect Harmony™ cell electrolytic capacitors will need to be reformed. Contact Siemens about reforming procedures for the GenIII. Failure to follow reforming procedures and guidelines may result in cell or system damage.

6.8 Anchoring Cabinets to Floors and Walls

When anchoring the cabinets to the floor, we recommend that the installer use cemented J-bars on all corners. Holes in the base of the drive cabinets are 0.81 inch in diameter and easily accept 0.5-inch threaded J-bars. If the drive is mounted against a wall, top angles may be used to secure the drive to the back wall in lieu of the rear J-bar connections to the floor. Refer to Figure “Proper Anchoring Technique for Cabinets” for an overview. Exact dimensions are given in the drawings supplied with the drive.

Tie bolts are used to connect the individual cabinets to each other, such as the Input/Transformer Cabinet and the Output/Cell Cabinet. Holes for tie bolts are located along the front and back edge of each cabinet section.

> **Note:** Refer to system drawings for the type of base structure used with each cabinet as well as the exact connection locations.

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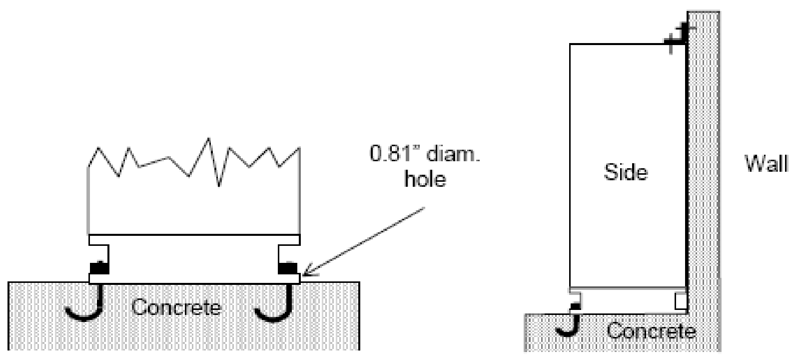

Figure 6-5: Proper Anchoring Technique for Cabinets

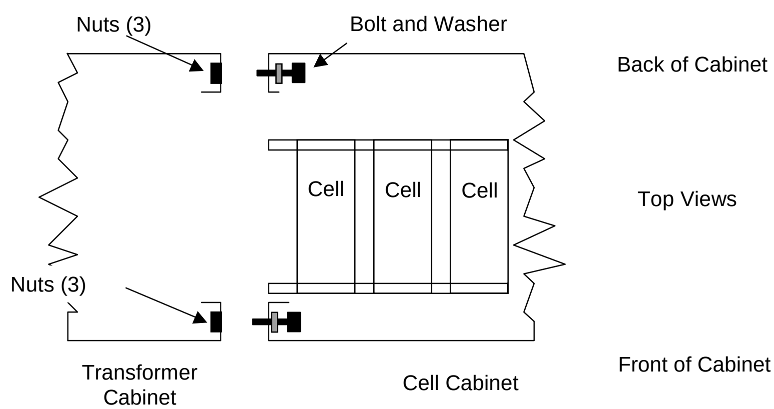

Figure 6-6: Connecting the Cabinets

6.9 External Wiring

6.9.1 Transformer Wiring

Located at the bottom of the transformer is a set of ±5% voltage taps for compensating the primary voltage source (see Figure “Transformer Cabinet Detail Showing Typical Tap Connections”). The Variable Frequency Drive (VFD) is shipped with the +5% taps connected. This means that the VFD secondary cell voltages are at the nominal 690 VAC (for example) for an input voltage of 5% above primary nominal rating.

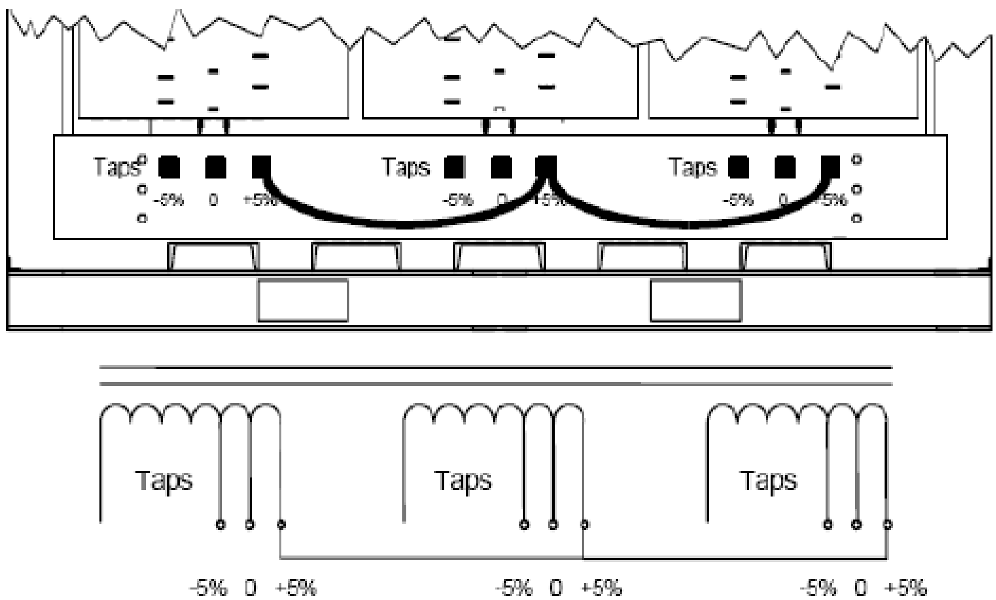

Figure 6-7: Transformer Cabinet Detail Showing Typical Tap Connections

Danger - Electrical Hazard!

The transformer primary winding neutral point is designed to operate floating (ungrounded). Do not bond the transformer primary winding neutral point to ground. Failure to adhere to this instruction will cause large, unbalanced currents to circulate in the ground / neutral path of the drive’s input source system during drive energization.

6.9.2 Input Power Wiring

Customer-supplied AC power for both control and blowers enters an access plate in the top or bottom of the Cell Cabinet. Customer-supplied medium voltage (MV) power enters an access plate in the top or bottom of the Input/ Transformer Cabinet.

Danger- Electrical Hazard!

Ground bonding jumpers are factory made. Reconnect ground bonding between cabinets at shipping splits. Ensure that the entire system is earth grounded at one of its grounding points.

Note: To maintain EMC compliance, input MV wiring must be installed in metallic electrical conduit and routed through the approved access plates.

Customer supplied low voltage I/O cabling #12 to #22 AWG must be routed separately from power cables / MV cables. Shielded low voltage cables shall maintain shield integrity for the length of the cable including all inter-connections and the shield shall be grounded only at the source.

6.9.3 I/O External Wiring

Refer to the project drawing F set for the customer I/O connection interface. All hardwired I/O cabling should be routed and terminated prior to commissioning.

Danger - Electrical Hazard!

Standard safety precautions and local codes must be followed during installation of external wiring. Protection separation must be kept between extra low voltage (ELV) wiring and any other wiring as specified in the Communaute Europeenne (CE) Safety Standard IEC61800-5-1.

6.9.4 Protection Circuits

The input protection scheme and E-Stop circuits described in Section “Coordinated Input Protection Scheme” should be integrated to the external wire scheme prior to Siemens startup (commissioning).

6.9.5 Torque Specifications

Connections made during the installation of the Perfect Harmony™ drive must be torqued to the appropriate values. Torque specifications for the Perfect Harmony™ drive are listed below.

Table 6-1: Torque Specifications for the Perfect Harmony™ Drive

Standard Torque Chart			Deviations to Standard Torque Specifications	
Fastener Size English (Metric)	**Tightening Torque (lb-in)**	**Metric Equivalent Tightening Torque (N-m)**	**Perfect Harmony™ Connectors**	**Tightening Torque**
2-56 (M2)	3.0	0.34	All Green Connectors	6.0 in-lb
4-40 (M3)	6.0	0.67	Receptacle GRND	36.0 in-lb
6-32 (M3.5)	12.0	1.34	Panel GRND	22.0 in-lb
8-32 (M4)	22.0	2.46	F4, F5, F21, F22	22.0 in-lb
10-32 (M5)	36.0	4.03	F23, F24, F25	36.0 in-lb
1/4-20 (M6)	70.0	7.84	3MI	9.0 in-lb
1/4-20 (M6) elec	100.0	11.20	TB2, TBAMA, B, C, Metal Cover	12.0 in-lb
1/4-28	70.0	7.84	T6, Relays, Receptacle Wiring	12.0 in-lb
5/16-18	155.0	12.92	Transformer GND (T5)	70.0 in-lb
(M8)	80.0	8.96	PB and Light Switches (Door)	9.0 in-lb
3/8-16, 3/8-24	275.0	30.80	RTM	4.0 in-lb
(M10)	180.0	20.16	Keypad	6.0 in-lb
1/2-13 (M12)	672.0	75.26	Breaker (Wiring) Lugs	36.0 in-lb
	(lb-ft)	**(N-m)**	CTB and CTC Terminals	12.0 in-lb
5/8-11	112.0	151.76		
3/4-10	198.0	268.29		
1	500.0	677.50		

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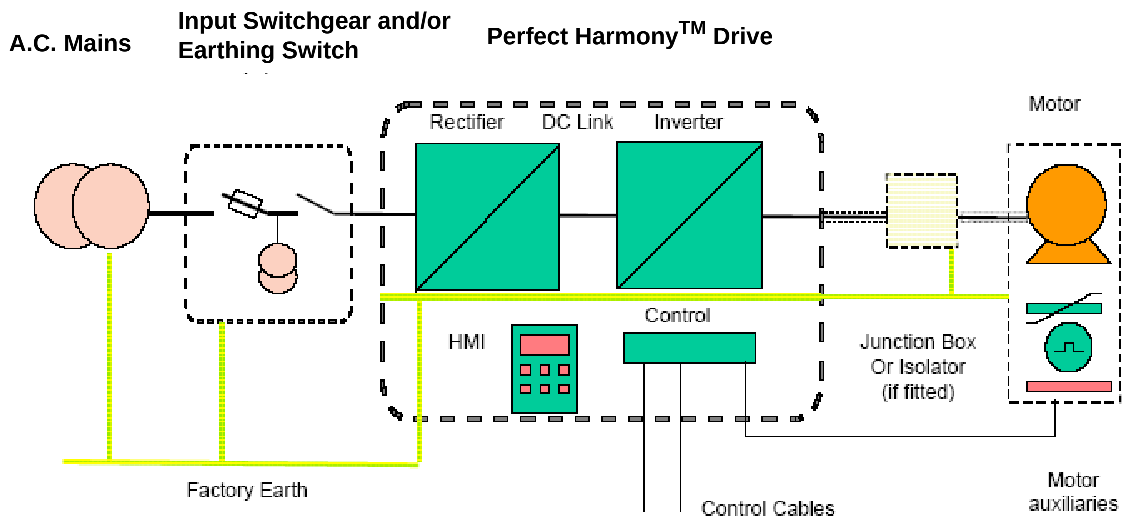
6.10 EMC Installation Guidelines for Perfect Harmony™

These guidelines cover the basic points to be considered when installing a Perfect Harmony™ motor drive with minimum Radio Frequency Interference (RFI) impact on the surrounding environment. A drive that limits RFI to within specified levels has achieved Electromagnetic Compatibility (EMC). There are four key areas that need to be addressed to achieve EMC: earthing, screening, filtering, and wiring.



6.10.1 Earthing

The Perfect Harmony™ drive has provisions for the customer to bond Protective Earth (PE) to the drive cabinets. These connection points are identified with a ⏚ symbol in the drive assembly. The PE connections are provided adjacent to the L1/L2/L3 power input and T1/T2/T3 power output terminals in the drive. All sections of the drive are internally PE bonded by green/yellow conductor or black conductor with green and yellow tape. All customer PE connections to the drive should be as short as physically possible and comply with all local safety regulations regarding earthing. Siemens Industry, Inc. I DT LD A recommends PE bonds be at only one point on the drive to prevent circulating ground currents. All PE bonds should be checked as part of routine drive maintenance.

6.10.2 Screening (Shielding)

The purpose of screening (shielding) is to prevent any unwanted radio frequency electromagnetic radiation from escaping or entering a system. To accomplish this, the screening must be part of the cabinets or enclosures as well as the connecting input and output cables. The Perfect Harmony™ drive, with its switching elements and microprocessor controllers, is a source of RFI. However, the enclosures of the Perfect Harmony™ drive have been engineered and tested to provide an effective Faraday Cage that limits the amount of RFI escaping from the drive. This cage also helps prevent unwanted RFI from entering the drive. All cables in and out of the drive (power/mains and control/signal) must be shielded to limit RFI emissions. The motor housing is typically an effective RFI screen. To achieve EMC, the three screens (cabinet, cable, and motor housing) must be bonded together to effectively form one screen. No interruptions in the cable shielding are permitted. The connections in the screening system must have a low impedance in the megaHertz (MHz) range. Special connectors are designed for this purpose and recommended.

6.10.3 Filtering

When CE labeling is specified, internal EMC line filters are installed in the Perfect Harmony™ drive on the customer control power inputs. The customer's control power connections to the drive must be in metallic tubing and must not be in close proximity with the internal EMC line filters.

6.10.4 Wiring

Control and Signal Cables

The control cabling is a part of the Faraday Cage as described in the screening section above.

- Use shielded cables for all analog and digital control connections whenever possible. Twisted pairs are an effective alternative to shielded cables.
- If twisted pairs are used the twist should be carried as close as possible to the appropriate terminals. If possible, avoid the use of a common return for different analog signals.
- Always separate digital and analog signals. Never mix 110 / 230 volt signals in the same cable as 24 volt signals. A conventional screened or armored cable should be used for 110 / 230V signals.
- Double-shielded cables will give the best performance.
- Control and signal cables must be separated from power cables.
- Route control and signal cables in separate cable trunks at least 200 mm (8 in) away from motor and power cables.
- If control and signal cables must cross power cables it should be at an angle as near to 90 degrees as possible. See Figure "Recommended Cable Segregation" below.

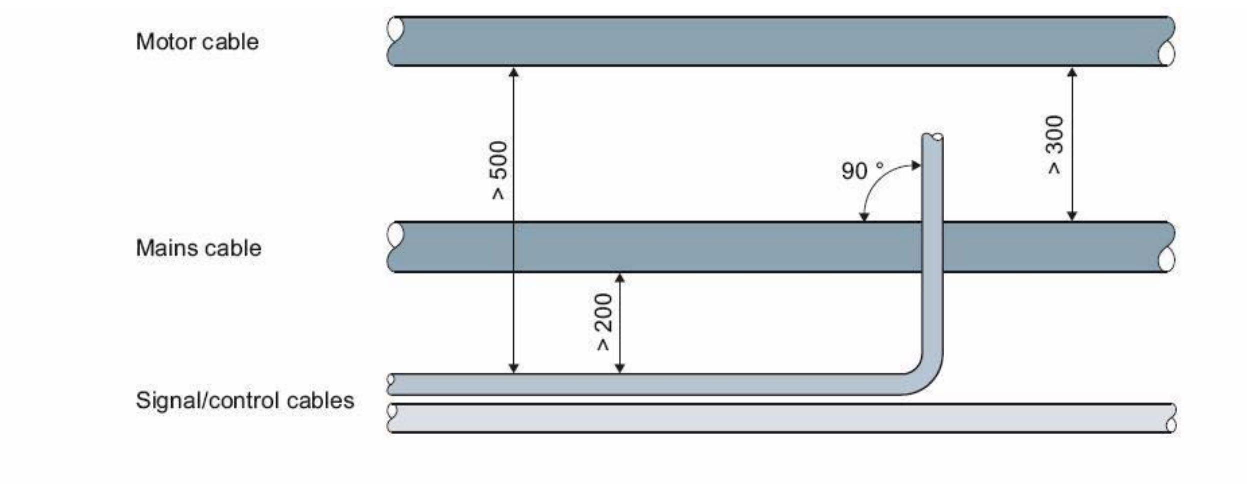


Figure 6-8: Recommended Cable Segregation

Power (Mains/Motor) Cables

Siemens Industry, Inc. I DT LD A recommends the input and output MV power cable, regardless of operating voltage, used for all Perfect Harmony™ drives be shielded to mitigate RFI and achieve EMC. The cable shield should be electrically continuous for the entire cable length and constructed of nonmagnetic metal, a tape shield is preferred. Cable armor and non-tape shields, such as Unishield, also serve to limit RFI emissions. Both of these types of cable have been successfully applied with Perfect Harmony™ drives, but they may not be as effective as a tape shield in limiting RFI.

- The cable manufacturer's recommendations for maximum pulling tension and minimum bend radius should always be followed when installing cable.
- No other cable shields, power or control/signal, should be bonded to the motor cable shield. Very high levels of electrical noise will be induced in such cables.
- Siemens Industry, Inc. I DT LD A recommends all drive input (mains) and output (motor) power cable shields be bonded to PE at one end only.
- Whenever armored cables are used, they should be properly terminated with a gland, the armor contacting the gland through all 360 degrees, and the gland circumferentially grounded to the gland plate and bonded to PE.

Serial Communication Cables

The signal transmission standard (RS232, RS485, Ethernet, etc.) and protocol standard (Profibus, ProfiNet, ControlNet, Modbus, etc.) will recommend suitable cable types. Follow the recommendations.

Encoder Cables

Pulse encoders may be galvanically connected to the motor rotor. It is important that any bearing insulation not be bridged. The recommendations of the encoder supplier, such as cable type, should always be strictly followed. The cable run from the encoder to the drive should be a continuous length and not interrupted by screw terminals.

For more information, refer to the Installation Guidelines for Power Drive Systems - User Guide No. 3:

- Go to Gambica website at http://www.gambica.org.uk
- Select Publications/Gambica Technical
- Download the *"Installation Guidelines for Power Drive Systems – User Guide No. 3"*

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CHAPTER

7 Commissioning

7.1 Pre-commissioning

7.1.1 Description

Instructions for receiving, off-loading, handling, placement, anchoring, and external wiring are defined in this manual. The customer or customer's agent is responsible for these tasks.

After the location of the drive has been determined and the drive is in the installed location (including bolting and anchoring the drive), Siemens can arrive at the site to commence the pre-commissioning process.

7.1.2 Process

1. Obtain site equipment information and verify that it matches factory information.
2. Install lockouts and de-energize the equipment (see Section "Maintenance and Earthing Procedure").
3. Torque check the cabinet connections. Inspect the entire drive for shipping and/or installation damage, and verify that each cell is properly engaged to its rear bus connectors.
4. Ensure that the enclosure is earth-grounded at the Protective Earth (PE) point of the drive. Confirm what type of cable the customer is using for the motor connections. If it is a shielded cable, only one end of the shield can be grounded. It must be grounded at the drive. Inspect medium voltage (MV) input cabling and hardwired I/O control wiring.
5. Check and note if the drive integral isolation transformer neutral is grounded. Note "yes" or "no" on form regarding whether it is transformer neutral grounded. Ohm check all secondary transformer connections to the chassis cabinet to ensure no damage has occurred during shipment.

Note: Siemens strongly recommends no ground on transformer neutral conductor. However, the transformer iron core is routinely chassis-grounded to the enclosure by Siemens.

6. Inspect customer load.
7. Inspect internal routing of the fiber optic connections and their integrity.
8. Obtain permission to energize.

9. At this time, it is necessary to have an auxiliary control voltage source connected per the Variable Frequency Drive (VFD) schematics to allow the pre-commissioning process to continue. A temporary source can be utilized.

Danger - Electrical Hazard!

Residual-Current Device (RCD) incompatibility:

Connecting this device to a power supply protected by a RCD can result in damage to property and minor personal injury.

This product can produce a DC current in the grounding conductor.

When using a RCD in cases where direct or indirect contact can be made, only a Type-B RCD shall be permissible on the line side of this product. If this is not possible, an alternative means of protection must be applied (for example, isolation from the environment through double or reinforced insulation or isolation from the power supply using a transformer).

Do not connect this device to a power supply that is protected by a Type-A RCD.

10. Remove lockouts and energize LV controls.
11. Power is required to test the Coolant System and Control. Energize auxiliary 120 VAC and 3-phase power to the blowers to verify the rotation and phase sequencing of the cooling fans.
12. Use project drawings to confirm that input and output voltage attenuator resistors and output Hall Effect current sensor burden resistors.

Notes:

The motor leads should not be connected to the drive when performing the following Open Loop Test Mode (OLTM) check.

The input MV switchgear should be locked and tagged out prior to OLTM checks in the next step.

13. In OLTM, backfeed the drive with a variac connected to one of the Perfect Harmony™ transformer secondary windings. Verify that all cell and the drive input line voltages are correct.
14. If the VFD has cell bypass, verify contactor operation by removing cell fiber optics at the NXG Digital Card Rack (DCR).
15. De-energize and apply lockouts until start up and commissioning is performed.
16. At the end of the pre-commissioning, a copy of the pre-commissioning report should be left with the responsible site manager.

7.2 Startup (Commissioning)

1. Initial inspection:

o Obtain motor phase sequence.

o Remove lockouts.

o Verify that the customer has not operated, altered, or energized equipment since pre-commissioning was done by Siemens.

o Verify hardwired I/O per system drawings.

o Ensure that the blower is running prior to applying input MV.

o Verify that Coordinated Input Protection Scheme (MV IP Breaker Enable) has been implemented. Jumpers are not permitted on the terminal blocks.

2. Energize MV input with the motor disconnected. Leave the power on the drive for at least 1 hour. If possible leave the power on overnight.

3. Verify that the control is working in OLTM, as per Table “Drive Test in Open Loop without Motor” in the *NXG Control Manual* (A5E02924900).

4. Where applicable, verify the cell bypass on each cell:

o Remove the fiber optic link. The contactor will close.

o Verify that all cells bypass correctly.

5. De-energize and apply lockouts. See Section “Maintenance and Earthing Procedure.”

6. Connect the motor to the VFD output (T1, T2, and T3) with the proper phase sequence.

7. Remove lockouts and energize the VFD.

8. Operate the motor at 1% speed and verify proper direction of rotor rotation.

9. Run the motor uncoupled from load, and verify the speed ranges and feedbacks per Section “Drive Test in Open Loop Test Mode with Motor Connected” and Table “Drive Test in Open Loop Test Mode with Motor Connected” in the *NXG Control Manual* (A5E02924900).

10. Couple the motor and operate according to Section “Drive Test in Open Loop Vector Control Mode with Motor Connected” and Table “Drive Test in Open Loop Vector Control Mode with Motor Connected” in the *NXG Control Manual* (A5E02924900).

Note: If the motor parameters are loaded in parameter list, do not use the auto-tune feature. Otherwise, reference Section “Auto-Tuning” in the *NXG Control Manual* (A5E02924900).

11. Complete speed loop and spinning load tuning. See Section “Spinning Load” in the *NXG Control Manual* (A5E02924900).

12. Verify Distributed Control System (DCS) address across serial link and verify DCS operation, where applicable.

13. Establish application manual parameters with the customer. See Section “Application Menus” in the *NXG Control Manual* (A5E02924900).

14. Once the system reaches the process design operating condition, utilize Siemens ToolSuite to record the following VFD data:

o Plant Load At Test Point

o Voltage VFD Input

o Current VFD Input

o Power Factor VFD Input

o Voltage VFD Output

o Current VFD Output

o Speed Demand

o Motor Speed (RPM)

o VFD Efficiency

Note: If plant is operated across a load range, take load data at incremental load points to obtain a profile of the VFD operation as part of the process.

15. Complete the cell identification page (Table 7-1) before leaving the site.

16. Test spares where applicable

17. Review the 6-month maintenance proced8.3ures with the end user, as described in Section 8.3.

18. The commissioning process is now complete. Acquiring the customer's signature provides acceptance of the Siemens equipment.

o Customer's signature (required)

o Print name

o Title

o Company

o Phone number

o E-mail address

Note: For output filters, encoders, synchronous motors, synchronous transfer applications, and startup criteria, refer to Chapter 6., "Startup Procedure" in the *NXG Control Manual* (A5E02924900).

7.3 Nomenclature ID

Record the following information at the end of the commissioning process.

Table 7-1: Customer Drive Nomenclature ID

A1 Serial Number Goes Here ______________	B1 Serial Number Goes Here ______________	C1 Serial Number Goes Here ______________
A2 Serial Number Goes Here ______________	B2 Serial Number Goes Here ______________	C2 Serial Number Goes Here ______________
A3 Serial Number Goes Here ______________	B3 Serial Number Goes Here ______________	C3 Serial Number Goes Here ______________
A4 Serial Number Goes Here ______________	B4 Serial Number Goes Here ______________	C4 Serial Number Goes Here ______________
A5 Serial Number Goes Here ______________	B5 Serial Number Goes Here ______________	C5 Serial Number Goes Here ______________
A6 Serial Number Goes Here ______________	B6 Serial Number Goes Here ______________	C6 Serial Number Goes Here ______________

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CHAPTER
8 Maintenance

8.1 General Maintenance

Siemens has designed, built, and tested the Perfect Harmony™ variable speed drive for long, trouble-free service. However, periodic maintenance is required to keep the drive working reliably, to minimize system downtime, and to maintain safety.

Danger - Electrical Hazard!

Handling the equipment with main input power connected will cause death or severe injuries. Always switch off the main input power to the equipment before attempting inspection or maintenance procedure.

Warning!

Incorrect handling and maintenance may cause death or severe injuries. Ensure that only qualified service personnel maintains Perfect Harmony™ equipment and systems.

8.2 Maintenance and Earthing Procedure

Note: The Perfect Harmony™ is a modular system that can be marketed into highly integrated applications. Therefore, these instructions do not cover all variations of equipment types or installations. Only qualified personnel should perform maintenance on these systems.

1. Stop drive operation through either remote or local controls.
2. De-energize the input voltage by opening the incoming switchgear and locking to the OPEN position with the mechanical interlock. Apply lock-out/tag-out principles, as required by local code.
3. De-energize the control voltages for the synchronous motor field/exciter controls.
4. Wait 10 minutes to allow stored energy to dissipate from the Perfect Harmony™ drive and until the door interlocking system has been released.
5. If applicable, isolate motor connections by opening output switchgear using interlock key from input switchgear and locking to the OPEN position using the mechanical interlock.
6. Observe the Cell Control Board (CCB) voltage Light-emitting Diodes (LED) by removing the interlock key from the input/output switchgear and opening the Perfect Harmony cell sections door(s).
7. When none of the cell LEDs are lit, the voltage at the input and output cell terminals is below 50 VDC. Use ancillary AC voltage sensing devices to confirm that the drive is de-energized.
8. Apply the grounding device to the input and output terminals.
9. Perform maintenance as required.
10. Remove the grounding device.
11. Close the Perfect Harmony™ doors in reverse sequence and replace the interlock key into the input switchgear.

8.3 Six Month Inspection

1. Check the operation of the fans in the blower assembly:
   - o While in operation, listen for audible noises that may indicate that impeller imbalance may be present.
   - o De-energize the medium voltage (MV) input to the drive (see Section “Maintenance and Earthing Procedure”) and low voltage to the blower.
   - o Wipe off any accumulated dust.
   - o Verify mounting bolt torque (M10).
   - o Inspect the electrical connections for stray wire strands or insulation failures.
   - o Check that the impeller rotates freely without obstruction.
   - o Record any ALARMS issued by the drive. If these alarms are persistent, a Siemens field service engineer can analyze the blowers with OEM software.
2. Use touch-up paint, as required, on any rusty or exposed parts on the enclosure exterior.
3. For drive internal inspection, contact Siemens about a preventative maintenance service agreement.
4. Verify the replacement part stock and contact Siemens for additional spares.
5. Replace the door filters on the enclosure.

Note: Do not clean the door filters with a pressurized device.

Door filters can be cleaned by wiping them off. The filters cannot be cleaned by use of any pressurized device (for example, water, air), as this will damage the filters preventing further use.

See Figure “Front View of Cell Door Filter during Normal Operation” for the front view of the cell door filter during normal operation.

Figure 8-1: Front View of Cell Door Filter during Normal Operation

8.3.1 Cell Door Filter Removal

1. Lift up on the filter retainer until the base is free from the door.
2. Pull out the base of the filter retainer to release it from the door, as shown in Figure “Filter Retainer.”

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Figure 8-2: Filter Retainer

Danger - Electrical Hazard!

The cell door includes partially expanded metal that holds the filter captive and provides protection against accidental contact with the electrical components. A high voltage is present behind this. Exposure may cause death or serious injury. Use caution to ensure that tools and etc. are not used close to or inserted into grille to avoid risk of electric shock.

3. Remove the filter and replace it with a spare. See Figure “Filter Removal.”

Figure 8-3: Filter Removal

Note: If the filter is removed but not replaced, ensure the same orientation upon reinsertion.

4. Reverse Steps 1 and 2 to reinstall the filter retainer.

8.4 Replacement of Parts

Replacement of component parts may be the best method of troubleshooting when spare parts are available. When any subassembly is to be replaced, always check that the part number of the new unit matches that of the old unit (including the revision letter).

Note: Companion manual *NXG Control Manual* (A5E02924900) includes a troubleshooting section in Chapter 7, "Troubleshooting and Maintenance."

- Failures traced to individual PC boards within the Control Cabinet are best serviced by replacing the entire board.
- Failures traced to individual power cells are best serviced by replacing the entire cell.

CAUTION!

The disposal of any failed components (capacitors, etc.) must be completed in accordance with local codes and requirements.

8.5 Basic Rules for Repairing Perfect Harmony™ Cells

Cell failures or component failures should be reported to both the Quality Group and Product Development at Siemens.

Always refer to the latest Bill of Material (BOM) and assembly drawings for approved component part numbers and procedures when repairing any cell. Failure to use components other than those listed in the BOM may result in poor cell performance or further failures.

Warning!

It is imperative to follow these rules for repairing Perfect Harmony™ cells.

1. Never parallel or series non-identical manufacturers part numbers (or Siemens LD A MDIT Numbers) for IGBTs or electrolytic capacitors in the same power cell.
2. Never substitute a non-specified CCB/GCB/SMPS board (or any specified component or subassembly) without formal approval from the Product Development Group.

3. Never change an input power fuse(s) without first determining the root cause for the fuse operation. Fuses are not designed to protect components in the power cell against overload. If a fuse(s) is open, there is usually a component failure within the cell. Reapplication of rated power may cause catastrophic damage. Always inspect the related transformer winding and cell before replacing fuses.

Note: In cases where the latest BOM specifies obsolete components and the substitution of an alternative is not available, contact the Siemens LD A Product Development Group for assistance. In such events, Product Development may suggest alternative components, only after sufficient technical review and verification.

8.5.1 Perfect Harmony™ Power Cells Removal

CAUTION!

Proper Personnel Protective Equipment MUST be worn.

To remove the GenIII Power Cell, perform the following steps:

1. Power down the GenIII system by following the standard shutdown procedures specified in Section "Maintenance and Earthing Procedures."
2. Open the doors to access the power cells.
3. Ensure that the DC bus LED (labeled "Charge LED"; see Section "Maintenance and Earthing Procedures"), which is located on the CCB, is off. Wait an additional 10 minutes before proceeding.

Warning!

Only Qualified Service Personnel should perform maintenance on the cell.

Danger - Electrical Hazard!

Never assume, even after waiting for 10 minutes and observing that the LED is not lit, that the capacitors inside the cell are discharged. These capacitors can have a residual charge that can lead to a shock hazard. The input voltage to the cells is 630 VAC, which can produce a DC potential of 976 VDC on the DC bus.

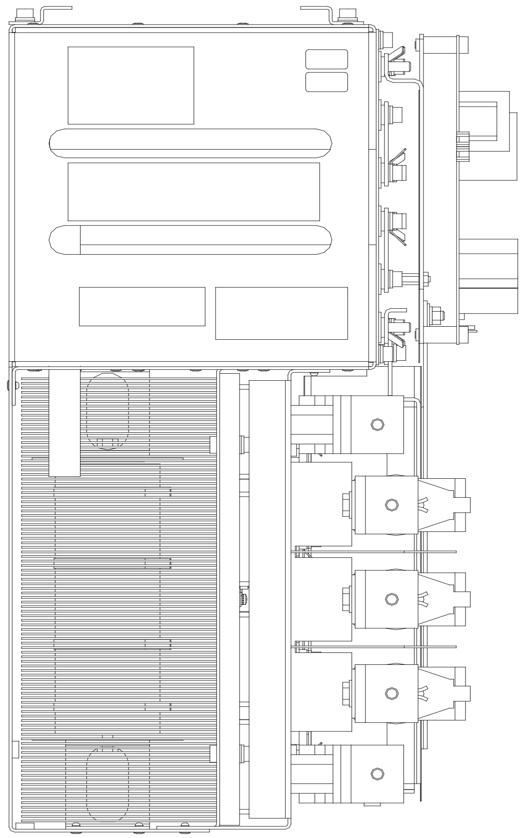

Figure 8-4: LED Indicators - 260A Cell Shown

Figure 8-5: Typical 100A Power Cell

Warning!

The power cells include discharge resistors to dissipate stored energy after the input voltage is removed. The power cell DC bus voltage decays to less than 50 VDC in less than 10 minutes.

Danger - Electrical Hazard!

When “Charge LED” LED is lit, it indicates that a voltage greater than 50 VDC is present.
When “Charge LED” LED is not lit, **do not assume that no charge is present**. A small residual charge may still be present. Measure DC voltages in accordance with NEED NEW FIGURE.

WARNING!
RISK OF ELECTRICAL SHOCK. DO NOT TOUCH METAL FRAME OF CELL. CAPACITORS STORE HAZARDOUS ENERGY. DISCONNECT ALL SOURCES OF SUPPLY, WAIT UNTIL ALL LEDS ON CCB ARE OUT BEFORE SERVICING CELL.

ATTENTION!
THIS POWER CELL IS INTENDED FOR USE WITH 630VAC, 50/60 HZ INPUT

ATTENTION!
CERTAIN RATINGS OF THESE POWER CELLS MAY WEIGH UP TO 500 LBS. CARE SHOULD BE EXERCISED IN REMOVING OR REPLACING FROM CABINET. CONSULT INSTALLATION MANUALS FOR FURTHER INFORMATION

WARNING!
THESE POWER CELLS MAY BE STORED VOLTAGE FREE AT UP TO 45˚C FOR UP TO 2 YEARS WITHOUT REFORMING THE FILTER CAPACITORS. BEYOND THE 2 YEAR LIMIT, CONSULT INSTALLATION MANUAL FOR REFORMING PROCEDURE. BEYOND THE 45˚C LIMIT CONSULT THE FACTORY. FAILURE TO OBSERVE THESE LIMITS MAY CAUSE POWER CELL FAILURE UPON VOLTAGE APPLICATION

Danger - Electrical Hazard!

Wear electrical safety gloves or appropriate Personnel Protective Equipment. Do not to touch any bare bus bars while removing the cell, as this could result in electric shock and serious injury or death.

Note: The gloves pictured are Hyflex cut resistant (CR) Nitrile palm-coated gloves.

4. Remove the fiber optic cable from the CCB, as shown in Figure “Fiber Optic Cable Removal/Installation.”

Figure 8-6: Fiber Optic Cable Removal/Installation

5. Remove the 5 power connections, as shown in Figure “Power Connection Removal/Installation.”

Figure 8-7: Power Connection Removal/Installation

6. Remove the 2 remaining bolts (1 located at the top of the cell and 1 located on the lower left side. See Figure “Bolt Removal.”

Figure 8-8: Bolt Removal

7. Move the cell lifter (P/N A1A163496.04) as close as possible to the designated cell. See Figure “Positioning the Cell Lifter for Cell Lifting.”

Figure 8-9: Positioning the Cell Lifter for Cell Lifting

8. Ensure the wheel locks in the rear of the cell lifter by pushing on the pedal in the center of the operator’s side of the cell lifter.
9. Slide the cell onto the cell lifter. See Figure “Sliding the Cell onto the Lifter.”

Figure 8-10: Sliding the Cell onto the Lifter

8.5.2 Returning the GenIII Power Cell to Siemens

Perform the following actions for packing cells for shipment (GenIII 70A, 100A, 140A, 200A, and 260A):

1. Place the cell in a box and wrapped in anti-static plastic to protect the boards and the cell. This ensures that the insta-pack foam will not touch the cells or the boards. See Figure “Packing Material - Uncovered” and Figure “Packing Material - Covered.”

Figure 8-11: Plastic Wrap- Uncovered

Figure 8-11: Plastic Wrap - Covered

2. Use foam to fill the space on the sides and the top of the cells. See Figure “Foam - Side View” and Figure “Foam - Top View.”

Figure 8-12: Foam - Side View

Figure 8-12: Foam - Top View

3. Seal the box, and place it on the skid.
4. Use metal banding to secure the box to the skid. If there are any concerns with the banding being hit by a pallet jack or fork lift, drill holes through the skid, and the banding can be routed through the holes. See Figure “Metal Banding.”

Figure 8-13: Metal Banding

5. Once the cell is secured to the skid, secure an outer box to the outside of the skid. Use either wooden crate “kids” or triwalls. See Figure “Outer Box.”

Figure 8-14: Outer Box

6. Use screws to secure the outer crate to the skid. Screws may also be used to seal the crates. This enables the package to be removed and stored by the customer. See Figure “Boxed Package.”

Figure 8-15: Boxed Package

7. Attach the crate walls to the skid base.

8.5.3 Perfect Harmony™ Power Cells Installation

To install the GenIII power cell, perform the following steps:

1. Use a Siemens cell lifter (P/N A1A163496.04) to center the power cell on the lifter platform.
2. Move the cell lifter as close as possible to the designated cell.
3. Raise the cell lifter so that it is level with the rails of the designated slider. See Figure “Positioning the Cell Lifter for Cell Lifting.”
4. Engage the wheel locks in the rear of the cell lift by pushing on the pedal in the center of the operator’s side of the cell lifter.
5. Slide the GenIII power cell onto the mounting rails. See Figure “Sliding the Cell onto the Lifter.”
6. Install and tighten the 2 retaining bolts (1 located on the top of the cell and one located on the lower left side of the cell). See Figure “Bolt Removal.”
7. Attach and tighten the 5 power connections. See Figure “Power Connection Removal/Installation.”
8. Connect the fiber optic cable. See Figure “Fiber Optic Cable Removal/Installation.”

8.6 General Repair Hints and Procedures

1. Input fuse(s) or control fuse(s) opening is almost always an indication of a component failure in a cell.
2. Damage to the cell chassis ground wire is always an indication of an insulation failure internal to the power circuit or its components or the result of arcing between the power circuit and chassis. Always perform the appropriate HIPOT test or check for arc damage before reusing the subject cell.
3. An electrolytic capacitor failure that results in venting, bulging, or header expulsion is usually caused by sustained over-voltage of 15 to 20% above its operating voltage rating.
4. If one or more electrolytic capacitors failed in a particular parallel group and there is no indication of other component damage, check for a shorted or high leakage capacitor in the other parallel groups.
5. If capacitor damage is apparent in all parallel groups and if there is damage to the IGBTs or CCB, the cell was most likely exposed to over-voltage. Furthermore, failed input fuses may indicate that an over-voltage was generated from the transformer secondary.
6. An IGBT failure is usually a result of an over-voltage because the cell has system level over-current protection.
   - In non-catastrophic IGBT failures (those that do not result in case rupture), the root cause can often be found by Product Development or the device manufacturer if the devices are returned for analysis. In most of these cases, the GCG and CCB are left unaffected and can be presumed functional.
   - In catastrophic IGBT failures (those that result in case rupture), the root cause is more difficult to determine. Failures of this type usually result in collateral damage to adjacent IGBTs, especially those IGBTs in the same pole (for instance, Q1/Q2 or Q3/Q4). These failures almost always cause damage to any connected GCB and CCB.
7. The following tests can be performed by qualified personnel to verify an IGBT's condition after a cell failure:
   - **G-E Check**: Short the collector to the emitter. Ohm check gate to emitter. Resistance should be 10M to infinite. A low resistance indicates device destruction. Device must be replaced.
   - **C-E Check**: Short the gate to the emitter. Ohm check collector to emitter. Resistance should be 10M to infinite. A low resistance indicates device destruction. Device must be replaced.
   - **A-K Check**: Use a diode checker to verify a small positive voltage drop (<1V) from emitter to collector (anode to cathode of the FWD) and blocking from collector to emitter (cathode to anode of the FWD). If a short, or if >1V is measured, the device must be replaced.

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CHAPTER
9 Spare Parts

Table 9-1: Spare Parts List

Spare Part	Control Voltage	Item Part Number			
Power Cell* Qty: 1		70A Cell A1A460Y83.070	100A Cell A1A460Y83.100	140A Cell A1A4608C0.140	
		200A Cell A1A461D63.2000	260A Cell A1A461D63.260		
Cell Input Fuses Qty: 3 per cell		70A Cell A1A093503	100A Cell A1A093502	140A Cell A1A090391	
		200A Cell A1A093504	260A Cell A1A093505		
Transformer Cabinet Air Filters		46” Cabinet, A1A090335, Qty 3 60” Cabinet, A1A090053, Qty. 3 80” Cabinet, A1A091389, Qty. 3			
Cell Cabinet Air Filters		77” Cabinet A1A090335 Qty:8		54” and 112” Cabinets A1A090053 Qty: 4 for 54” Cabinet and 6 for 112” Cabinet	
NXGII Qty: 1		SBC and Keypad Adapter A1A10000623.00M	System I/O Board A1A10000423.00M	BGA Modulator A1A10000350.00M	I/O Breakout Board 120V I/O A5E01649325
		Communications Board A1A363818.00M	NXGII Power Supply A1A14000461.00	Signal Control Board A5E01708486	I/O Breakout Board 24V I/O A5E01649374
		Backplane A1A363628.00	Fiber Optic Link board** A1A461D85.00	Keypad A1A460A68.23	
WAGO I/O Modules Qty: 1		1–2 Channel Digital Input, 120 VAC A1A091537		1– 4 Channel Digital Input, 24 VDC A1A090789	
		1– 2 Channel Analog Input, 4-20mA A1A091113		1– 2 Channel Analog Input, 0-10V A1A092745	
		1– 2 Channel Relay Output, 120Vac or 24 VDC A1A092363		1– 2 Channel Analog Output, 4-20mA A1A091539	
		Field bus coupler A1A091143			

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Spare Part	Control Voltage	Item Part Number			
Control Transformer Fuses	575V Control	Primary Fuse 2.5A, 600 VAC A1AH024968 Qty: 2		Secondary Fuse 6A, 600 VAC A1A081099 Qty: 1	
	480V Control	Primary Fuse 3.0A, 600 VAC A1A080752 Qty: 2			
	230V / 380V / 415V Control	Primary Fuse 3.5A, 600 VAC A1A089205 Qty: 2			
	200V Control	Primary Fuse 4.0A, 600 VAC A1A081097 Qty: 2			
Input CT Qty: 2		CT, 50:5 A1A091705	CT, 75:5 A1A091706	CT, 100:5 A1A091707	CT, 150:5 A1A091708
		CT, 200:5 A1A091709	CT, 250:5 A1A091710	CT, 300:5 A1A091711	CT, 400:5 A1A091712
		CT, 500:5 A1A091713	CT, 600:5 A1A091714	CT, 750:5 A1A091715	CT, 800:5 A1A091716
		CT, 1000:5 A1A091717	CT, 200:5 A1A096254	CT, 3000:5 A1A096255	
Communications Network Qty: 1		Profibus DP A1A252241.155	Devicenet Profile 12 A1A2252241.156	Modbus Ethernet A1A252241.157	
		Control Net A1A252241.158	Modbus + A1A252241.159		
Input Voltage Attenuator Qty: 3		2 4 kV A1A164877.00	3.0 kV A1A164877.01	3.3 kV A1A164877.02	4.16 kV A1A164877.03
		4.8 kV A1A164877.04	6.0 kV A1A164877.05	6.6 kV A1A164877.06	6.9 kV A1A164877.07
		7.2 kV A1A164877.08	8.4 kV A1A164877.09	10 kV A1A164877.10	11 kV A1A164877.11
		12 kV A1A164877.12	12.5 kV A1A164877.13	13.2 kV A1A164877.14	13.8 kV A1A164877.15
Output Voltage Attenuator Qty: 3		2 4 kV A1A164877.00	3.0 kV A1A164877.01	3.3 kV A1A164877.02	4.16 kV A1A164877.03
		4.8 kV A1A164877.04	6.0 kV A1A164877.05	6.6 kV A1A164877.06	6.9 kV A1A164877.07
		7.2 kV A1A164877.08			

Spare Part	Control Voltage	Item Part Number			
Cell Bypass		Bypass Contactor A1A252090.776 Qty: 1 per cell		Bypass Control PCA A1A363662.01M Qty: 1	
		For 630V Secondaries Bypass Power Supply A5A363549.00 Qty: 1 Bypass Power Supply Fuse A1A090674 Qty: 2			
Blower Qty: 1			EBM RH56 Blower (46" / 60" / 80" Transformer Cabinet)	EBM RH50 Blower (77" Cell Cabinet)	EBM RH71 Blower (112" Cell Cabinet)
		Other than 575V	A1A089659	A1A090428	A1A089659
		575V	A1A090215	A1A091243	A1A090215
Cell Lifter Qty: 1		A1A163496.04			
*Customer may request IGBTs, diode rectifiers, and Cell Control Boards rather than a complete spare cell. Contact Siemens for further information regarding individual cell P/Ns. **Used if more than 12 cells.					

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Table 9-2: 120 VAC and 24 VDC Transformer/Cell Blower Fuse Control Voltages

Line-up	200V/50Hz	230V/60Hz	380V/50Hz	415V/50Hz	460V/60Hz	575V/60Hz
Transformer/Cell Blower Fuses (120 VAC), Qty: 3						
46/54	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.8A, 600V, A1A090711	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 3A, 600V A1A090206	Fuse Class J, 2.25A, 600V A1A090712
46/77	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 7A, 600V A1A090069	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 7A, 600V A1A090069	Fuse Class J, 8A, 600V A1A090711 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.25A, 600V A1A090712 Fuse Class J, 4A, 600V A1A090207	Fuse Class J, 3A, 600V A1A090206 Fuse Class J, 5A, 600V A1A090211

Line-up	200V/50Hz	230V/60Hz	380V/50Hz	415V/50Hz	460V/60Hz	575V/60Hz
60/54	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 3A, 600V A1A090206	Fuse Class J, 2.25A, 600V A1A090712
60/54 R	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 3A, 600V A1A090206	Fuse Class J, 2.25A, 600V A1A090712
60/77	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 7A, 600V A1A090069	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 7A, 600V A1A090069	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4A, 600V A1A090207	Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 5A, 600V A1A090211
60/77 R	Fuse Class J, 3.5A, 600V A1A090713 and Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 7A, 600V A1A090069	Fuse Class J, 3.5A, 600V A1A090713 and Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 8A, 600V A1A089149	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5A, 600V A1A090211	Fuse Class J, 2.5A, 600V A1A090714 and Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 2A, 600V A1A090715 and Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637
60/112	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 6A, 600V A1A089148	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637
60/112 R	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 6A, 600V A1A089148	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637

Line-up	200V/50Hz	230V/60Hz	380V/50Hz	415V/50Hz	460V/60Hz	575V/60Hz
80/77	Fuse Class J, 7A, 600V A1A090069 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 7A, 600V A1A090069 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 5A, 600V A1A090211 and Fuse Class J, 6A, 600V A1A089148	Fuse Class J, 4A, 600V A1A090207 and Fuse Class J, 4.5A, 600V A1A089637
80/77 R	Fuse Class J, 3.5A, 600V A1A090713 and Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 8A, 600V A1A089149	Fuse Class J, 3.5A, 600V A1A090713 and Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 8A, 600V A1A089149	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5A, 600V, A1A090211	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5A, 600V A1A090211	Fuse Class J, 2.5A, 600V A1A090714 and Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 2A, 600V A1A090715 and Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637
80/112	Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 6A, 600V A1A089148	Fuse Class J, 4.5A, 600V A1A089637
80/112 R	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 6A, 600V A1A089148	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637
Transformer/Cell Blower Fuses (24 VDC), Qty: 3						
46/54	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 4.5A 600V A1A089637	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 3A, 600V A1A090206	Fuse Class J, 2.25A, 600V A1A090712
46/77	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 7A, 600V A1A090069	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 7A, 600V A1A090069	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4A, 600V A1A090207	Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 5A, 600V A1A090211

Line-up	200V/50Hz	230V/60Hz	380V/50Hz	415V/50Hz	460V/60Hz	575V/60Hz
60/54	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 3A, 600V A1A090206	Fuse Class J, 2.25A, 600V A1A090712
60/54 R	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 2.8A, 600V A1A090711	Fuse Class J, 3A, 600V A1A090206	Fuse Class J, 2.25A, 600V A1A090712
60/77	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 7A, 600V A1A090069	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 7A, 600V A1A090069	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4A, 600V A1A090207	Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 5A, 600V A1A090211
60/77 R	Fuse Class J, 3.5A, 600V A1A090713 and Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 7A, 600V A1A090069	Fuse Class J, 3.5A, 600V A1A090713 and Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 8A, 600V A1A089149	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5A, 600V A1A090211	Fuse Class J, 2.5A, 600V A1A090714 and Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 2A, 600V A1A090715 and Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637
60/112	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A08133	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 6A, 600V A1A089148	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637
60/112 R	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 2A, 600V A1A090715 and Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 2A, 600V A1A090715 and Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637	Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 6A, 600V A1A089148	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637

Line-up	200V/50Hz	230V/60Hz	380V/50Hz	415V/50Hz	460V/60Hz	575V/60Hz
80/77	Fuse Class J, 7A, 600V A1A090069 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 7A, 600V A1A090069 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 5A, 600V A1A090211 and Fuse Class J, 6A, 600V A1A089148	Fuse Class J, 4A, 600V A1A090207 and Fuse Class J, 4.5A, 600V A1A089637
80/77 R	Fuse Class J, 3.5A, 600V A1A090713 and Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 8A, 600V A1A089149	Fuse Class J, 3.5A, 600V A1A090713 and Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 8A, 600V A1A089149	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5A, 600V A1A090211	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5A, 600V A1A090211	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 2A, 600V A1A090715 and Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637
80/112	Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 6A, 600V A1A089148	Fuse Class J, 4.5A, 600V, A1A089637
80/112 R	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 4.5A, 600V A1A089637 and Fuse Class J, 9A, 600V A1A081333	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 2.8A, 600V A1A090711 and Fuse Class J, 5.6A, 600V A1A090716	Fuse Class J, 3A, 600V A1A090206 and Fuse Class J, 6A, 600V A1A089148	Fuse Class J, 2.25A, 600V A1A090712 and Fuse Class J, 4.5A, 600V A1A089637

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APPENDIX

A General Ambient Conditions Table

Condition	Storage	Transport	Operation
Climatic Ambient Conditions			
Ambient Temperature	-5°C to +45°C	-25°C to +70°C	+5°C to +40°C
Relative Air Humidity	<95% (converter must be completely dry before commissioning)	<95% (converter must be completely dry before commissioning)	<95% (condensation not permitted)
Other Climactic Conditions in Accordance with Class	1K3, 1Z2 in accordance with IEC 60721-3-1	2K2 in accordance with IEC 60721-3-2	3K3 in accordance with IEC 60721-3-3
Degree of Pollution	2 without conductive pollution in accordance with IEC 61800-5	2 without conductive pollution in accordance with IEC 61800-5	2 without conductive pollution in accordance with IEC 61800-5
Mechanical Ambient Conditions			
Stationary Vibration, Sinusoidal			
Displacement	1,5 mm (2 to 9 Hz)	3,5 mm (2 to 9 Hz)	0,3 mm (2 to 9 Hz)
Acceleration	5 m/s2 (9 to 200 Hz)	10 m/s2 (9 to 200 Hz) 15 m/s2 (200 to 500 Hz)	1 m/s2 (9 to 200 Hz)
Other Mechanical Conditions in Accordance with Class	1M2 in accordance with IEC 60721-3-1	2M1 in accordance with IEC 60721-3-2	3M1 in accordance with IEC 60721-3-3
Other Ambient Conditions			
Biological Ambient Conditions in Accordance with Class	1B1 in accordance with IEC 60721-3-1	2B1 in accordance with IEC 60721-3-2	3B1 in accordance with IEC 60721-3-3
Chemical Active Substances in Accordance with Class	1C1 in accordance with IEC 60721-3-1	2C1 in accordance with IEC 60721-3-2	3C1 in accordance with IEC 60721-3-3
Mechanical Active Substances in Accordance with Class	1S1 in accordance with IEC 60721-3-1	2S1 in accordance with IEC 60721-3-2	3S1 in accordance with IEC 60721-3-3

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APPENDIX

B Abbreviations and Acronyms

This appendix contains a list of symbols and abbreviations commonly used throughout the Perfect Harmony™ series of manuals.

Abbreviation	Meaning
µ, m/s	Microsecond
°	Degree
#	Number
*	Note
™	Trademark
A	Amp, Amphere
AC	Alternating Current
ADC	Analog to Digital Converter
BCC	Bypass Control Circuit
BDM	Basic Drive Model
BOM	Bill of Material
BPPS	Bypass Power Supply
C	Centigrade
CCB	Cell Control Board
CDM	Control Drive Model
CDS1	Control Disconnect Switch
CE	Communaute Europeenne
CFM	Cubic feet per minute
CLVC	Closed Loop Vector Control
CPS	Control Power Supply

CR	Cut Resistant
CSMC	Closed Loop Synchronous Machine Control
cu	Cubic
curr	Current
D	Depth
DC	Direct Current
DCR	Digital Card Rack
DCS	Distributed Control System
EC	European Community
EEC	European Economic Community
ELV	Extra-low Voltage
EMC	Electromagnetic Compatibility
EPS	Encoder Power Supply
ESD	Electrostatic Discharge
ESP	Electrical Submersible Pump
E-Stop	Emergency Stop
F	Fahrenheit
f_c	Power Cell Output Current Rating Deration for Cell Carrier Frequency
f_o	Power Cell Output Current Rating Deration for Drive Maximum Output Frequency
ft, ‘	Feet
GenIII	Generation III
GenIIIe	Generation IIIe
GenIV	Generation IV
H	Height

Hp	Horsepower
hr	Hour
HV	High Voltage
HVF	Harmonic Voltage Factor
Hz	Hertz
lbs	Pounds
ID	Identification
IEC	International Electrotechnical Commission
IGBT	Insulated Gate Bipolar Transistor
In, “	Inch(es)
IOB	I/O Breakout Board
IOC	Inversion of Control
I/O	Input(s)/Outputs(s)
k	1,000 (Kohm)
kg	Kilogram
kHz	KiloHertz
KR	Key Reset
kV	Kilo Volts
kVA	One-thousand Volt Amps
kVAC	One-thousand Volts Alternating Current
kW	Kilowatt
LED	Light-emitting Diode
LFR	Latch Fault Relay
LVD	Low Voltage Directive

mA	Milliamperes
max	Maximum
MD	Machinery Directive
MHz	Megahertz
min	Minimum, Minute
mm	Millimeter
MV	Medium Voltage
MW	Megawatt
NEMA	National Electrical Manufacturers Association
NSW	Network Switch
NXG	Next Generation Control
OLTM	Open Loop Test Mode
OLVC	Open Loop Vector Control
PC	Personal Computer or Printed Circuit
PCB	Printed Circuit Board
PDS	Power Drive System
PE	Protective Earth
PED	Pressure Equipment Directive
PLC	Programmable Logic Controller
PLL	Phase Locked Loop
ProTops	Process Tolerant Protection Strategy
psi	Pounds Per Square Inch
PWM	Pulse Width Modulated
RCD	Residual-current Device

ref	Reference
RFI	Radio Frequency Interface
RMS	Root-mean-squared
RPM	Revolutions Per Minute
SCB	Signal Conditioning Board
SCR	Silicon Controlled Rectifier
s, sec	Second(s)
SOP	System Operating Program
SMC	Synchronous Motor Control
sw	Switch
TB	Terminal Block
TDD	Total Demand Distortion
THD	Total Harmonic Distortion
TP	Test Point
V	Volts
VA	Volt-Ampheres
VAC	Volts Alternating Current
VAVAILABLE	Available System Output Capability
VDC	Volts Direct Current
VFD	Variable Frequency Motor Drive
V/Hz	Volts per Hertz Control
VMR	Voltage Monitoring Relay
VSI	Voltage Source Indicator
W	Width, Watts

WCIII	Water Cooled III
xfmr, xformer	Transformer

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NOTES

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