

**INSTALLATION MANUAL
FOR
AIR COOLED
PERFECT HARMONY
GENIII/E SERIES**
Adjustable Speed AC Motor Drives with
Next Generation Control

Manual Number: 19000403

Version 1.1

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A Subsidiary of High Voltage Engineering Corporation

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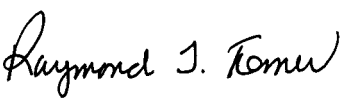
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| declares that the product: | |
| Product Name: | AC Variable Frequency Drives, Perfect Harmony Series GEN II, GEN III, and GEN3E Air Cooled and Liquid Cooled (Product models (459XXX.XX & 3100XXXX.XX)) |
| Product Description: | 50Hz/60Hz, 200 HP to 20,000HP, 2.4 kV to 13.8 kV input, 2.4 kV to 7.2 kV output |
| Product Options: | This declaration covers all options of the product described. |
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This manual applies to all air-cooled Perfect Harmony adjustable-speed AC motor drives including GEN III (GEN3) (200 hp through 10,000 hp) having the following cell sizes:

00A through 5C (460 V cells)
 70, 100, 140, 200, and 260 (630 V cells)
 360H, 315H, 375H, 500H, and 660H (690 V cells).

For the support representative nearest you, please call ASIRobicon's main office at (724)-339-9500.

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Installation Manual for Perfect Harmony Series (p/n 19000403)

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SAFETY PRECAUTIONS AND WARNINGS

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

Danger - Electrical Hazards!

- **Always** follow the proper lock-out/tag-out procedures before beginning any maintenance or troubleshooting work on the drive.
- **Never** touch anything within the Perfect Harmony cabinets (other than the control cabinet) until verifying that it is neither thermally hot nor electrically alive.
- **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 the CE safety standard.
- **Never** assume that switching off the input disconnect will remove all voltage from internal components. Voltage is still present on the terminals of the input disconnect. Also, there may be voltages present that are applied from other external sources.
- **Always** work with one hand, wear insulated or rubber safety shoes, and wear safety glasses. Also, always work with another person present.
- **Use** only instrumentation (e.g., meters, oscilloscopes, etc.) intended for high voltage measurements (that is, isolation is provided inside the instrument, not provided by isolating the chassis ground of the instrument). Never defeat the instrument's grounding.
- **Never** remove safety shields (marked with a **HIGH VOLTAGE** sign) or attempt to measure points beneath the shields.
- **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.
- **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.
- **Never** run the drive with cabinet doors open. The only exception is the control cabinet, which contains extra low voltages (ELV).
- **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."



Warning!

- **Never** disconnect control power while medium voltage is energized. This could cause severe system overheating and/or cell damage.
- **Never** store flammable material in, on or near the drive enclosure. This includes equipment drawings and manuals.
- **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** 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** comply with local codes and requirements if disposal of failed components is necessary (for example, CPU battery, capacitors, etc.).
- **During** operation, the nominal weighted sound pressure level may exceed 70 dB at a distance of 1 meter from the drive.



ESD Sensitive Equipment!

Always be aware of electrostatic discharge (ESD) when working near or touching components inside the Perfect Harmony cabinet. The printed circuit boards contain components that are sensitive to static electricity. Handling and servicing of components that are sensitive to ESD should be done only by qualified personnel and only after reading and understanding proper ESD techniques. The following ESD guidelines should be followed. Following these rules can greatly reduce the possibility of ESD damage to PC board components.



- Make certain that anyone handling the Perfect Harmony printed circuit boards is wearing a properly grounded static strap. The wrist strap should be connected to ground through a 1 megaohm 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.
- Always transport static sensitive equipment in antistatic bags.
- When handling a PC board, always hold the card by its edges.
- Do not slide printed circuit boards across any surface (e.g., a table or work bench). If possible, perform PCB maintenance at a workstation that has a conductive covering which is grounded through a 1 megaohm 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.
- Always use a soldering iron that has a grounded tip. Also, use either a metallic vacuum-style plunger or copper braid when desoldering.
- When returning components to ROBICON, 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.



ABOUT THIS MANUAL

Separation of Manuals

This manual is one component of a three-part series of manuals intended for use with the Perfect Harmony series of adjustable speed AC motor drives. Each part in this series is for use by individuals having unique job functions and qualifications. The manuals in this series are listed below:

- Installation Manual (this manual) (manual number 19000403)
- User's Manual (manual number 19000405)
- Startup and Advanced Topics Manual (manual number 19000404)

The *Installation Manual* provides a brief overview of the product including a hardware overview and important safety issues. The steps leading up to and including the installation of the drive are discussed in detail in this manual.

The *User's Manual* is for use by operators of the drive. The User's Manual contains a brief overview of the product including a hardware overview of the external components of the drive and basic safety precautions. The keypad and display interface is explained in detail. A parameter listing is provided for reference. A troubleshooting and maintenance section is also provided in this section to help the operator to diagnose and correct any potential problems that may occur, and reduce the potential for future problems through inspections and regular maintenance.

The *Startup and Advanced Topics Manual* is intended to address the more technical aspects of drive setup, configuration and operation. This manual includes detailed descriptions of all parameters, functions, and picklist menu items. Software setup and startup procedures are also included. Advanced topics such as the theory of operation, technical specifications, system programming, compiler and reverse compiler software operation, uploading and downloading functions, and other application and operation issues are discussed.

All manuals in this series contain a glossary of terms, a list of commonly used abbreviations, and other reference tools. In addition, a readers' comments form is provided. 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
- a list of all figures and their associated captions as they appear in the manual
- a list of all tables and their associated titles as they appear in the manual
- 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 with special locator references for illustrations and tables.

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 ASIROBICON.

Conventions Used in this Manual

The following conventions are used throughout this manual.

- This manual for use with the CE Mark Perfect Harmony product line.
- The terms “Perfect Harmony”, “VFD”, “variable frequency drive” and “drive” are used interchangeably throughout this manual.



Note icons in the outer margins alert readers of important operational or application information that may have extra special significance. The associated text is enclosed in a border for high visibility.



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



Caution - Electrical Hazard! Electrical hazard icons in the outer margins alert readers of 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 outer margins alert readers of static sensitive devices. Proper electrostatic discharge precautions should be taken before proceeding or handling the equipment.

- Chapter numbers are highlighted in the outer margins to facilitate referencing (see margin).
- Test points and terminal block designations are shown in uppercase, boldface, 8 pt Arial fonts (e.g., **TB1A**).
- In the index, locator page numbers appear in regular type faces for standard index references (e.g., 7-10). For index references that correspond to items found in tables, the locator page numbers are shown in an italic type face (e.g., 6-24). For index references that correspond to items found in figures and illustrations, the locator page numbers are shown in a boldface type face (e.g., **3-3**). Illustrations that also appear in tables have locator page numbers that are both boldface and italic (e.g., **6-16**).
- The symbol “▽ ▽ ▽” is used to mark the end of each section.

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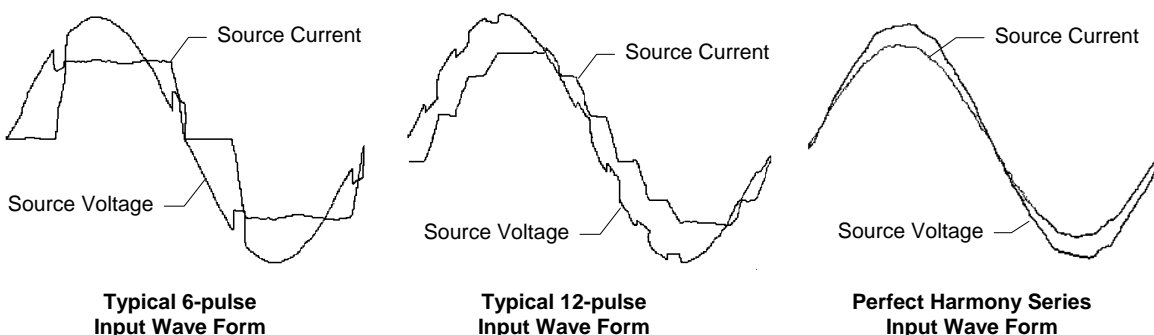
CHAPTER 1: INTRODUCTION

1.1. Introduction to the Perfect Harmony

Perfect Harmony is a series of pulse-width modulated, variable frequency AC motor drives designed and manufactured by ASI Robicon. The Perfect Harmony drive system addresses the following power quality issues: providing clean power input, providing a high power factor, and providing nearly perfect sinusoidal output.

1.1.1. Clean Power Input

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



**Figure 1-1. Harmonic Distortion Wave Form Comparisons
(6-pulse, 12-pulse and Perfect Harmony)**

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

The above comparisons were done using a typical 1,000 hp current source drive (6-pulse and 12-pulse modes) and a Perfect Harmony series drive operating from a 1100 kVA, 5.75% impedance source.



1.1.2. High Power Factor and Nearly Perfect Sinusoidal Input Currents

Power factor is a measure of the fraction of current that produces real power to the load. Typically, power factor is given as a percentage. A high power factor VFD (e.g., 95%) makes much better use of its input line current demand in producing real power to the motor than a VFD operating at a low power factor (e.g., 30%). VFDs having low operating power factor often generate square-wave shaped line currents. 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 95% throughout the entire speed range without the use of external power factor correction capacitors. This eliminates utility penalties for power factor and demand charges, and improves voltage regulation. In addition, feeders, breakers and transformers are not overloaded with reactive power. Low speed applications specifically benefit from the Perfect Harmony series because a high and stable power

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factor is maintained throughout the entire speed range using standard induction motors. **Figure 1-2** compares graphs of power factor versus percent speed for the Perfect Harmony series and a typical phase-controlled SCR drive.

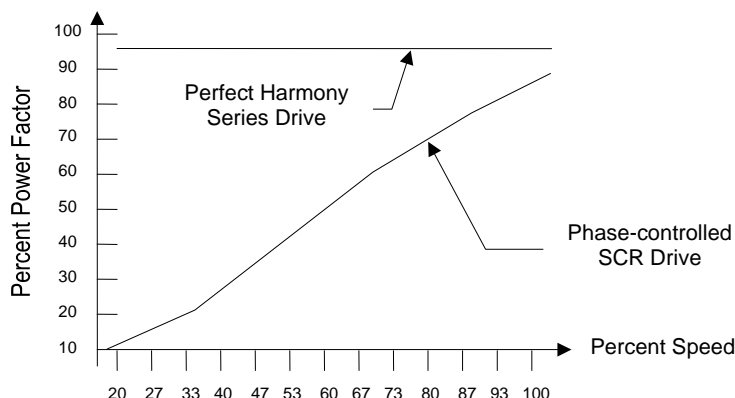


Figure 1-2. Comparison of Perfect Harmony and a Typical Phase-controlled SCR Drive

1.1.3. Nearly Perfect Sinusoidal Output Voltages

The design of the Perfect Harmony series of variable frequency drives inherently provides a sinusoidal output without the use of external output filters. This means that the drive provides a low distortion output voltage wave form 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 which cause motor heating. Similarly, VFD-induced torque pulsations are eliminated (even at low speeds), thereby reducing the stress on mechanical equipment. Common mode voltage stress and dV/dt stress are also minimized. A typical graph of the output current from a Perfect Harmony drive is illustrated in **Figure 1-3**.

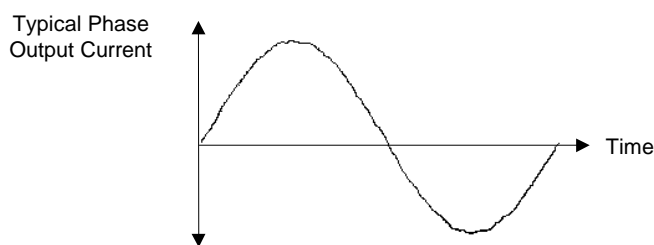


Figure 1-3. Nearly Sinusoidal Wave Form of the Output Current from a Perfect Harmony Drive

1.2. Hardware Overview

The cabinet configurations of Perfect Harmony drives vary based on the horsepower of the drive, the number and type of cells, and other factors. However, cabinet configurations can generally be divided into two broad categories:

- GEN III style (shown in **Figure 1-4**)
- GEN IIIe style (shown in **Figure 1-5**)

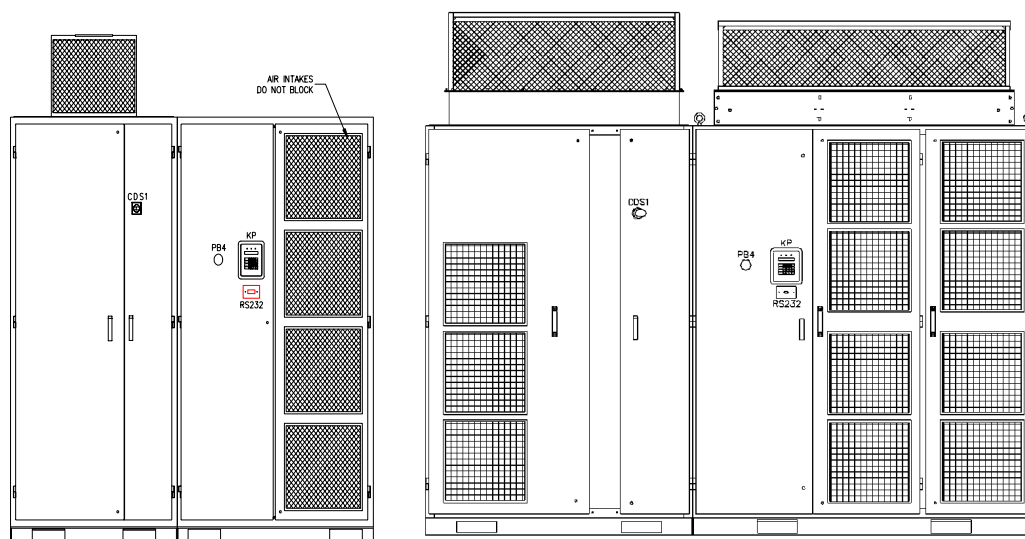


Figure 1-4. Typical 4,160V (Left) and 6,600V (Right) GEN III Perfect Harmony VFDs

This style is discussed in Chapter 2: Hardware Components.

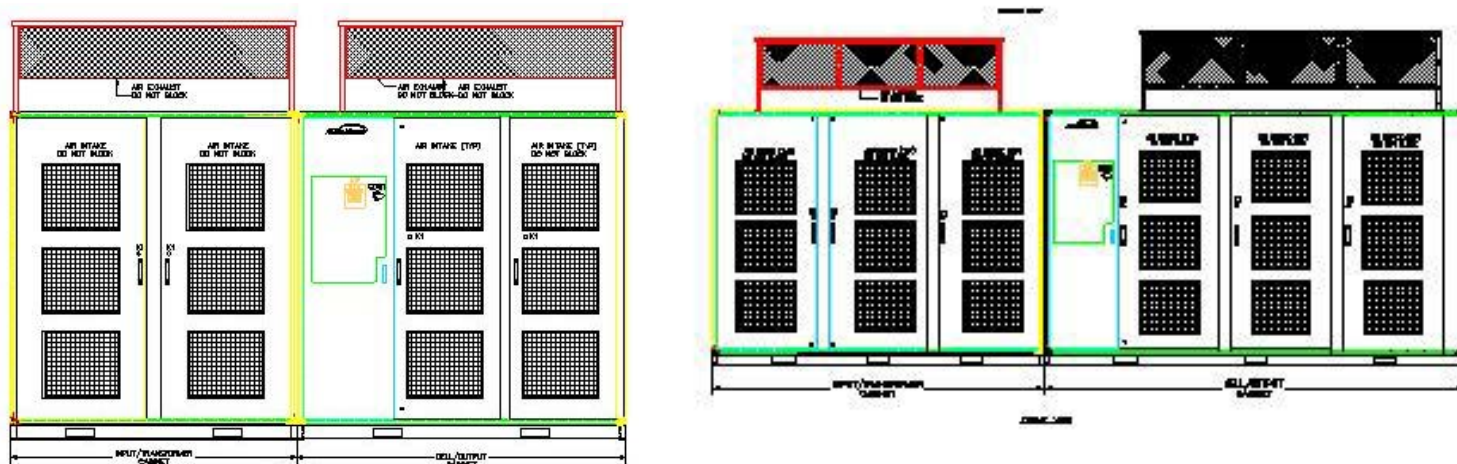


Figure 1-5. Typical 4,160V (Left) and 6,600V (Right) GENIIIe Perfect Harmony VFDs

1**1.3. Features Overview**

Additional features of the Perfect Harmony drive include the following:

- redundant cooling blowers
- high efficiency
- reliability
- modular construction
- surge arrestors
- fiber optic control circuitry
- soft start protection
- multi-motor operation
- trip-free operation
- dual performance operation modes
- undervoltage ride-through
- spinning load restart
- transparent cell bypass
- PC tool interface
- power cell check
- cell back-up
- serial port
- reports capabilities
- micro PLC capabilities
- keypad and English message display
- on-line diagnostics
- digital display module
- advanced diagnostics
- on-line operation while tuning
- industry standard communications
- dual frequency braking
- auto tuning
- input monitoring

1.4. Specifications

Table 1-1 lists common electrical and mechanical specifications for all standard Perfect Harmony systems. Note that Perfect Harmony specifications may be changed without notice.

Table 1-1. Common Specifications for Standard Perfect Harmony Systems

| Item | Description |
|--|---|
| hp range | GEN III: Up to 3,000 hp at 6,300V GEN IIIe: Up to 8000hp at 6,600V |
| Input line voltages | 2.2 kV, 3.0 kV, 3.3 kV, 4.1 kV, 4.8 kV, 6.0 kV, 6.6 kV, 6.9 kV, 7.2 kV, 8.4 kV, 10.0 kV, 11.0 kV, 12.0 kV, 12.5 kV, 13.2 kV, and 13.8 kV. |
| Input voltage tolerance | +10%, -5% from nominal 3-phase at rated output |
| Input power factor | 0.95 above 10% load |
| Output line voltages | 2.4 kV, 3.3 kV, 4.16 kV, 4.8 kV, 6.0 kV, 6.6 kV, 6.9 kV, and 7.2 kV. |
| Output frequency drift | ±0.5% |
| Speed range | 0.5-330 Hz (motor dependent) |
| Overload capability | A function of the installed type of cell. |
| Accel/decel time range | 0.5-3,200 sec (load dependent) |
| Output torque | 15-139 Hz rated torque; 3-14 Hz and 140-330 Hz derated torque |
| Enclosure | NEMA 1 ventilated, IP31 |
| Ambient temperature | 0-40°C |
| Storage Temperature (System w/o Cells) | -40 to 70°C |
| Storage Temperature (Cells*) | -55 to 45°C |
| Humidity | 95% non-condensing |
| Altitude | Up to 3,300 feet. Above 3,300 feet require derating. |
| Dust contamination | <100 micron @ 6.5 mg/cu. ft. |
| Gas contamination | <4 PPB reactive halides and sulfides |

*Non-energized cells should not be stored at more than 45°C to preserve reliability of Filter Capacitors. Non-energized cells stored for more than two (2) years should be reformed per procedure indicated in Section 3-12 of this manual.

1



CHAPTER 2: HARDWARE COMPONENTS

2.1. Hardware Configuration

Figure 2-1 depicts a typical GEN III style configuration in which each VFD normally consists of a single cabinet with multiple sections. These sections, described below, are:

- the transformer section
- the customer I/O section
- the control section
- the cell section

Depending on the HP and voltage ratings, some GENIII systems may be shipped as a single unit in which the Transformer and Cell Cabinet are integrated into one unit. Larger GENIII systems may be shipped so that the Transformer and Cell Cabinets are split due to size and weight restrictions. In all GENIII systems, the input and output connections are located in the Transformer Cabinet. The control section is a swinging panel that resides in the left side of the cell cabinet.

Figure 2-2 depicts a typical GEN IIIe style configuration in which each VFD of a Cell/Control cabinet connects to a Transformer Cabinet. These sections, described below, are:

GENIIIe (which are higher current versions of GENIII systems) is always shipped so that the Transformer and Cell Cabinets are separated. In these systems, the Output section is always on the left side of the cell cabinet (behind the control panel) and the Input section is always in the Transformer Cabinet. The control section is a swinging panel that resides in the left side of the cell cabinet.

2

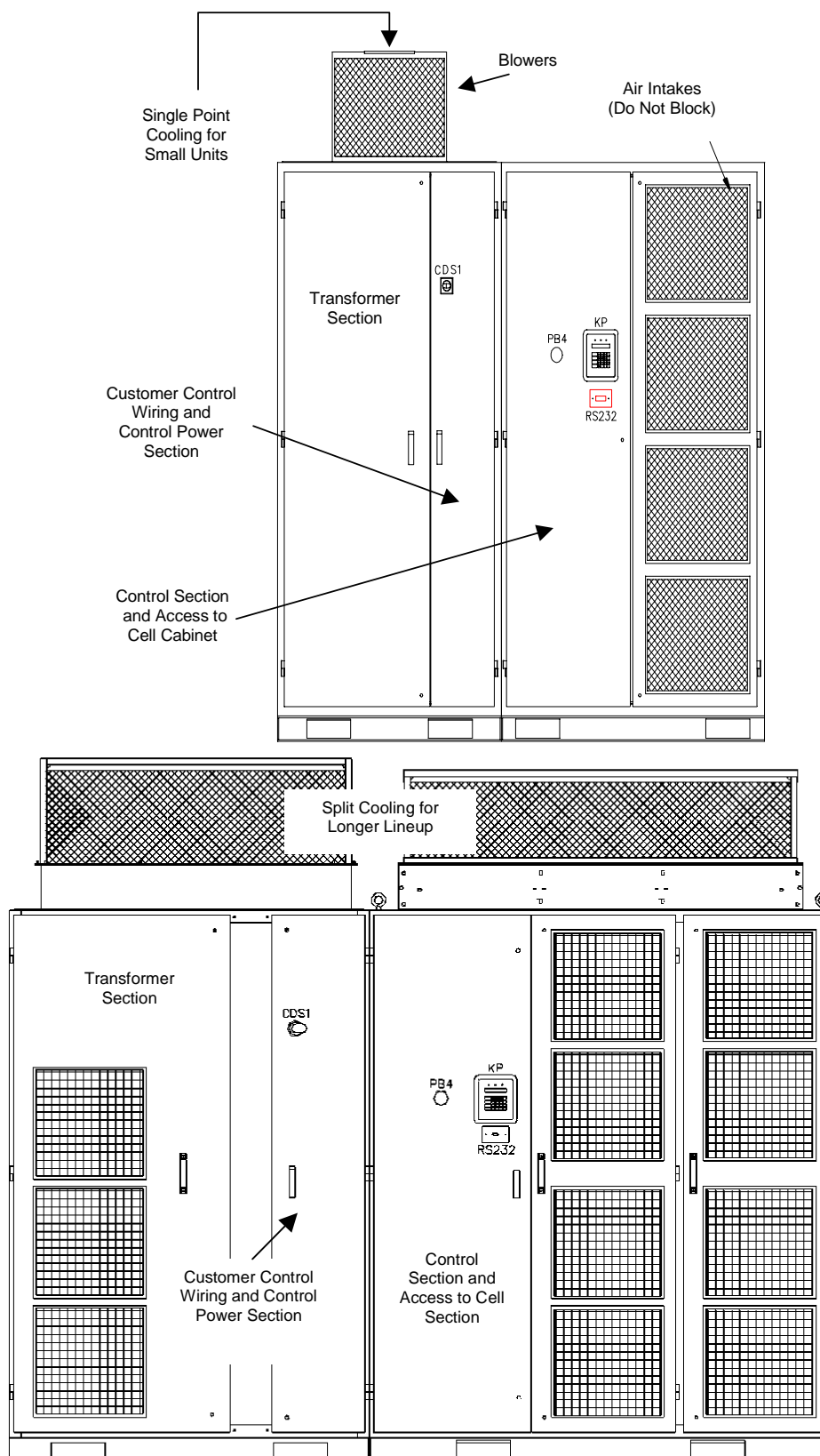


Figure 2-1. Typical GEN III-style VFDs

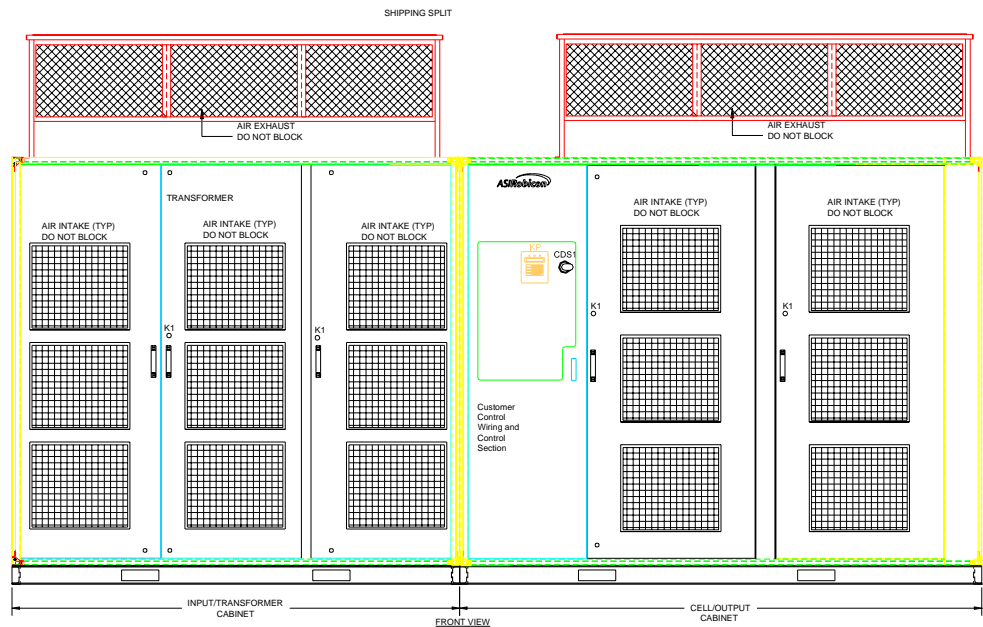


Figure 2-2. Typical GEN IIIe-style VFDs

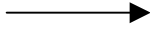
2.1.1. Transformer Section

The transformer section of the Perfect Harmony drive contains the input power transformer. Input power wires enter the drive through this section and output wires to the motor exit the drive through this section. The input and output power wiring can enter and exit the drive from either the top or bottom of this section. In addition to the main multi-secondary phase-shifting power transformer, the transformer section contains either one or more blowers (at the top of the cabinet) used to cool the drive. Refer to Figure 2-3. Major components of the transformer section are illustrated in Figure 2-3 and described in **Table 2-1**.

Input and output wiring enters the cabinet from the top or bottom of the transformer section.

2

Blower

**Figure 2-3. Power Section (Typical) of a GEN III-style Perfect Harmony Drive****Table 2-1. Field Connections and Major Components in the Transformer Section**

| Item | Description |
|---------------------------|--|
| L1, L2, L3 | Input power terminals |
| T1, T2, T3 | Output power terminals |
| T1 | Multi-secondary, phase-shifting power transformer |
| T5 | Control power transformer |
| F24-F35 | Control fuses |
| F21, F22 | Blower fuses |
| F4, F5 | Fuses |
| BM1-BM5 | Blower motor starters |
| CDS1 | Control power disconnect switch |
| RA1-RA4, RB1-RB4, RC1-RC4 | Input and output voltage feedback resistors |
| CT4, CT5 | Output current transformers |
| TB-120-CUS | Customer wiring terminal strip |
| METERING | Metering terminal strip |
| TB-ELV | Low voltage terminal strip (4-20 mA signals, etc.) |

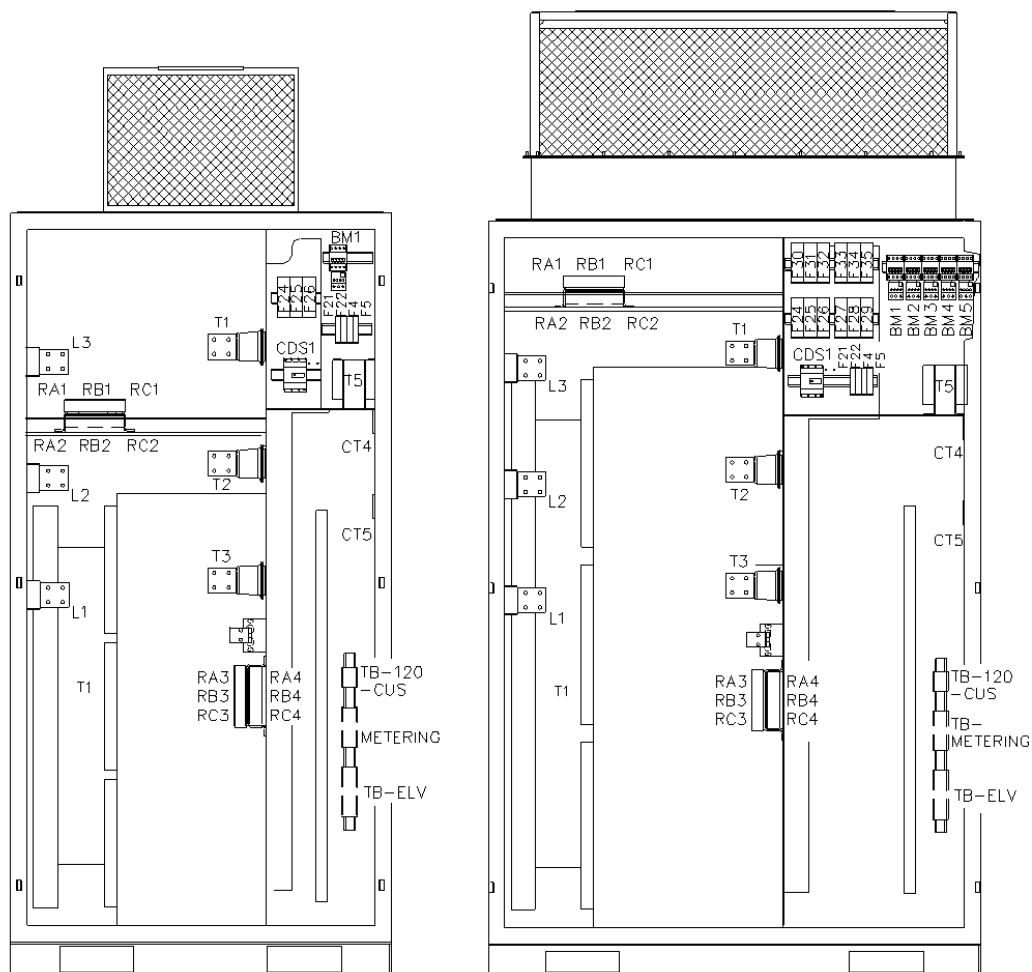


Figure 2-4. Field Connections and Major Components in the GEN III Transformer Section

2

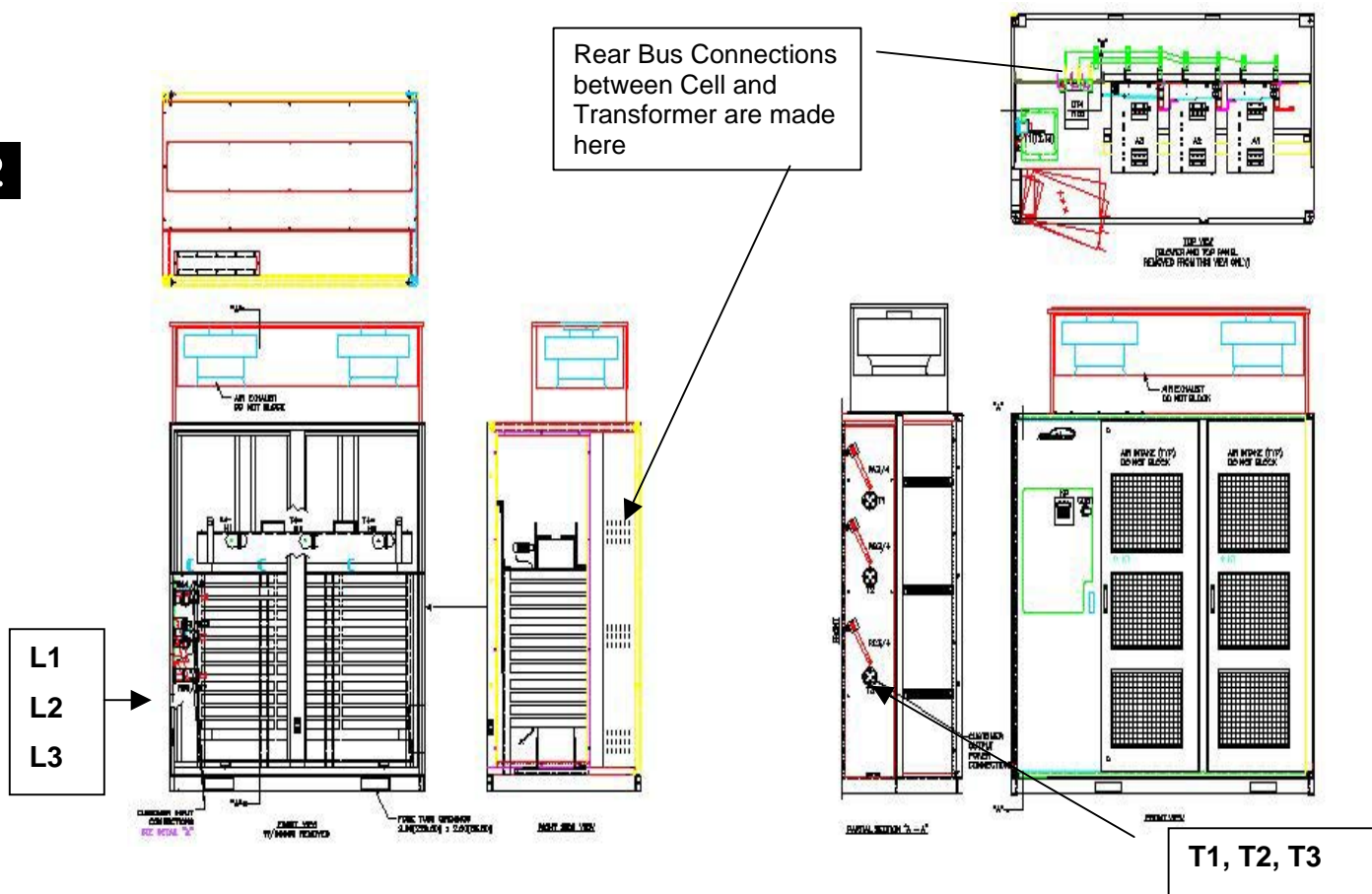


Figure 2-5. Field Connections and Major Components in the GEN IIIe Transformer Section (left) and Cell Section (right)

2.1.2. Customer I/O Section

The customer I/O section of the drive contains terminal blocks for customer control wiring connections, control power connections, and the blower control panel. Optional motor monitors and power quality meters (PQMs) are mounted in this section if they are ordered with the drive. Refer to **Figure 2-6**.

*Refer to the “as built” system drawings that are shipped with the drive for information on specific customer I/O connections.



Note: The rear bus connections need to be made prior to startup. It is recommended, but not necessary, to have a minimum of two feet between the rear of the VFD and any wall or structure. This is to allow easier connection of the rear bus between the transformer and the cell cabinets. The VFD can be moved against the wall once the connections are made and the rear panel re-installed. If space behind the VFD cannot be provided, the connections are made by removing the hall effect CT's and the panels between the fuse group. These are located behind the control box.



Figure 2-6. Customer I/O Section (Typical) of a GEN III-style Perfect Harmony Drive

2.1.3. Cell and Control Sections (GEN III Cell Specifications)

The control section is a hinged section that swings out to provide access to the cell section. The control section contains master control components. The cell section contains power cells and up to three blowers mounted on top of the cabinet.

The AC drive system is offered in 5 basic cell sizes (current ratings), grouped to provide output operating voltages of 3300 VAC (3 cells in series), 4160 VAC (4 cells in series), 4800 VAC (5 cells in series), and 6600 VAC (6 cells in series). **Table 2-2** provides the basic specifications associated with all cell combinations for the drives.

Note: Output current ratings are a function of the selected cell size. Input current ratings are a function of the transformer size associated with each hp rating. All specifications are subject to change without notice.



Table 2-2. GENIII Cell Specification Details

| Output Cells Per Phase | Line-to-line Voltages (VAC) | Cells in Drive (Without Spares) | hp Range | Available Cell Sizes |
|------------------------|-----------------------------|---------------------------------|------------|-----------------------------|
| 3 | 3,300 | 9 | up to 1500 | 70A, 100A, 140A, 200A, 260A |
| 4 | 4,160 | 12 | up to 2000 | 70A, 100A, 140A, 200A, 260A |
| 6 | 6,600 | 18 | up to 3000 | 70A, 100A, 140A, 200A, 260A |

Table 2-3. GENIIIe Cell Specification Details

| Output Cells Per Phase | Line-to-line Voltages (VAC) | Cells in Drive (Without Spares) | hp Range | Available Cell Sizes |
|------------------------|-----------------------------|---------------------------------|------------|------------------------|
| 2 | 2,300 | 6 | up to 3000 | 315A, 375A, 500A, 660A |
| 3 | 3,300 | 9 | up to 4000 | 315A, 375A, 500A, 660A |
| 4 | 4,160/4,800 | 12 | up to 6000 | 315A, 375A, 500A, 660A |
| 5 | 6,000 | 15 | up to 8000 | 315A, 375A, 500A, 660A |
| 6 | 6,600 | 18 | up to 0000 | 315A, 375A, 500A, 660A |

The individual output cells are located in the Cell Section. All cells are electrically and mechanically identical, so that they may be interchanged. Each cell contains its own control boards, which communicate with the system through a fiber optic link. This link is the only connection between the cells and the master control located in the Control Section, thus each cell is isolated from the main control. Refer to **Figure 2-7** for GENIII type cell. Refer to **Figure 2-8** and **Figure 2-9** for GENIIIe type cells.

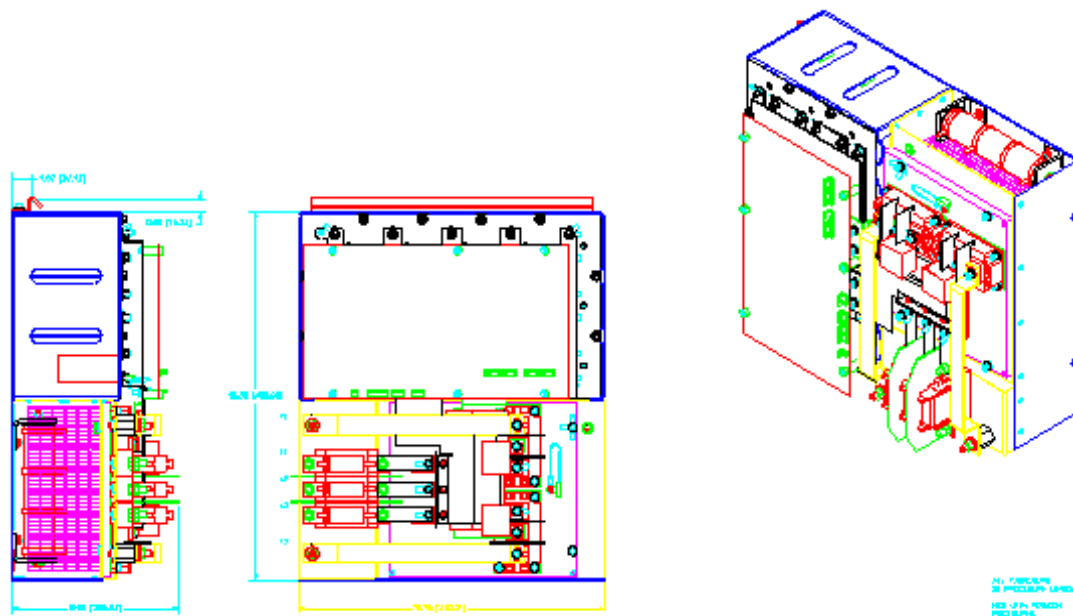


Figure 2-7. Typical GEN III Cell

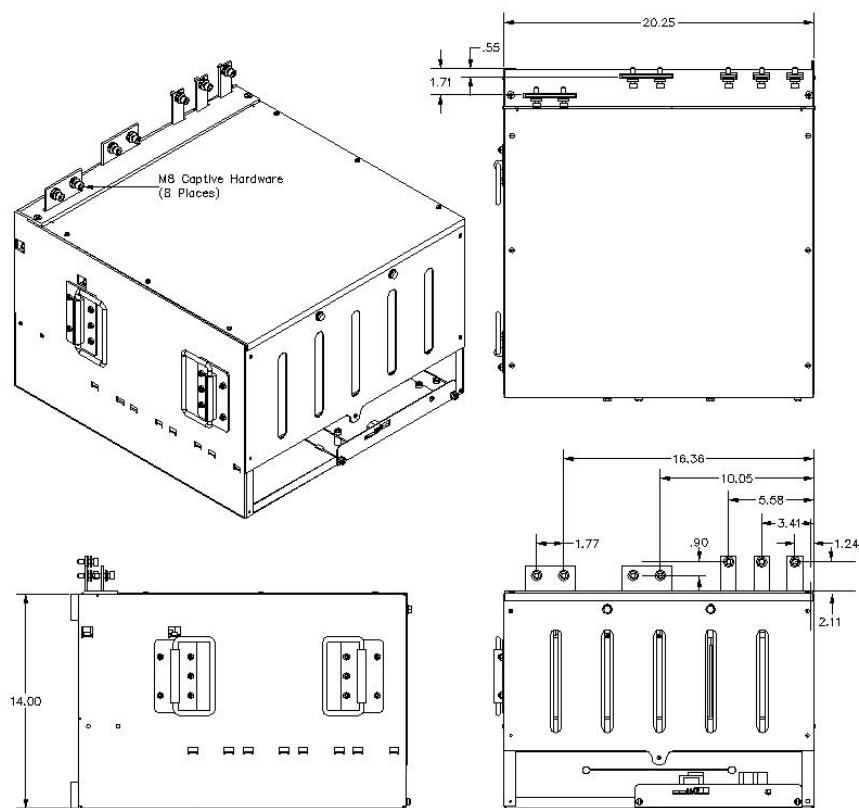


Figure 2-8. Typical GENIIIe Cell

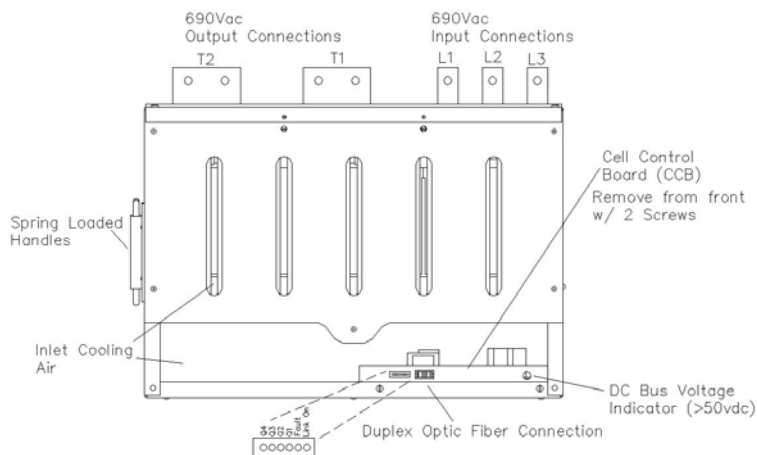


Figure 2-9. Details of GENIIIe Terminals and Indicators



Figure 2-10. Cell Section (Typical) of a GEN III-style Perfect Harmony Drive

A switch mode power supply located on the Cell Control/Gate Driver Board allows the control power to be derived from the individual 3-phase secondary connections of the transformer.

The Control Section contains PC boards which provide central control of the Perfect Harmony drive system. The Control Section is physically and electrically isolated from all medium voltage for safety.

Control for each of the output cells is provided via a fiber optic communications link between the Master Control System and the Cell Control/Gate Driver Board located within each output cell.

The following tables give length and weight information for many common configurations of sectional Perfect Harmony drives, based on 60 Hz input power at the voltages listed. If applications require inputs at 50 Hz or HP not listed, sizes and weights will increase. GenIIIe weights and ventilation are estimated.



Note: The ventilation information (in CFM) and losses information (in BTUs) given in the following tables represent worst case conditions. Actual values may vary based on load, blower size, cell size and transformer size.

Table 2-4. 3,300 VAC GENIII Cell Specifications: 9 Cells Total, 3 (630 VAC) Cells in Series

| Hp ¹ | Amps In ² | Amps Out ³ | Losses ⁴ | Ventilation ⁵ | Length ⁶ | Weight ⁷ | Size ⁸ |
|-----------------|----------------------|-----------------------|---------------------|--------------------------|---------------------|---------------------|-------------------|
| 200 | 33 | 70 | 20,000 | 4,400 | 100 | 4,800 | 70 |
| 300 | 49 | 70 | 30,000 | 4,400 | 100 | 4,800 | 70 |
| 400 | 64 | 70 | 40,000 | 4,400 | 100 | 5,600 | 70 |
| 500 | 80 | 100 | 50,000 | 4,400 | 100 | 6,200 | 100 |
| 600 | 96 | 100 | 60,000 | 4,400 | 100 | 6,200 | 100 |
| 700 | 112 | 140 | 70,000 | 4,400 | 100 | 7,500 | 140 |
| 800 | 128 | 140 | 80,000 | 4,400 | 100 | 7,500 | 140 |
| 900 | 145 | 200 | 90,000 | 8,800 | 123 | 7,500 | 200 |
| 1000 | 162 | 200 | 100,000 | 8,800 | 123 | 8,000 | 200 |
| 1250 | 202 | 260 | 125,000 | 8,800 | 137 | 8,500 | 260 |
| 1500 | 242 | 260 | 150,000 | 8,800 | 137 | 9,000 | 260 |

Table 2-5. 4,160 VAC GENIII Cell Specifications: 12 Cells Total, 4 (630 VAC) Cells in Series

| Hp ¹ | Amps In ² | Amps Out ³ | Losses ⁴ | Ventilation ⁵ | Length ⁶ | Weight ⁷ | Size ⁸ |
|-----------------|----------------------|-----------------------|---------------------|--------------------------|---------------------|---------------------|-------------------|
| 300 | 38 | 70 | 30,000 | 4,400 | 100 | 5,100 | 70 |
| 400 | 51 | 70 | 40,000 | 4,400 | 100 | 5,100 | 70 |
| 500 | 63 | 70 | 50,000 | 4,400 | 100 | 5,800 | 70 |
| 600 | 75 | 100 | 60,000 | 4,400 | 100 | 6,600 | 100 |
| 700 | 89 | 100 | 70,000 | 4,400 | 100 | 6,600 | 100 |
| 800 | 101 | 140 | 80,000 | 4,400 | 100 | 7,700 | 140 |
| 900 | 114 | 140 | 90,000 | 4,400 | 100 | 7,700 | 140 |
| 1000 | 126 | 140 | 100,000 | 4,400 | 100 | 7,700 | 140 |
| 1250 | 160 | 200 | 125,000 | 8,800 | 137 | 9,500 | 200 |
| 1500 | 192 | 200 | 150,000 | 8,800 | 137 | 9,500 | 200 |
| 1750 | 224 | 260 | 175,000 | 8,800 | 137 | 10,000 | 260 |
| 2000 | 256 | 260 | 200,000 | 8,800 | 137 | 11,000 | 260 |

Table 2-6. 6,600 VAC GENIII Cell Specifications: 18 Cells Total, 6 (630 VAC) Cells in Series

| Hp ¹ | Amps In ² | Amps Out ³ | Losses ⁴ | Ventilation ⁵ | Length ⁶ | Weight ⁷ | Size ⁸ |
|-----------------|----------------------|-----------------------|---------------------|--------------------------|---------------------|---------------------|-------------------|
| 600 | 48 | 70 | 60,000 | 8,800 | 137 | 7,700 | 70 |
| 700 | 56 | 70 | 70,000 | 8,800 | 137 | 9,000 | 70 |
| 800 | 64 | 70 | 80,000 | 8,800 | 137 | 9,000 | 70 |
| 900 | 72 | 100 | 90,000 | 8,800 | 137 | 9,000 | 100 |
| 1000 | 80 | 100 | 100,000 | 8,800 | 137 | 10,400 | 100 |
| 1250 | 100 | 100 | 125,000 | 8,800 | 137 | 10,400 | 100 |
| 1500 | 120 | 140 | 150,000 | 8,800 | 137 | 12,300 | 140 |
| 1750 | 140 | 140 | 175,000 | 8,800 | 137 | 12,300 | 140 |
| 1750 | 141 | 200 | 175,000 | 13,200 | 172 | 12,500 | 200 |
| 2000 | 162 | 200 | 200,000 | 13,200 | 192 | 13,000 | 200 |
| 2250 | 182 | 200 | 225,000 | 13,200 | 192 | 13,000 | 200 |
| 2500 | 202 | 260 | 250,000 | 13,200 | 192 | 13,500 | 260 |
| 2750 | 222 | 260 | 275,000 | 13,200 | 192 | 14,000 | 260 |
| 3000 | 242 | 260 | 300,000 | 13,200 | 192 | 14,000 | 260 |

Table 2-7. 2,300 VAC GENIIIe Cell Specifications: 6 Cells Total, 2 (690 VAC) Cells in Series

| Hp ¹ | Amps In ² | Amps Out ³ | Losses ⁴ | Ventilation ⁵ | Length ⁶ | Weight ⁷ | Size ⁸ |
|-----------------|----------------------|-----------------------|---------------------|--------------------------|---------------------|---------------------|-------------------|
| 1500 | 324 | 375 | 114,000 | 8,800 | 172 | 7,450 | 375H |
| 1750 | 378 | 375 | 133,000 | 8,800 | 172 | 8,200 | 375H |
| 2000 | 432 | 500 | 152,000 | 8,800 | 172 | 8,800 | 500H |
| 2250 | 486 | 500 | 171,000 | 8,800 | 172 | 9,500 | 500H |
| 2500 | 540 | 660 | 190,000 | 8,800 | 172 | 10,200 | 660H |
| 3000 | 648 | 660 | 228,000 | 8,800 | 188 | 11,500 | 660H |

Table 2-8. 3,300 VAC GENIIIe Cell Specifications: 9 Cells Total, 3 (690 VAC) Cells in Series

| Hp ¹ | Amps In ² | Amps Out ³ | Losses ⁴ | Ventilation ⁵ | Length ⁶ | Weight ⁷ | Size ⁸ |
|-----------------|----------------------|-----------------------|---------------------|--------------------------|---------------------|---------------------|-------------------|
| 1750 | 264 | 315 | 133,000 | 15,000 | 172 | 9,700 | 315H |
| 2000 | 301 | 315 | 152,000 | 15,000 | 172 | 11,200 | 315H |
| 2250 | 339 | 375 | 171,000 | 15,000 | 172 | 11,200 | 375H |

HARDWARE COMPONENTS**Perfect Harmony GENIII/e Installation Manual**

| Hp ¹ | Amps In ² | Amps Out ³ | Losses ⁴ | Ventilation ⁵ | Length ⁶ | Weight ⁷ | Size ⁸ |
|-----------------|----------------------|-----------------------|---------------------|--------------------------|---------------------|---------------------|-------------------|
| 2500 | 377 | 375 | 190,000 | 15,000 | 172 | 12,000 | 375H |
| 3000 | 452 | 500 | 228,000 | 15,000 | 188 | 13,400 | 500H |
| 3500 | 527 | 660 | 266,000 | 15,000 | 188 | 14,900 | 660H |
| 4000 | 603 | 660 | 304,000 | 15,000 | 188 | 16,400 | 660H |

2**Table 2-9. 4,160 VAC GENIIIe Cell Specifications: 12 Cells Total, 4 (690 VAC) Cells in Series**

| Hp ¹ | Amps In ² | Amps Out ³ | Losses ⁴ | Ventilation ⁵ | Length ⁶ | Weight ⁷ | Size ⁸ |
|-----------------|----------------------|-----------------------|---------------------|--------------------------|---------------------|---------------------|-------------------|
| 2250 | 269 | 315 | 171,000 | 18,000 | 192 | 13,800 | 315H |
| 2500 | 299 | 315 | 190,000 | 18,000 | 192 | 14,600 | 315H |
| 3000 | 359 | 375 | 228,000 | 18,000 | 208 | 16,200 | 375H |
| 3500 | 418 | 500 | 266,000 | 18,000 | 208 | 17,900 | 500H |
| 4000 | 487 | 500 | 304,000 | 18,000 | 208 | 19,100 | 500H |
| 5000 | 598 | 660 | 380,000 | 18,000 | 232 | 22,800 | 660H |

Table 2-10. 6,000 VAC GENIIIe Cell Specifications: 15 Cells Total, 5 (690 VAC) Cells in Series

| Hp ¹ | Amps In ² | Amps Out ³ | Losses ⁴ | Ventilation ⁵ | Length ⁶ | Weight ⁷ | Size ⁸ |
|-----------------|----------------------|-----------------------|---------------------|--------------------------|---------------------|---------------------|-------------------|
| 3500 | 290 | 315 | 266,000 | 25,000 | 248 | 20,100 | 315H |
| 4000 | 331 | 375 | 304,000 | 25,000 | 272 | 21,900 | 375H |
| 5000 | 414 | 500 | 380,000 | 25,000 | 272 | 25,500 | 500H |
| 6000 | 497 | 500 | 450,000 | 25,000 | 272 | 29,100 | 500H |
| 7000 | 580 | 660 | 532,000 | 25,000 | 272 | 32,700 | 660H |

Table 2-11. 6,600 VAC GENIIIe Cell Specifications: 18 Cells Total, 6 (690 VAC) Cells in Series

| Hp ¹ | Amps In ² | Amps Out ³ | Losses ⁴ | Ventilation ⁵ | Length ⁶ | Weight ⁷ | Size ⁸ |
|-----------------|----------------------|-----------------------|---------------------|--------------------------|---------------------|---------------------|-------------------|
| 3500 | 264 | 315 | 266,000 | 28,000 | 248 | 21,900 | 315H |
| 4000 | 301 | 315 | 304,000 | 28,000 | 272 | 23,800 | 315H |
| 5000 | 377 | 375 | 380,000 | 28,000 | 272 | 27,700 | 375H |
| 6000 | 452 | 500 | 450,000 | 28,000 | 272 | 31,600 | 500H |
| 7000 | 527 | 660 | 532,000 | 28,000 | 272 | 35,500 | 660H |
| 8000 | 603 | 660 | 608,000 | 28,000 | 272 | 39,400 | 660H |

¹ Motor nameplate hp may not exceed the drive rated hp.² Drive rated input current (in Amps) is the transformer rated current.³ Drive rated output current (in Amps) is the maximum cell current.⁴ Losses are given in BTU/hr and are based on a loss of 3 kW per 100 hp.⁵ Minimum ventilation requirements are given in CFM (lps in parentheses)⁶ Represents lineup minimum length in inches (centimeters in parentheses), subject to change.⁷ Represents estimated minimum weight of lineup in pounds (kg in parentheses), subject to change.⁸ Cell sizes for each hp are based on motors with $\geq 95\%$ efficiency and $\geq 85\%$ power factor.

The basic electrical diagrams for all Perfect Harmony systems are similar. Depending on the operating voltages, different numbers of output cells are operated in series to develop the required output operating voltage (refer to the previous tables).

2.1.4. Cell Bypass Option

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

Anytime a cell malfunctions and is bypassed, the control automatically compensates (shifts the neutral point) so that the motor voltage stays balanced. To compensate for the loss in voltage, systems with up to 5 cells per phase can be equipped (as an option) with an extra cell per phase. The 3 spare cells would then compensate for the loss in voltage. If spare cells are not installed, then the VFD will operate at a slightly lower voltage, but will still provide full rated current.

The cell bypass system includes a bypass contactor per cell, a contactor control board (installed inside the cell cabinet) and a fiber optic link between the master control system and the contactor control board.

2

2.2. The Cell Control System

All Perfect Harmony cells are controlled in the same manner. The Cell Control/Gate Driver Boards reside within the output cell and accept all communication from the Digital Modulator in the Control Cabinet via fiber-optic links.

Control power for all cell boards is supplied from a switch mode power supply resident on the Cell Control/Gate Driver Board.

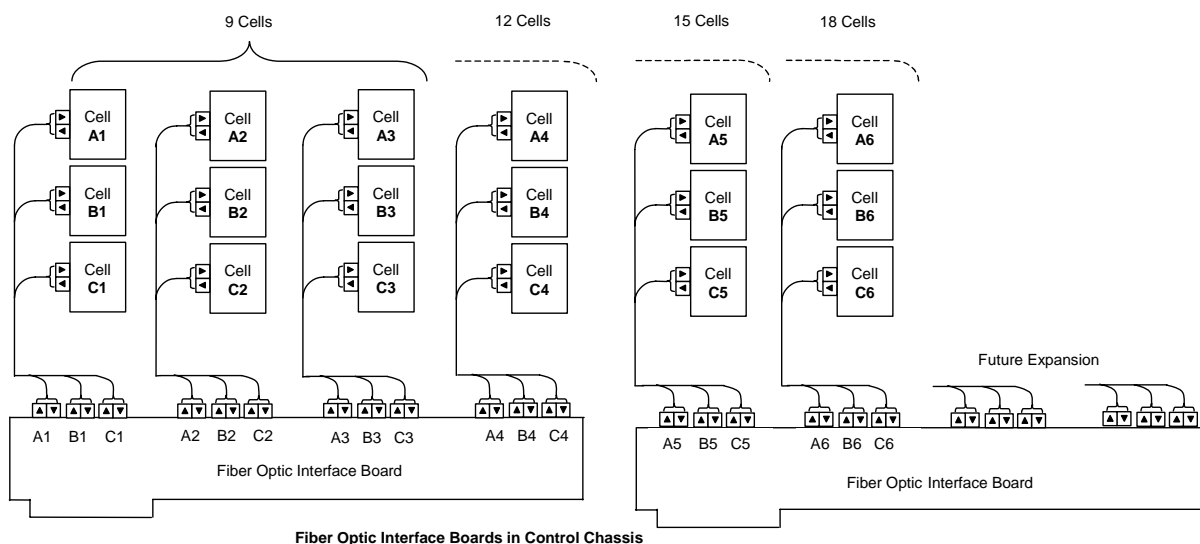


Figure 2-11. Typical Connection Diagram for an 18 Cell 6.6 KV System

2.3. The Master Control System

The Master Control located within the Control Cabinet consists of a chassis and several control boards refer to **Figure 2-12**. The chassis is supplied power by a standalone power supply. The heart of the control is the Microprocessor board. This board is the master of the backplane bus and controls the operation of each board in the system.

Contained on the Microprocessor Board is Flash Disk, which may be removed from the Microprocessor Board if, for any reason, the microprocessor board would need to be replaced. The Flash Disk contains

all the specific parameter information and system program for the VFD and therefore, allows the Microprocessor Board to be replaced without the need to re-program the VFD.



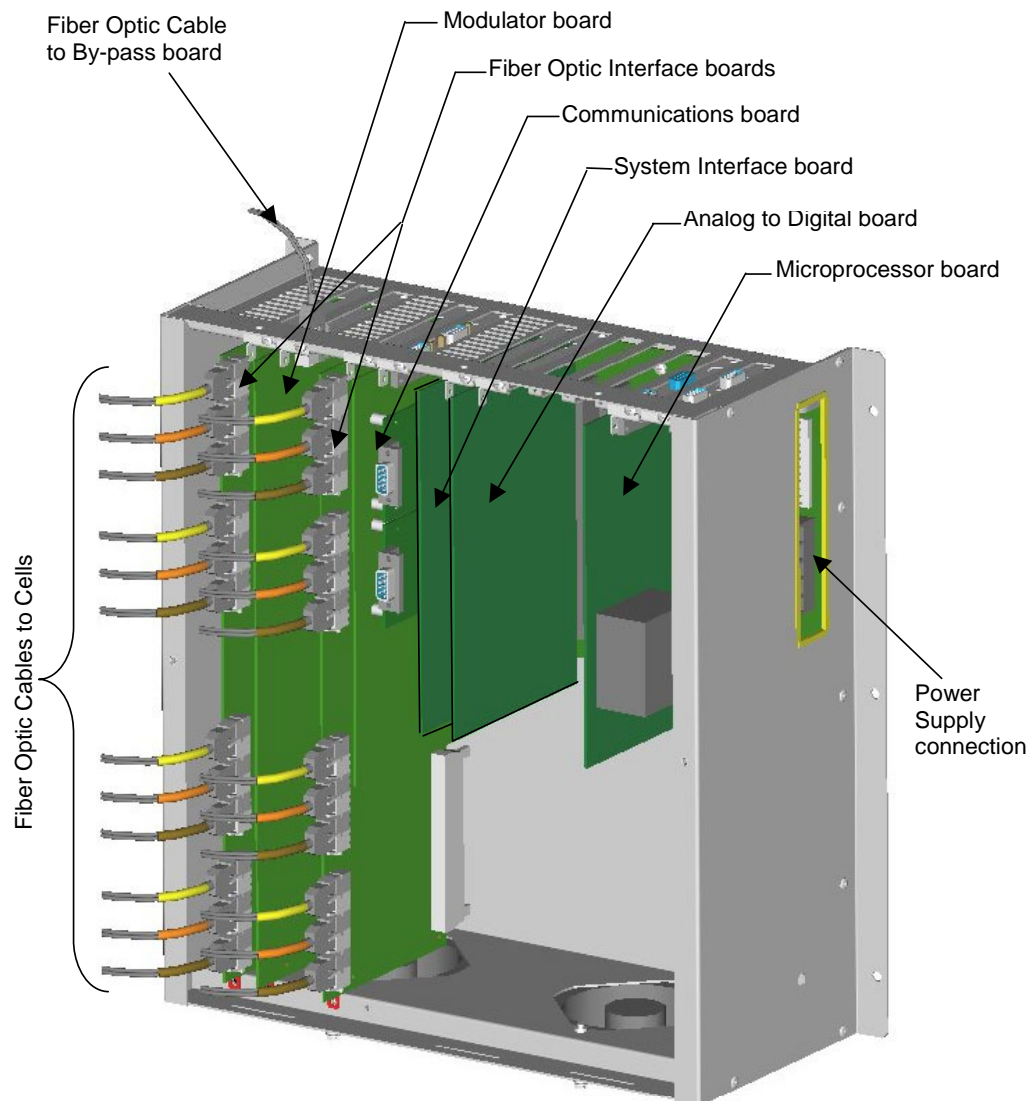
NOTE! If the Microprocessor Board is replaced, the Flash Disk should be moved to the new board. See **Figure 2-13**.

2

The System Interface board collects the drive input and output feedback signals and sends them to the Analog to Digital board. The Analog to Digital board executes the conversion at specified intervals and sends digital representations of the feedback signals to the Microprocessor board. The Microprocessor board then computes the next set of values to be sent to the Digital Modulator and sends them. The Digital Modulator then determines the switching commands for each cell and compiles a message with this command for each cell. These messages are then sent through the Fiber Optic Interface boards. Refer to **Figure 2-12**.

Note that the number of Fiber Optic Interface Boards and the number of fiber optic channels varies depending on the number of cells in the drive.

Also shown in **Figure 2-12** is a communications board. This board provides a direct interface to a Modbus network and allows network adapter boards for several other industrial networks to be connected to the drive control. A typical schematic of the master control is shown in **Figure 2-14**.



2

Figure 2-12. Master Control System

2

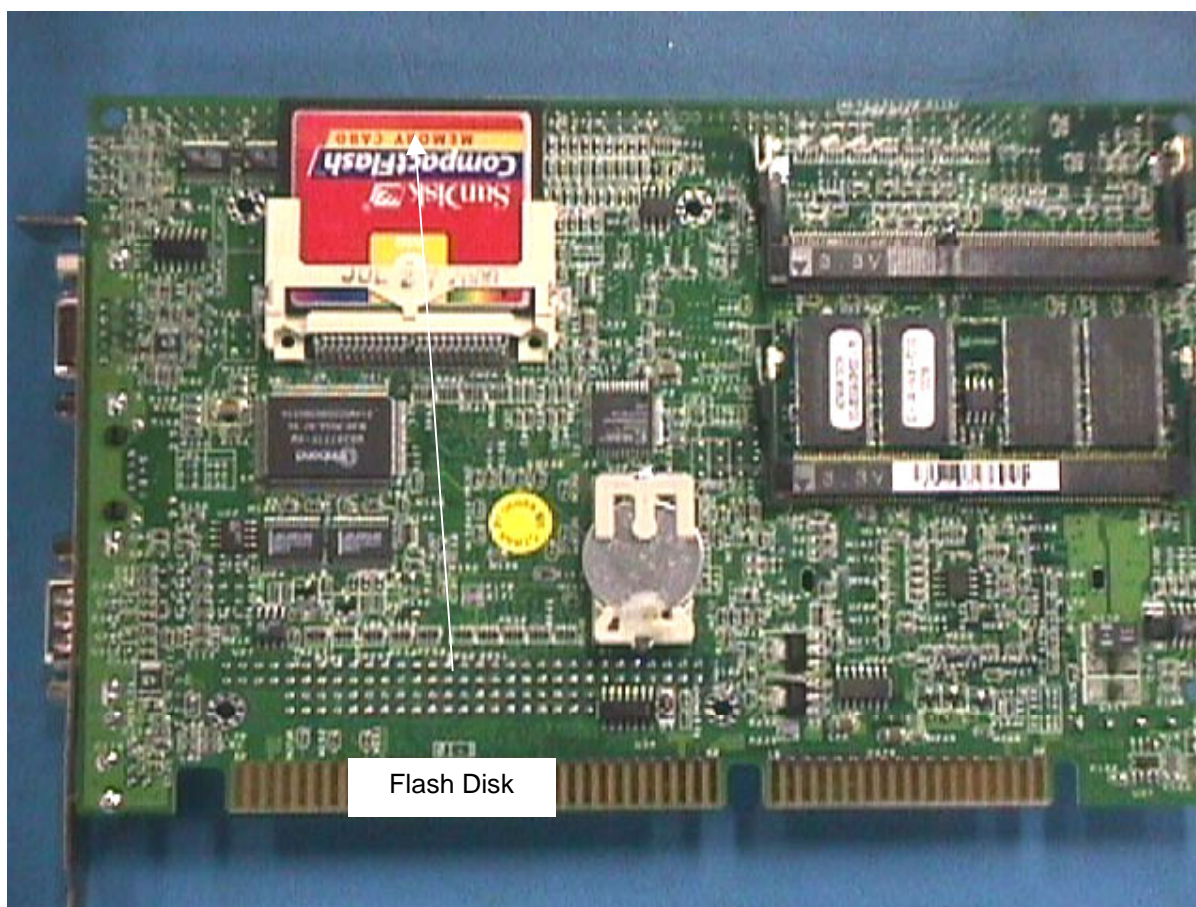


Figure 2-13. Location of Flash Disk on Microprocessor Board

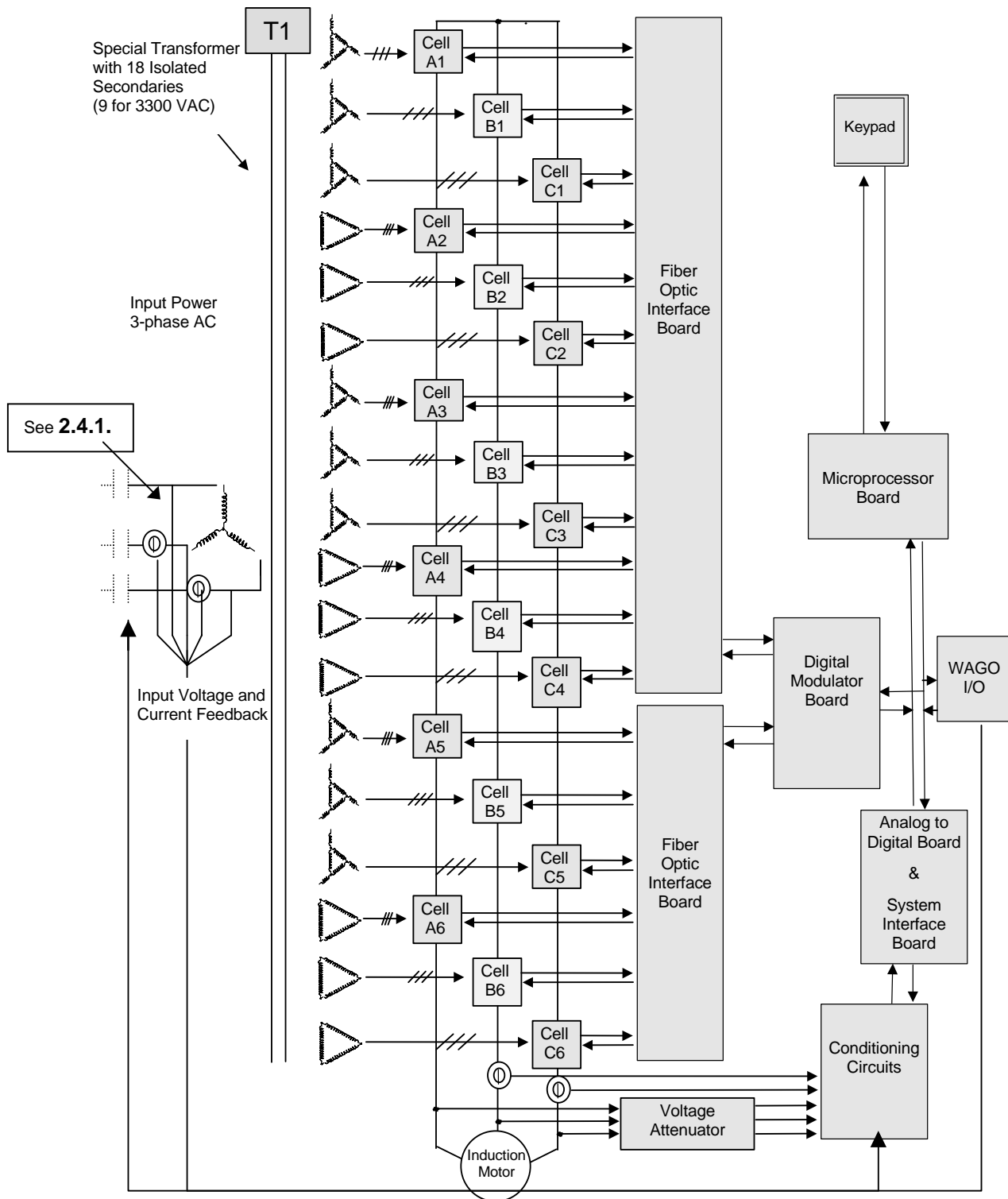


Figure 2-14. Typical Perfect Harmony Power Circuit

2.4. The Power Circuit

The basic power schematic for an 18 cell (4160 VAC) system is shown in **Figure 2-14**. Besides the direct operating information received from each cell by the Fiber Optic System, input voltage, output voltage, and current are also directly monitored. Input and output voltage information is supplied to the control boards by an attenuator system consisting of a voltage divider and voltage clamps.

2

Two Hall Effect sensors placed on output phases B and C sense output motor current. Two CTs placed on input phase B and C sense drive input current. Polarity and burden resistor values must always be maintained.

Each secondary of the power transformer T1 serves one cell only. Each cell receives modulation information through the Fiber Optic System in a way that develops the required output voltage and frequency demanded by the load. Unlike standard PWM systems, the voltage applied to the motor leads is developed in many small steps instead of through a few large steps. This provides two distinct advantages: the voltage stress on the motor insulation is dramatically reduced, and the quality of the motor currents is dramatically increased.



DANGER—Electrical Hazard! Even though each cell by itself develops no more than 690 VAC, the voltage to ground can increase to the rated drive output.

Since each cell is fed from transformer T1 with varying degrees of phase shift (see **Figure 2-14**), the input VFD current distortion is dramatically reduced. Input power factor is always maintained greater than 0.94 lagging.

Each VFD cell within a specific system is identical (refer to **Figure 2-15**). Larger and smaller versions of power cells differ in the size or quantity of input diodes, filter capacitors and IGBTs.

At a minimum, each cell contains a Cell Control Board and an IGBT Gate Driver Board. The Cell Control Board performs all communication and control for each cell.

2.4.1. Monitoring of Input Power Quality

Input currents and voltages to the drive input T1 transformer are also measured and processed continuously by the control system. Information such as efficiency, power factor, and harmonics are available to the user. The input monitoring also protects against T1 transformer secondary side faults that cannot be seen by typical primary protection relaying. Thus it is very important that the drive input medium switchgear, if not supplied as standard, is interlocked to the control system so that input medium voltage can be interrupted upon the rare event of such a fault.

A Form C 250VAC/300VDC rated contact output is supplied standard with each drive to trip the drive input medium voltage circuit breaker or contactor. This contact is designated "TRIP INPUT MEDIUM VOLTAGE" and changes state whenever the drive input power and power factor are outside hardcoded normal operating conditions. This contact must be integrated with input switchgear to deactivate drive input medium voltage in the rare event of a T1 transformer secondary circuit fault.



DANGER! This contact must be integrated with input switch-gear to deactivate the drive input medium voltage upon the rare event of a secondary circuit fault.

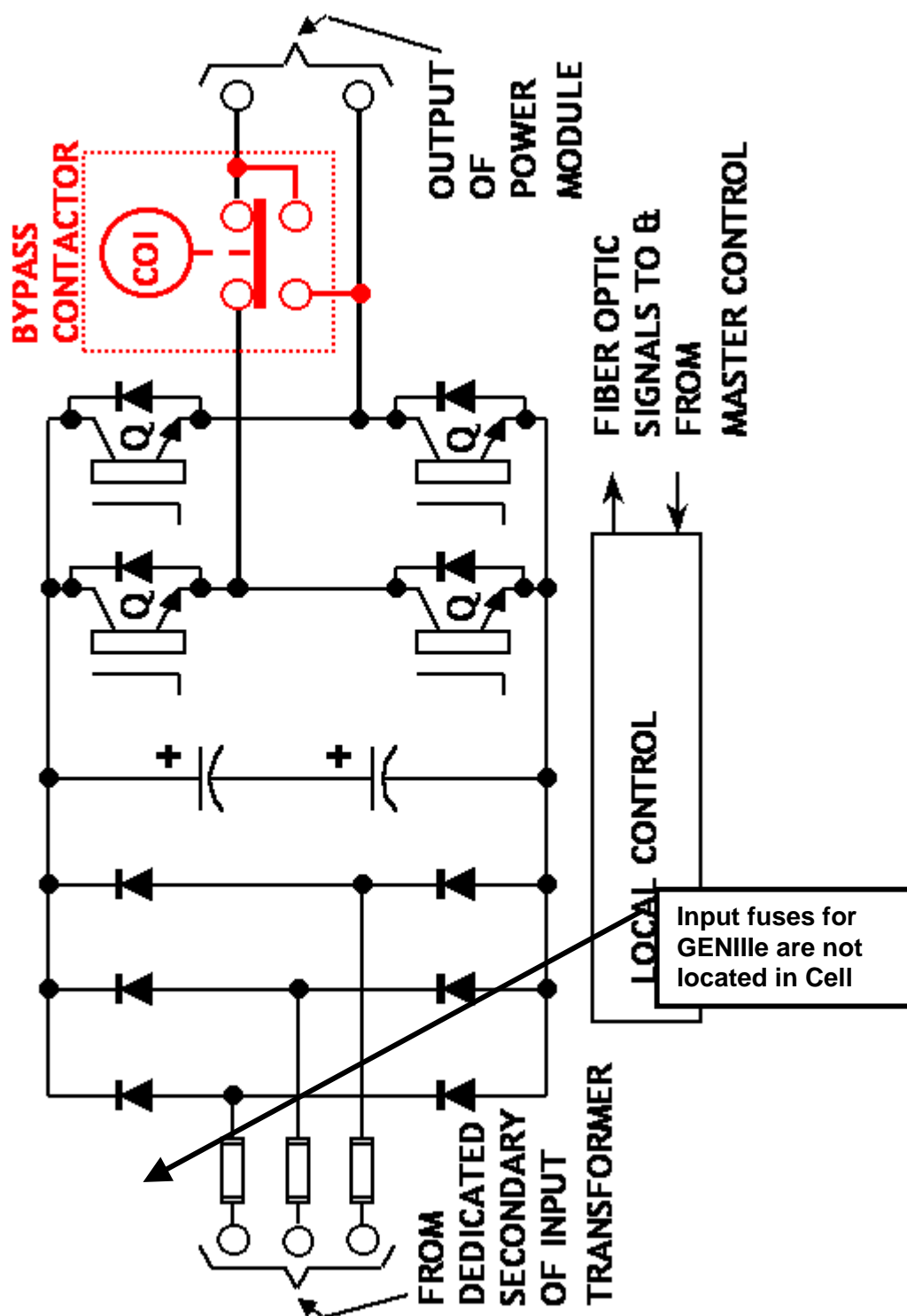


Figure 2-15. Typical Power Cell Schematic

2



CHAPTER 3: INSTALLATION AND SET-UP

3.1. Introduction

Be sure to read and understand this procedure before installing the Perfect Harmony drive. Installation is divided into the following sections:

- receiving
- shipping splits
- weight estimates
- handling
- location
- re-connecting shipping splits
- anchoring cabinets to floors and walls
- re-connecting internal wiring
- external wiring
- torque specifications and insulation resistances.

3

Each of these installation components are discussed in the sections that follow.

3.2. Receiving

The proper receiving procedure consists of the following steps:

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

3.3. Shipping Splits

The GEN III unit is self contained and shipped as one unit (see **Figure 3-7**). The GENIIIe units, depending on size, may be in shipped self-contained or in two sections only (Transformer/Input section and Cell-Control/Output section)

3.4. Weight Estimates

Because the Perfect Harmony drive system is a customizable system, exact weights of systems will vary based on the ratings of the drive and included options. However, approximate dimensions and weight estimates for Perfect Harmony drives are given in tables in **Chapter 2**.

3.5. Handling

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. Advanced planning and coordination between the manufacturer, the carrier, the installation contractor, and the owner are vital.

Danger! Never attempt to support the Transformer Cabinet using only the upper cabinet structure. **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 (for example, the Transformer Cabinet).



Perfect Harmony enclosures are provided with heavy duty base structures that contain transverse tubes to accept fork-lift tines. There are four possible methods of handling cabinets:

- overhead crane lifting using slings (cabinet must have base tubes)
- fork lift truck lifting (cabinet must have base tubes)
- roller dollies

- pipe rollers.

These methods are summarized in the sections that follow.

3.5.1. Overhead Crane Lifting Using Slings

If an overhead crane is available, the best method is to pass fabric slings through the base tubes and lift as shown in **Figure 3-1**. The slings must be long enough that the crane hook is at least 4 feet above the top of the enclosure to prevent buckling of the drive cabinet. If this distance cannot be maintained, spreader bars of appropriate strength must be used. The strength of the slings must be adequate for the weight given on the drawings (or estimated in Chapter 2).



Attention! Be sure to use slings that are strong enough to support the weight of the drive and long enough to prevent the cabinet from buckling. Refer to **Figure 3-1**.

3

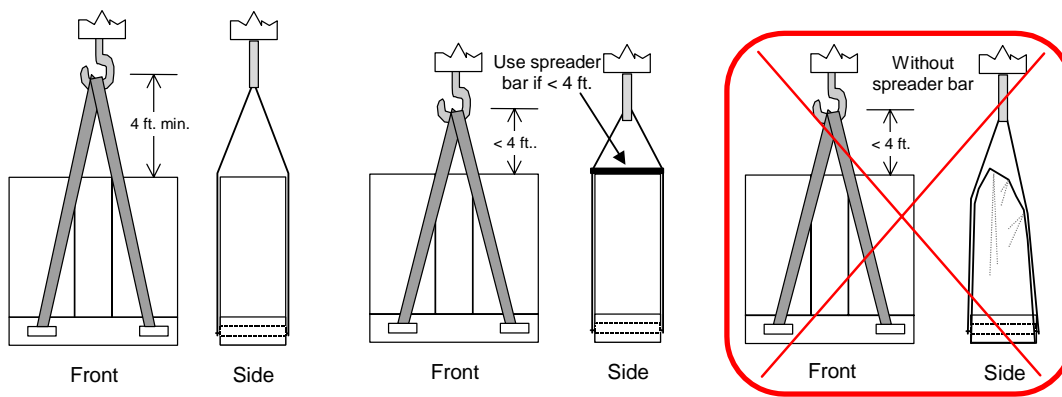


Figure 3-1. Proper Handling Using the Sling Lifting Technique and an Overhead Crane

3.5.2. Using a Fork Lift Truck

A second handling method is to use a suitable fork lift truck. The tines of the truck must be at least 40" long, and no greater than 10" wide or 2.5" thick. Transformer cabinets will accept tines that are up to 2.75" thick. The tine spacing must be adjustable from 30" to 50".



Warning!

Be sure that the fork truck is appropriately rated for the weight being lifted. Be careful that the fork lift does not damage the front surface of the enclosure. It is a good idea to place a wooden stop block in the corner of the tines as shown in Figure 3-2. The center of gravity of the Perfect Harmony enclosure is approximately midway between the front and back surfaces.

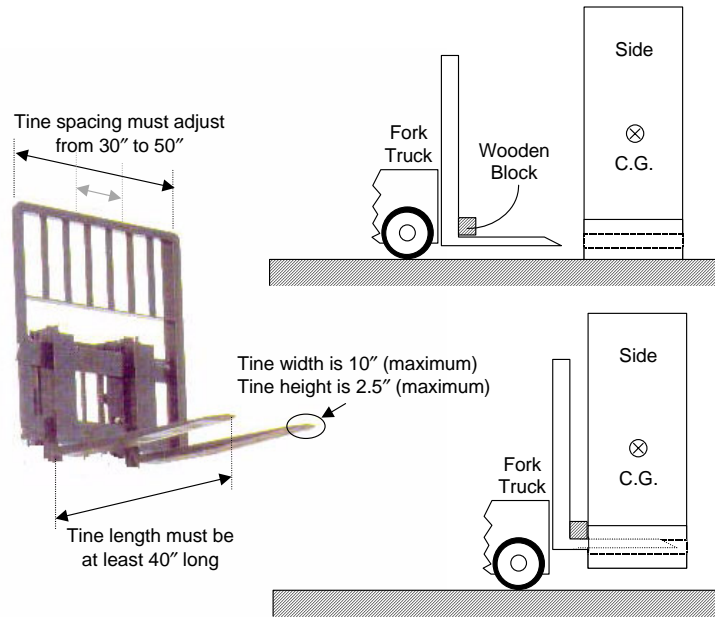


Figure 3-2. Proper Fork Lift Handling and Dimensions

3.5.3. Using Roller Dollies

If roller dollies are used on the GenIII enclosures, they should be placed under the front and rear channels of the base, just outside the fork tubes as shown in **Figure 3-3**. An additional roller may be needed under the middle transformer support on the GenIIIe units. If this is not feasible, the rollers must be placed under the transformer support structure.

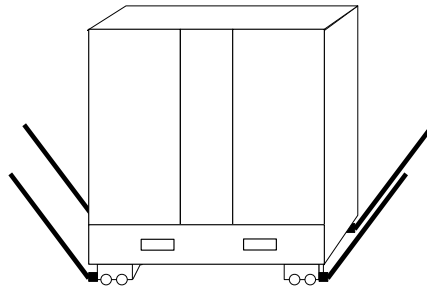


Figure 3-3. Proper Placement of Roller Dollies

Warning! Be sure that the roller dollies are appropriately rated for the weight being supported.



3.5.4. Using Pipe Rollers

This is the least preferred method of handling. It is possible to set the enclosure on many parallel pipe sections placed on the floor and move it by rolling.



Warning! If pipe rollers are used, the pipes must be no less than 2" in diameter and at least 48" in length for GenIII units and 50" to 54" for the GenIIIe units depending on the cabinet depth. The pipes must be spaced no more than 18" apart. Refer to **Figure 3-4**.

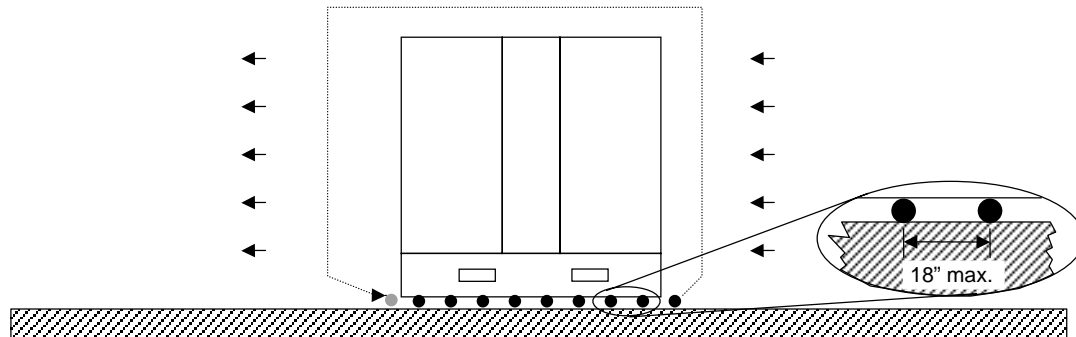


Figure 3-4. Proper Use of Pipe Rollers in Handling Perfect Harmony Cabinets

3.6. Location

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.

When installing the GenIIIe cabinets, it is recommended, but not necessary, to leave approximately two feet between the rear of the unit and any wall or structure. This is done to allow easy access to the electrical and mechanical connections between the transformer and cell sections. Once the connections are made, the unit may be moved flush with the wall.



Warning! If the mounting surface is not flat, the metal cabinets of the drive may buckle, causing the cabinet doors to be misaligned. If this happens, the cabinet doors may not open and close properly.

All cooling air for both the Cell and Transformer Cabinets is drawn through the front doors and ejected through the roof. The final placement of the drive should permit appropriate air circulation. Refer to the tables in **Chapter 2** for rated losses and ventilation requirements for various drive sizes.

Caution!

The performance of the centrifugal blower is strongly affected by output plenum pressure and air resistance.

Indoor equipment is not weatherproof and must be protected. If it is necessary to temporarily store the drive or its components in an outdoor area, heaters should be used in the equipment to prevent moisture accumulation. A protective cover such as plastic or a tarp should be placed over the drive to eliminate exposure to the outside elements. This is especially important if the storage is for more than a few days.

In GEN II drives, verify that all rear cabinet plenum connections between Transformer and Cell. Blower Cabinets must be securely connected so that all gaps are less than 1/8". Larger gaps may significantly reduce the cooling airflow that passes across the cells and transformer.



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3.7. Anchoring Cabinets to Floors and Walls

Holes for anchor bolts are located on the base-mounting channel for each cabinet section (see **Figure 3-5**). When anchoring the unit to the floor, the installer should use cemented J-bars on all corners. Holes in the base of the drive cabinets are 0.81" in diameter and easily accept 0.5" threaded J-bars. If the drive is mounted against a wall, top angles may be used to secure the drive to the back wall in lieu of the rear J-bar connections to the floor. Refer to **Figure 3-5**. Exact dimensions are given in the system drawings supplied with the drive.

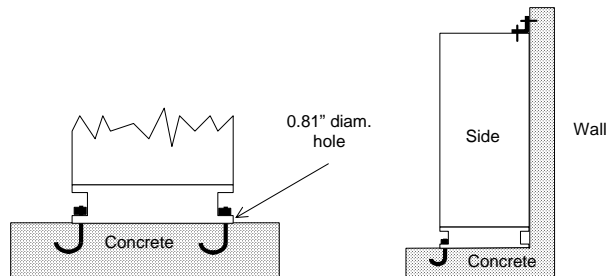


Figure 3-5. Proper Anchoring Techniques for Perfect Harmony Cabinets

3.8. Transformer Cabinet Wiring

Located at the bottom of the transformer is a set of $\pm 5\%$ voltage taps for compensating the primary voltage source (see **Figure 3-6**). The VFD is shipped with the $+5\%$ taps connected. This means that the VFD secondary cell voltages are at the nominal 460 VAC or 690VAC (for example) for an input voltage of 5% above primary nominal rating.

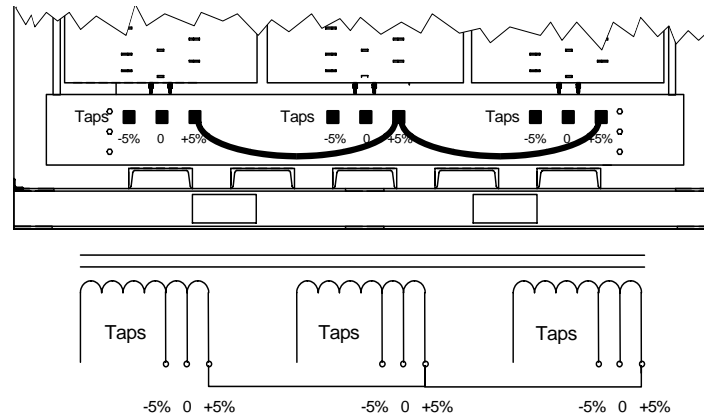


Figure 3-6. Transformer Cabinet Detail Showing Typical Tap Connections



Attention! Do not change the transformer tap connections unless operating experience requires it.



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

3.9. External Wiring

External wiring diagrams are provided with the drawing package that is shipped with the Perfect Harmony system. Follow the instructions on the drawings provided with your system.



Caution – Electrical Hazard!

Standard safety precautions and local codes must be followed during installation of external wiring. Protective separation must be kept between extra low voltage (ELV) wiring and any other wiring as specified in the CE safety standard.



Warning!

For proper cooling, always maintain the control power when medium voltage is applied to the VFD.
To maintain EMC compliance, be sure to use shielded cables as described on the drawings shipped with the Perfect Harmony system.

3.9.1. Input Power Wiring



Attention!

In order to maintain EMC compliance, input power wiring must be installed in metallic electrical conduit and routed through the approved wire ways. Improper phasing of the AC Control Power will cause the blower motor(s) to run in reverse. Be sure to verify proper phasing to avoid overheating the drive. GEN III AC power input must be routed through input CTs.

Customer-supplied AC power for both control and blowers enters an access plate in the top or bottom of the Control Cabinet. Customer-supplied medium voltage power enters an access plate in the top or

bottom of the Power Input Cabinet. **Figure 3-7** shows the location of these access plates on a typical Perfect Harmony VFD Lineup.

3.9.2. Input Primary Power Interruption

Input currents and voltages to the drive input T1 transformer are also measured and processed continuously by the control system. Information such as efficiency, power factor, and harmonics are available to the user. The input monitoring also protects against T1 transformer secondary side faults that cannot be seen by typical primary protection relaying. Thus it is very important that the drive input medium switchgear, if not supplied as standard, is interlocked to the control system so that input medium voltage can be interrupted upon the rare event of such a fault.

A Form C 250VAC/300VDC rated contact output is supplied standard with each drive to trip the drive input medium voltage circuit breaker or contactor. This contact is designated "TRIP INPUT MEDIUM VOLTAGE" and changes state whenever the drive input power and power factor are outside hard-coded normal operating conditions. This contact must be integrated with input switchgear to deactivate drive input medium voltage in the rare event of a T1 transformer secondary circuit fault.

Danger! This contact must be integrated with input switch-gear to deactivate the drive input medium voltage upon the rare event of a secondary circuit fault.

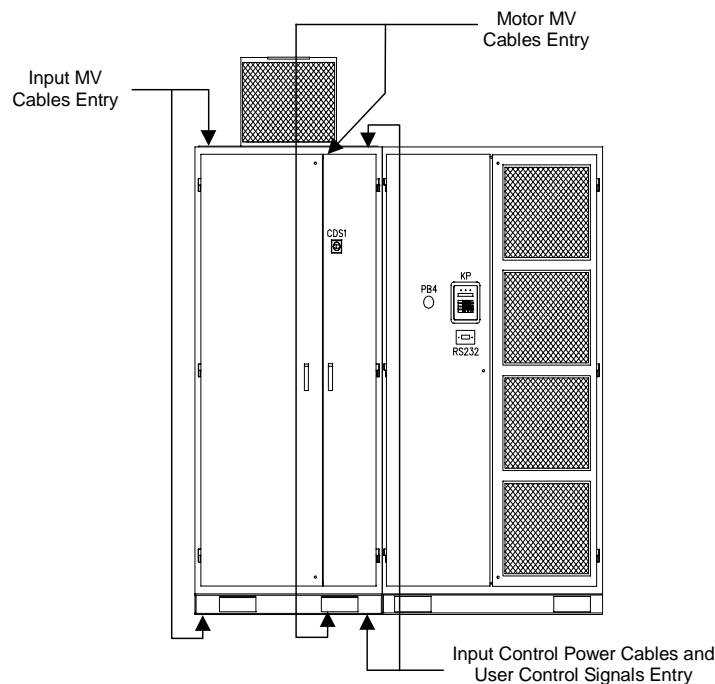


Figure 3-7. Typical GEN III VFD

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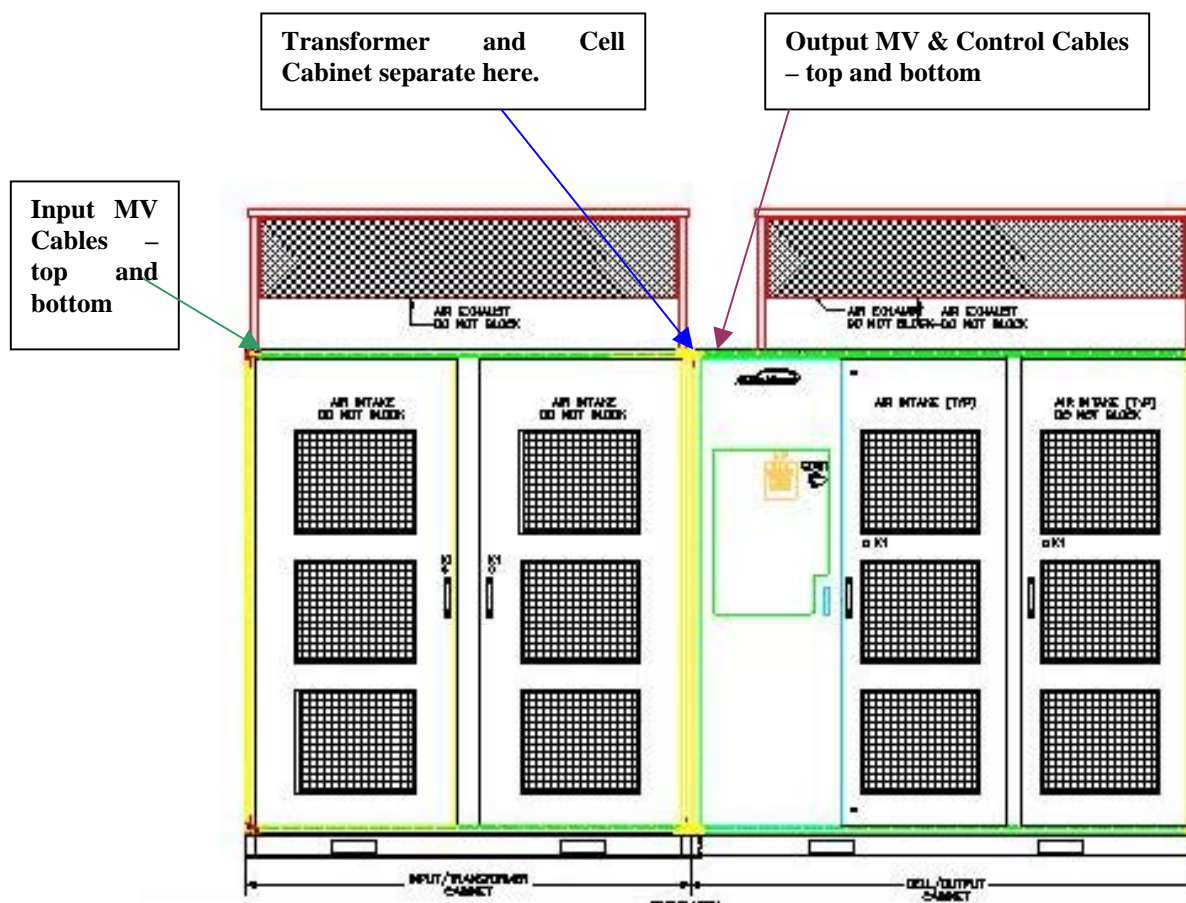


Figure 3-8. Typical GEN IIIe VFD



Note: Harmony drives are wired to have correct blower rotation for R-S-T phase sequencing. Wire all phases according to standard codes (wire the phases from left to right [T1-T2-T3 or R-S-T] for proper operation). Check blower rotation at start-up. With blowers running and doors closed, make sure air flows into air filters and comes out the top of the cabinet by using a piece of paper.

Conductor sizes for input power may vary based on the size of the drive and the dynamics of the system. The customized system power schematic (included with your drive) shows the conductor size used on the main transformer taps. The size of the input power conductors will usually match this size, however, be sure to size the input conductors appropriately for your particular application, taking into account the length of the input power feed and your local standards and electrical codes. Torque specifications are given in **Section 3.10**.

3.9.3. Grounding



Danger - Electrical Hazard! Ground bonding cables are factory made. Re-connect ground bonding between cabinets at shipping split(s). A fixed ground connection is also required. Ensure that the entire system is earth grounded at one of its grounding points. Grounding points are located inside the cabinet and are labeled with the protective earth symbol ⊕.

The cross sectional area of the grounding conductors relates to the cross sectional area of the service conductors as shown in **Table 3-1**.

Table 3-1. Grounding Conductor Sizes

| Cross Sectional Area of Phase Conductors S (in mm^2) | Minimum Cross Sectional Area of the Corresponding Protective Conductor S_p (in mm^2) |
|--|--|
| $S \leq 16$ | S |
| $16 < S \leq 35$ | 16 |
| $S > 35$ | $S/2$ |

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3.9.4. Drive Inhibit and Emergency Stop Wiring

The Perfect Harmony system provides an option for an emergency stop (or E-stop) “mushroom” push button that performs two distinct functions (see **Figure 3-9**):

1. It issues an internal stop command causing all IGBTs to stop firing. (Drive Inhibit)
2. If installed properly, it deactivates a customer-supplied electromechanical contactor that removes VFD power. (E-stop)

Normally-closed push button provides coordinated access to an E-stop function and an inhibit function.

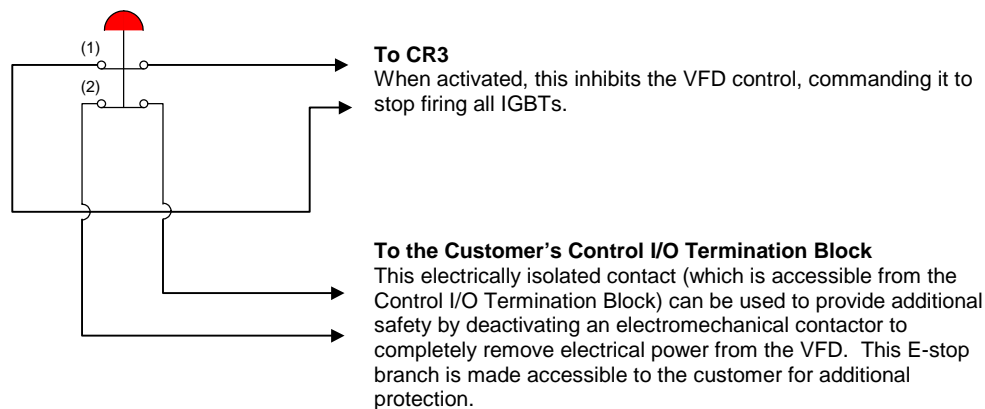


Figure 3-9. The Drive Inhibit/Emergency Stop of the Perfect Harmony

3.10. 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 3-2. Torque Specifications for the Perfect Harmony

| Standard Torque Chart | | Deviations to Standard Torque Specifications | |
|-----------------------------------|----------------------|--|----------------------|
| Fastener Size English (Metric) | Tightening Torque | Perfect Harmony Connectors | Tightening Torque |
| 2-56 (M2) | 3.0 in-lb | all green connectors | 6.0 in-lb |
| 4-40 (M3) | 6.0 in-lb | receptacle GRND | 36.0 in-lb |
| 6-32 (M3.5) | 12.0 in-lb | panel GRND | 22.0 in-lb |
| 8-32 (M4) | 22.0 in-lb | F4, F5, F21, F22 | 22.0 in-lb |
| 10-32 (M5) | 36.0 in-lb | F23, F24, F25 | 36.0 in-lb |
| 1/4-20 (M6) | 70.0 in-lb | 3MI | 9.0 in-lb |
| 1/4-20 (M6) elec | 100.0 in-lb | TB2, TBAMA, B, C, metal cover | 12.0 in-lb |
| 1/4-28 | 70.0 in-lb | T6, relays, receptacle wiring | 12.0 in-lb |
| 5/16-18 | 155.0 in-lb | transformer GND (T5) | 70.0 in-lb |
| (M8) | 80.0 in-lb | PB and light switches (door) | 9.0 in-lb |
| 3/8-16, 3/8-24 | 275.0 in-lb | RTM | 4.0 in-lb |
| (M10) | 180.0 in-lb | keypad | 6.0 in-lb |
| 1/2-13 (M12) | 672.0 in-lb | breaker (wiring) lugs | 36.0 in-lb |
| 5/8-11 | 112.0 ft-lb | CTB and CTC terminals | 12.0 in-lb |
| 3/4-10 | 198.0 ft-lb | | |
| 1 | 500.0 ft-lb | | |

3.11. Insulation Resistances

After all necessary wiring is reconnected, insulation resistance of interconnecting conductors must be measured and verified against the values in **Table 3-3**.

Table 3-3. Minimum Values of Insulation Resistances

| Nominal Circuit Voltage | Test Voltage | Insulation Resistance |
|--|-----------------|--------------------------|
| Extremely low voltages (ELVs) ¹ (≤ 50 VAC and ≤ 120 VDC) | 250 VDC | ≥ 0.25 M Ω |
| Up to and including 500 V, with the exception of the above cases | 500 VDC | ≥ 0.5 M Ω |
| Above 500 V | 1000 VDC | ≥ 1.0 M Ω |

1 - This includes protective ELV (PELV), safety ELV (SELV) and functional ELV (FELV) when the circuit is supplied from a safety transformer (IEC 364-4-411.1.2.1) and also fulfills the requirements of IEC 364-4-411.1.3.3.

3.12. Cell Capacitor Reforming

The electrolytic capacitors used in the filter section of each power cell should be re-formed to replenish lost oxide prior to full power primary energization if one or both of the following conditions are noted:

- Cell have been stored voltage free for more than 2 years at between the storage temperature of - 55°C and 45°C
- Cells have been stored voltage free above 45°C for more than 1 month.

Reformation requires operation from a variable voltage source of at least 1KVA rating for up to 1.5hrs. This can be accomplished by using a single or 3 phase variable voltage source (variac) capable of 0-760vac. (Consult ASI/Robicon service support for more information). The procedure is as follows:

- Connect variac to input terminals L1-L2-L3
- Raise voltage to 25% increments of the rated cell voltage for 15 minutes at a time (about 125vac for 460vac rated cells and about 200vac for 690vac cells) until the 10% High line rating of the cell is achieved (500vac for 460vac cells or 760vac for 690vac cells)
- Maintain 10% High line rated voltage for an additional 1.5 hours.

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APPENDIX A: GLOSSARY OF TERMS

A

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

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

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

automatic bypass operation - Automatic bypass operation is the same as bypass operation, but it occurs automatically if a drive fault occurs and a pre-defined time has elapsed after the fault.

automatic mode - Automatic mode is a control scheme in which the operator selects an input to be used as the desired velocity input. Speed profiling is used in automatic mode to allow the operator to scale the output based on a programmable input range.

baud rate - Baud rate is a measure of the switching speed of a line representing the number of changes of state of the line per second. Note that that this term commonly (and erroneously) is used to specify a “bits per second” value for any modem speed. The baud rate of the serial port of the Perfect Harmony is selected through the Baud Rate parameter in the Communications Menu [9].

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

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

bypass option - Bypass is an option that can be selected to customize a drive to provide optional line operation of the motor.

carrier frequency - Carrier frequency is a unique frequency that is used to “carry” data within its boundaries. The carrier frequency is measured in cycles per second (Hz).

“catch a spinning load” feature - Catch a spinning load is a feature that can be used with high-inertia loads (e.g., fans) in which the drive may attempt to turn on while the motor is already turning. This feature can be enabled using the Spinning Load Select parameter in the Drive Parameter Menu [14]. Also reference the Spinning Load Threshold parameter in the Standard Control Submenu [24].

comparator - A comparator is a device that compares two quantities and determines their equality. The Perfect Harmony contains 16 software equivalents located in submenus 121 through 136. These comparator submenus allow the programmer to specify two variables to be compared. The results of the 16 custom comparison operations can be used in the system program.

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

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

DC link - The DC link is a large inductor between the converter and inverter section of the drive. The DC link, along with the converter, establish the current source for the inverter.

De Morgan’s Theorem - The duality principal of Boolean algebra. Refer to the system program section for more information.

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

DRCTRY - Directory file which contains system tokens and internal addresses.

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drive - The term “drive” refers to the controlled source for both power and control of a motor (i.e., the Perfect Harmony system).

EEPROM - EEPROM is an acronym for electrically erasable programmable read-only memory. An EEPROM is a memory chip that holds its contents without power. Parameter values such as setpoints are stored in EEPROM.

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

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

EPROM - EPROM is an acronym for erasable programmable read-only memory. An EPROM is used to hold the program code that runs the drive.

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

fault log - Fault messages are saved to memory so that the operator may view them at a later time. This memory location is called the fault log. The fault log lists fault messages, the date and time that they occurred. The Fault Log Menu [33] contains functions that are used to display and upload the fault log.

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

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

GAL - GAL is an acronym for Generic Array Logic - a device similar to a PAL (programmable array logic) that is electrically erasable and programmable like an EEPROM.

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

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

hexadecimal digits - Hexadecimal (or “hex”) digits are the “numerals” used to represent numbers in the base 16 (hex) number system. Unlike the more familiar decimal system which uses the numerals 0 through 9 to make numbers in powers of 10, the base 16 number system uses the numerals 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F to make numbers in powers of 16. Hex numbers A through F are rarely used in the Perfect Harmony, but can be entered from the keypad using the [Shift] plus the number keys [1] through [6].

historic log - The historic log is a troubleshooting/diagnostic tool of the Perfect Harmony. The historic log continuously logs 78 entries, each containing the drive state, two fault words and 10 user-selectable variables. This information is sampled every 1 ms (1,000 times per second). When a fault condition occurs, the previous 58 samples are recorded along with the next 20 samples (for a total of 78 samples) and stored in backed-up NVRAM. This information stays in NVRAM until the next fault occurs, at which

time the old information is overwritten. The information in NVRAM is stored in ASCII hex format and can be uploaded via the drive's serial port to a PC for troubleshooting analysis.

hmpd - The term "hmpd" refers to a set of four security fields associated with each parameter of the system. These fields allow the operator to individually customize specific security features for each menu option (submenu, parameter, pick list and function). These fields are shown in parameter dumps and have the following meanings. Setting H=1 hides the menu option from view until the appropriate access level has been activated. Setting M=1 blocks submenus from printing when a parameter dump is performed. Setting P=1 locks out the menu option during parameter dump printouts. Setting D=1 hides the menu option only when the drive is running.

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

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

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

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

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

jerk rate - Jerk rate is the time it takes for the drive to go from one acceleration rate to another. The jerk rate is a programmable parameter used to limit the rate of change of the acceleration. Jerk rate has no effect if acceleration is constant. Jerk rate helps to prevent small overshoots and provides the "S-curve" (time/speed plot) characteristic as the speed setpoint is reached.

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

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

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

LCD - liquid crystal display. On the Perfect Harmony, a 2-line by 24-character back-lit display interface located on the front panel of the system.

LED - LED is an acronym for light emitting diode. The Perfect Harmony uses three LEDs as diagnostic indicators on the keypad/display assembly.

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

manual mode - Manual mode is a control scheme of the Perfect Harmony in which the desired velocity of the drive is set manually by the operator. In local manual mode, the desired velocity is set using the up

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and down arrow keys on the front keypad of the drive. In remote manual mode, the desired velocity is set using a potentiometer input (located remotely from the drive) that is wired to the drive.

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

microprocessor - A microprocessor is a central processing unit (CPU) that exists on a single silicon chip. The microprocessor board is the printed circuit board on which the microprocessor is mounted.

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

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

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

NVRAM - An acronym for non-volatile random access memory, NVRAM is an area of memory that is backed-up by battery. In other words, information stored in NVRAM is maintained if power to the drive is lost (however backup power in the form of a battery, for example, must be maintained or the contents are lost).

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

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

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

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

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

qualified user - A qualified user is an individual who is familiar with the construction and operation of the equipment and the hazards involved.

quick menu - Quick menu is a feature of the menu system that allows the operator to directly access one of the nine top level menus (1-9) rather than scrolling through the Main Menu [5] to the appropriate menu. This feature uses the [Shift] button in conjunction with the numerical buttons 1-9. The corresponding menus are listed in green text above the numbers on the keypad buttons. Note that the Security Edit Menu [0] is not available through the quick menu feature. It is available only through the Main Menu [5].

RAM - RAM is an acronym for random access memory, a temporary storage area for drive information. The information in RAM is lost when power is no longer supplied to it. Therefore, it is referred to as volatile memory. Compare RAM with NVRAM (non-volatile RAM) which is electrically backed-up memory that does not lose its contents when the drive is shut off.



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

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

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

RS232C - RS232C is a serial communications standard of the Electronics Industries Association (EIA). The RS232C interface is a DB25 serial port located on the front of the drive or on DB9 of the microprocessor board. This interface is used to connect the drive to a printer, dumb terminal or PC to allow parameter listing, system program downloading (after off-line editing), and uploading of historical and diagnostic log files.

serial port - Serial port refers to the external connector on the Perfect Harmony that is used to connect to a serial device such as a PC, serial printer, or serial network. The serial port transmits information one bit (1 or 0) at a time sequentially, as compared to parallel transmission which transmits 8 or 16 bits (for example) at a time.

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

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

$$\text{Slip} = \frac{\omega_s - \omega_r}{\omega_s}$$

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

slip compensation - Slip compensation is a method of increasing the speed reference to the speed regulator circuit (based on the motor torque) to maintain motor speed as the load on the motor changes. The slip compensation circuit increases the frequency at which the inverter section is fired to compensate for decreased speed. For example, a motor with a speed of 1760 rpm has a slip of 40 rpm. The no load rpm would be 1800 rpm. If the motor name plate current is 100 A, the drive is sending a 60 Hz wave form to the motor, and the motor is fully loaded, then the slip compensation circuit would fire the inverter 1.33 Hz faster to allow the motor to run at 1800 rpm.

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

standard control - Standard control is one of two available application modes of the Perfect Harmony drive. Standard control mode means that the control algorithm of the drive consists of an *open loop* speed control component with *closed* loop voltage and current control. In standard control applications, the drive compensates for the load by using the current and voltage loops. Encoders and magnetic pickups are not needed in standard control applications. Typical standard control applications include centrifugal loads such as fans and pumps. Compare with *vector control*.

stop mode - Stop mode is used to shut down the drive in a controlled manner, regardless of its current state. To enter this mode, the operator must either press the [Manual Stop] button on the system keypad or press a user-supplied, digital input switch that is programmed as a manual stop input.

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

synchronous speed - Synchronous speed refers to the speed of an AC induction motor's rotating magnetic field. It is determined by the frequency applied to the stator and the number of magnetic poles

A

present in each phase of the stator windings. Synchronous Speed equals 120 times the applied Frequency (in Hz) divided by the number of poles per phase.

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

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

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

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

vector control - Vector control is one of two available application modes of the Perfect Harmony drive. Vector control mode means that the control algorithm of the drive consists of a *closed loop* speed control component and a *closed loop* torque control component. Since vector control applications require (a) precisely controlled starting torques ($\pm 0.1\%$), (b) precisely controlled speeds ($\pm 0.1\%$), and/or (c) fast response, such applications use either an encoder or a magnetic pickup for direct speed control feedback. Typical vector control applications include centrifuges, extruders and test stands. Compare with *standard control*.



APPENDIX B: COMMONLY USED ABBREVIATIONS

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

Table B-1. Commonly Used Abbreviations

| Abbreviation | Meaning | Abbreviation | Meaning |
|--------------|-------------------------------|---------------|---|
| • | Boolean AND function | div | division |
| + | addition or Boolean OR | dmd | demand |
| \geq | greater than or equal to | e | error |
| \leq | less than or equal to | EEPROM | electrically erasable programmable read-only memory |
| ° | degrees | ELV | extra low voltage |
| " | inches | EMC | electromagnetic compatibility |
| Σ | summation | EMF | electromotive force |
| τ | torque | EPROM | erasable programmable read-only memory |
| AC | alternating current | ESD | electrostatic discharge |
| accel | acceleration | ESTOP, e-stop | emergency stop |
| ack | acknowledge | fb, fdbk | feedback |
| AI | analog input | ffwd | feed forward |
| alg | analog | FLC | full load current |
| avail | available | FOHB | Fiber Optic Hub Board |
| BTU | British thermal units | freq | frequency |
| cap | capacitor | ft, ' | feet |
| ccw | counter clockwise | fwd | forward |
| cmd | command | GAL | generic array logic |
| com | common | gnd | ground |
| conn | connector | H | height |
| CT | current transformer | hex | hexadecimal |
| CTS | clear to send | hist | historic |
| cu | cubic | hp | horsepower |
| curr | current | hr | hour |
| cw | clockwise | Hz | Hertz |
| D | derivative (PID), depth | I | current, integral (PID) |
| D/A | digital-to-analog (converter) | I/O | input(s)/output(s) |
| DC | direct current | ID | identification |
| DCL | drive communications link | IGBT | insulated gate bipolar transistor |
| decel | deceleration | | |
| deg | degrees | | |

B

COMMONLY USED ABBREVIATIONS**Perfect Harmony GENIII/e Installation Manual****B**

| Abbreviation | Meaning |
|--------------|--|
| in | input |
| in, " | inches |
| info | information |
| INH | inhibit |
| K | 1,000 (e.g., Kohm) |
| LAN | local area network |
| lbs | pounds (weight) |
| LCD | liquid crystal display |
| ld | load |
| LED | light-emitting diode |
| lim | limit |
| LOS | loss of signal |
| lps | liters per second |
| mA | milliamperes |
| mag | magnetizing |
| max | maximum |
| MCC | motor control center |
| mg | milligram |
| min | minimum, minute |
| msec | millisecond(s) |
| msl | mean sea level |
| mvt | motor voltage |
| NEMA | National Electrical Manufacturer's Association |
| no. | number |
| NMI | non-maskable interrupt |
| NVRAM | non-volatile random access memory |
| oamp | output current |
| OOS | out of saturation |
| overld | overload |
| P | proportional (PID) |
| Pa | Pascals |
| pb | push button |
| PC | personal computer |
| PIB | Power Interface Board |

| Abbreviation | Meaning |
|--------------|------------------------------------|
| PID | proportional integral derivative |
| PLC | programmable logic controller |
| pot | potentiometer |
| pp | peak-to-peak |
| ppb | parts per billion |
| PPR | pulses per revolution |
| PQM | power quality meter |
| PSDBP | power spectral density break point |
| psi | pounds per square inch |
| pt | point |
| PT | potential transformer |
| PWM | pulse width modulation |
| rad | radians |
| RAM | random access memory |
| ref | reference |
| rev | reverse, revolution(s) |
| RFI | radio frequency interference |
| RLBK | rollback |
| rms | root-mean-squared |
| RPM | revolutions per minute |
| RTS | request to send |
| RTU | remote terminal unit |
| RX | receive |
| s | second(s) |
| sec | second(s) |
| ser | serial |
| SOP | sum of products |
| spd | speed |
| stab | stability |
| std | standard |
| sw | switch |
| TB | terminal block |
| TOL | thermal overload |
| TP | test point |
| trq, τ | torque |

| Abbreviation | Meaning |
|--------------|------------------------------|
| TX | transmit |
| UPS | uninterruptable power supply |
| um | user module |
| V | voltage, volts |
| VAC | volts AC |
| var | variable |
| VDC | volts DC |
| vel | velocity |
| VFD | variable frequency drive |
| vlts | voltage(s), volts |
| W | width, watts |
| XCL | external communications link |
| xformer | transformer |

B

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