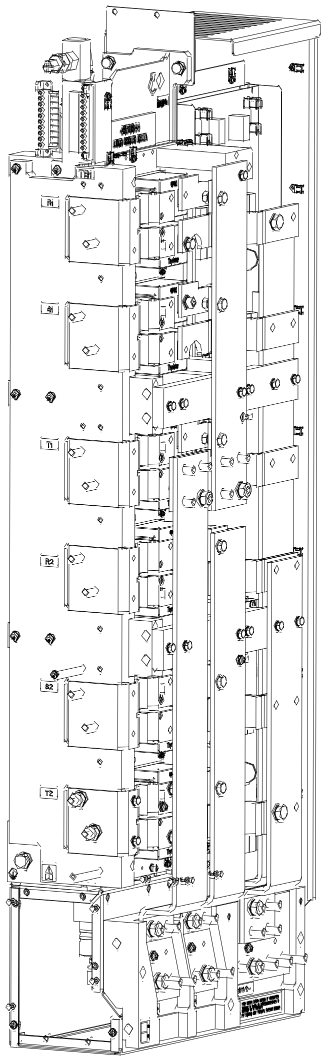
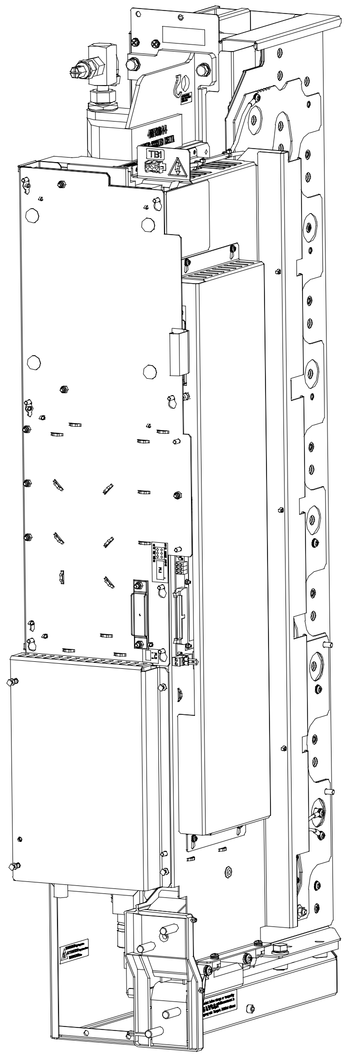
GE

Power Conversion

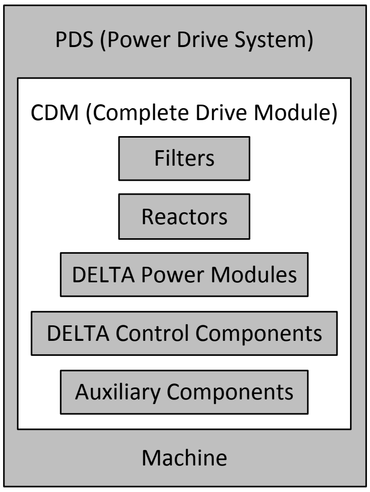
T1693EN Technical Manual Rev. 09

MV3000 Liquid Cooled DELTA





DEFINITIONS



PDS (Power Drive System)

AEM	Active Energy Management
CDC	Common Drive Controller
CDM	Complete Drive Module
DDM	Drive Data Manager™
DELTA	Generic term for the transistor module or rectifier unit in the DELTA modular drive
DFE	Diode Front End
DIB	DELTA Interface Board
Drive	Cubiclised DELTA components (CDM)
DNV	Det Norske Veritas
I/O	Input / Output
IEC	International Electro-technical Committee
IGBT	Insulated Gate Bipolar Transistor
Machine Bridge	The machine bridge controls the bi-directional power flow between the d.c. link and the motor or generator
MVM	Mains Voltage Monitor
Network Bridge	The network bridge controls the power flow from the mains supply into the d.c. link. In the case of an AEM system, bi-directional power flow between the supply and the d.c. link is controlled.
PDS	Power Drive System
PWM	Pulse Width Modulation
SFE	Sinusoidal Front End
SMPS	Switch Mode Power Supply
System	General term for the PDS

SAFETY INSTRUCTIONS

Care has been taken with the design of this product to ensure that it is safe. However, in common with all products of this type, misuse can result in injury or death. Therefore, it is very important that the instructions in this manual and on the product are observed during transportation, commissioning, operation, maintenance and disposal.

This technical manual must be regarded as part of the product. It should be stored with the product and must be passed on to any subsequent owner or user.

Local safety laws and regulations must always be observed.

Persons working on the product must be suitably skilled and should have been trained in that work for these products.

The product is a component designed for incorporation in installations, apparatus and machines.

The product must not be used as a single item safety system. In applications where maloperation of the product could cause danger, additional means must be used to prevent danger to persons.

Product approvals and certifications will be invalidated if the product is transported, used or stored outside its ratings or if the instructions in this manual are not observed.

Third party approvals to safety standards UL508C and CSA C22.2 No 14 are marked on the product.

In the European Union:

- Products within the scope of the Low Voltage Directive, 2014/35/EU are CE marked.
- The product complies with the essential requirements of the EMC directive 2014/30/EU, when installed and used as described in this manual. The requirements of the EMC Directive should be established before any installation, apparatus or machine which incorporates the product is taken into service.
- A machine must not be taken into service until the machine has been declared in conformity with the provisions of the Machinery Directive, 2006/42/EC.

WARNINGS, CAUTIONS & NOTES

WARNING
• **"An instruction that draws attention to the risk of injury or death" (BS 4884-1: 1992).**

CAUTION
• **"An instruction that draws attention to the risk of damage to the product, process or surroundings" (BS 4884-1: 1992).**

NOTES: **Notes separate important information from the text and give additional information.**

UNITS COVERED

LIQUID COOLED DELTA POWER MODULES

MVDL643-4702	Transistor Module 643 A, 690 V a.c. 1200 V d. c.
MVDL800-47xx	Transistor Module 800 A, 690 V a.c. 1250 V d.c.
MVDL800-xxxxxxxx	Transistor Module 800 A, 690 V a.c. 1250 V d.c.
MVDL1000-47xx	Transistor Module 1000 A, 690 V a.c. 1250 V d.c.
MVDL1000-xxxxxxxx	Transistor Module 1000 A, 690 V a.c. 1250 V d.c.
MVRL2100-4601	Rectifier Module 2100 A, 690 V a.c.
MVRL2100-4602	Rectifier Module 2100 A, 690V a.c. Hosetail connection.

DFE NETWORK BRIDGE SHARING REACTORS

50Z0081/01	3 phase, 986 A, 690 V a.c.

AEM AND MACHINE BRIDGE SHARING REACTORS

50Z0126/01	3 phase, 645 A, 690 V a.c.
50Z0126/02	3 phase, 800 A, 690 V a.c.
50Z0126/03	3 phase, 1000 A, 690 V a.c.

DELTA CONTROL COMPONENTS

MVC3001-400x	MV3000e Controller
MVC3002-4001	User I/O Termination Panel
MVC3003-40xx	Switched Mode Power Supply
MVC3006-400x	Mains Voltage Monitor
MVS3000-4001	Drive Data Manager™ (Keypad)
MVS3001-4001	Drive Data Manager ™ (Keypad) Mounting Kit

DELTA RIBBON CABLES + ACCESSORIES

MVS3017-4001	16way Ribbon Cable Earthing Clamp
MVS3018-400x	40way Ribbon Cable Earthing Clamp
MVS3019-4001	50way Ribbon Cable Earthing Clamp
MVS3020-40xx	40way Screened Ribbon Cable

LIQUID COOLED DELTA MOUNTING FRAMES FOR RITTAL TS8 ENCLOSURE

MVDL-TS-4001	Liquid Cooled DELTA Mounting Kit 800D x 600W
MVDL-TS-4002	Liquid Cooled DELTA Mounting Kit 800D x 800W
MVDL-TS-4003	Liquid Cooled DELTA Mounting Kit 800D x 1000W
MVDL-TS-4004	Liquid Cooled DELTA Mounting Kit 800D x 1200W
MVDL-TS-4005	Liquid Cooled DELTA Mounting Kit 600D x 600W
MVDL-TS-4006	Liquid Cooled DELTA Mounting Kit 600D x 800W
MVDL-TS-4007	Liquid Cooled DELTA Mounting Kit 600D x 1000W
MVDL-TS-4008	Liquid Cooled DELTA Mounting Kit 600D x 1200W

CONTENTS

1. INTRODUCTION

1.1 GENERAL DESCRIPTION

An MV3000e DELTA a.c. drive is used to control a motor, generator, or power conditioning application.

It uses a modular approach which allows the use of a small number of common components to create a large number of system variants.

1.1.1 Advantages Of The Modular System

- The DELTA transistor and rectifier modules are of a standard mechanical design, using the same mounting method and dimensions;
- DELTA rectifier and transistor modules can be connected in parallel to provide a wide range of power levels;
- Modular construction makes maintenance and repair work simple, and enables rapid module replacement;
- DELTA transistor and rectifier modules can be withdrawn on a simple slide system for ease of assembly and maintenance.
- Ease of handling – smaller, lighter modules are assembled to form large drives.

1.1.2 DELTA Product Range

- Rectifier module;
- Transistor modules;
- MV3000e Controller
- SMPS (Switch Mode Power Supply) units;
- User I/O termination panel;
- MVM (Mains Voltage Monitor);
- DDM (Drive Data Manager™)– Keypad;
- Reactors and transformers;
- Installation accessories (mounting kits and control cables).

1.2 ASSOCIATED MANUALS

- T1676 – MV3000e Getting Started Manual (for rectifier fed systems);
- T1679 – MV3000e Software Manual (and Firmware Supplement T2154);
- T2002 – MV3000e Getting Started Manual (for AEM systems).

The T1676 and T2002 manuals include commissioning and operating details for the complete MV3000e DELTA drive.

The T1676, T1679 and T2002 manuals should be regarded as part of the DELTA product. Individual DELTA component instructions sheets that may also be required are shown below:

- T1694 MVS3007-4002 - Profibus Field Coupler 12 Mb/s;
- T1915 MVS3000-4001 – Drive Data Manager ™ (keypad);
- T1916 MVS3001-4001 - Keypad mounting kit;
- T1930 MVC3006-4003 – Mains Voltage Monitor (MVM);
- T1968 MVS3011-4001 - CANbus communications module;
- T1973 MVC3003-40xx – Switch Mode Power Supply (SMPS) Module;
- T2034 MVS3012-400x - Ethernet interface;
- T2100 MVDL800 DELTA Transistor Module;
- T2101 MVDL1000 DELTA Transistor Module;
- T2112 MVC3001-400x – DELTA Controller.

These manuals should be retained for the life of the product and passed on to any subsequent owner.

1.3 ABOUT THIS MANUAL

Section 1 – Introduction

- Overview of the main concepts used in DELTA drives;

Section 2 – Specifications

- Common environmental data for the DELTA product range;
- Gives individual DELTA component data.

Section 3 – Complete Drive Module (CDM) Design

- Guidance for component selection;
- Enclosure design;
- Cooling system design;

Section 4 – Power Drive System (PDS) Design

- Motor requirements;
- Motor and supply cable selection;
- Encoder details.

Section 5 – Complete Drive Module (CDM) Assembly

- Guidance for assembly of DELTA components into an enclosure.

Section 6 – CDM Commissioning

- Guidance for commissioning the CDM, including electrical safety checks and functional testing.

Section 7 – PDS Commissioning

- Guidance for commissioning the CDM in the final location.

Section 8 – Maintenance

- Diagnostic information;
- Preventative maintenance;
- Module replacement.

Section 9 – Disposal

Appendices

- Mechanical drawings of DELTA components;
- Electrical connection diagrams
- Torque values.

1.4 DRIVE CONFIGURATIONS

A DELTA drive consists of two 'bridges' – the network bridge and the machine bridge.

Two generic configurations are available, each with a different network topology:

- Diode Front End (DFE) – power transfer from the network to the load only;
- Active Energy Management (AEM) – power transfer to and from the network.

Both the DFE and AEM drives share the same machine bridge topology.

Figure 1–1 is a simplified schematic diagram of a DFE system. Figure 1–2 is a simplified schematic diagram of an AEM system.

Circuit diagrams for the various drive configurations are included in Appendix B: Electrical Connection Diagrams.

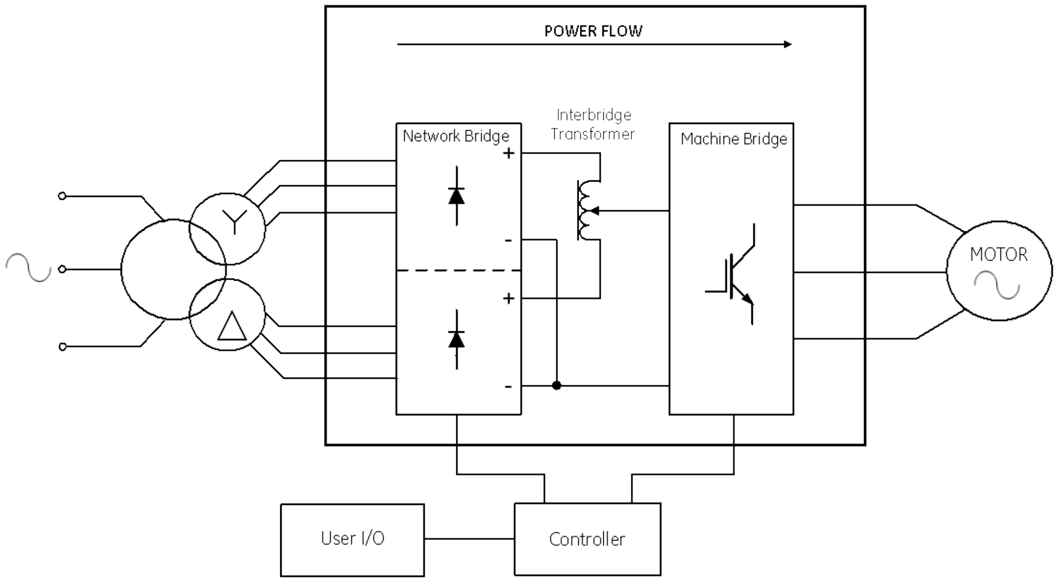


Figure 1–1. – Schematic Diagram of a DFE DELTA System

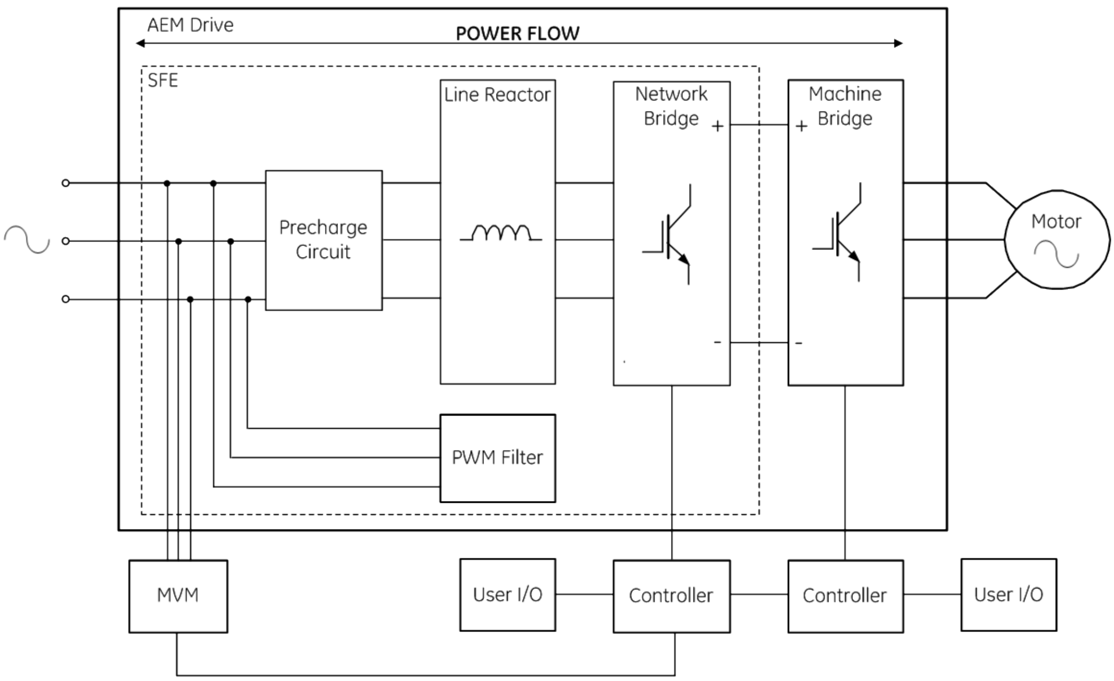


Figure 1–2. – Schematic Diagram of an AEM DELTA System

1.4.1 DFE Network Bridge

A DFE network bridge comprises of one or more diode rectifier modules, plus ancillary components, which could include:

- Line reactor;
- Fusing;
- Pre-charge circuit;
- Interbridge transformer;
- D.C. Link inductor.

The network bridge converts the a.c. supply to an unsmoothed d.c. voltage. Power flow is from the network supply only.

Harmonic currents produced in the supply system by variable speed drives with uncontrolled rectifier inputs may be reduced by changing from 6 pulse to 12 pulse (6 phase) input.

In the case of a 12 pulse input:

- A phase shifting transformer is used to produce the additional 3 phases which are phase shifted by 30° as shown in Figure 1–1. These two sets of three phase supplies are rectified by two rectifier bridges.
- Instantaneous voltage differences, between the outputs of the two rectifiers, are absorbed by an interbridge transformer connected between the two positive outputs of the rectifiers. The output to the d.c. link is taken from the centre-tap of the interbridge transformer.

1.4.2 Sinusoidal Front End (AEM Network Bridge)

The network bridge of an AEM drive comprises of one to six DELTA transistor modules. The network bridge is combined with the following ancillary components to form a Sinusoidal Front End (SFE):

- Line reactor;
- Fusing;
- PWM filter;
- MVM unit;
- Sharing reactors;
- MV3000e Controller.

The SFE bridge can be used to convert the a.c. supply to a d.c. voltage, but also has the capability to allow regeneration of energy back into the network, and as such is required for power generation applications (e.g. wind turbines).

The AEM network bridge provides a very clean voltage waveform, but the harmonic content will require filtering.

1.4.3 Machine Bridge

The machine bridge converts between a d.c. and an a.c. voltage of variable frequency and amplitude. Generally in a DFE system, the power flows from the d.c. link, out into the a.c. load. In an AEM system, power flow is bi-directional.

The machine bridge comprises of one to six DELTA transistor modules and the following ancillary components:

- Sharing reactors;
- Fusing;
- MV3000e Controller.

1.5 TYPICAL LAYOUT OF KEY DELTA COMPONENTS

A typical layout showing the key DELTA components that may be combined to build a CDM (Complete Drive Module) is shown in Figure 1–3.

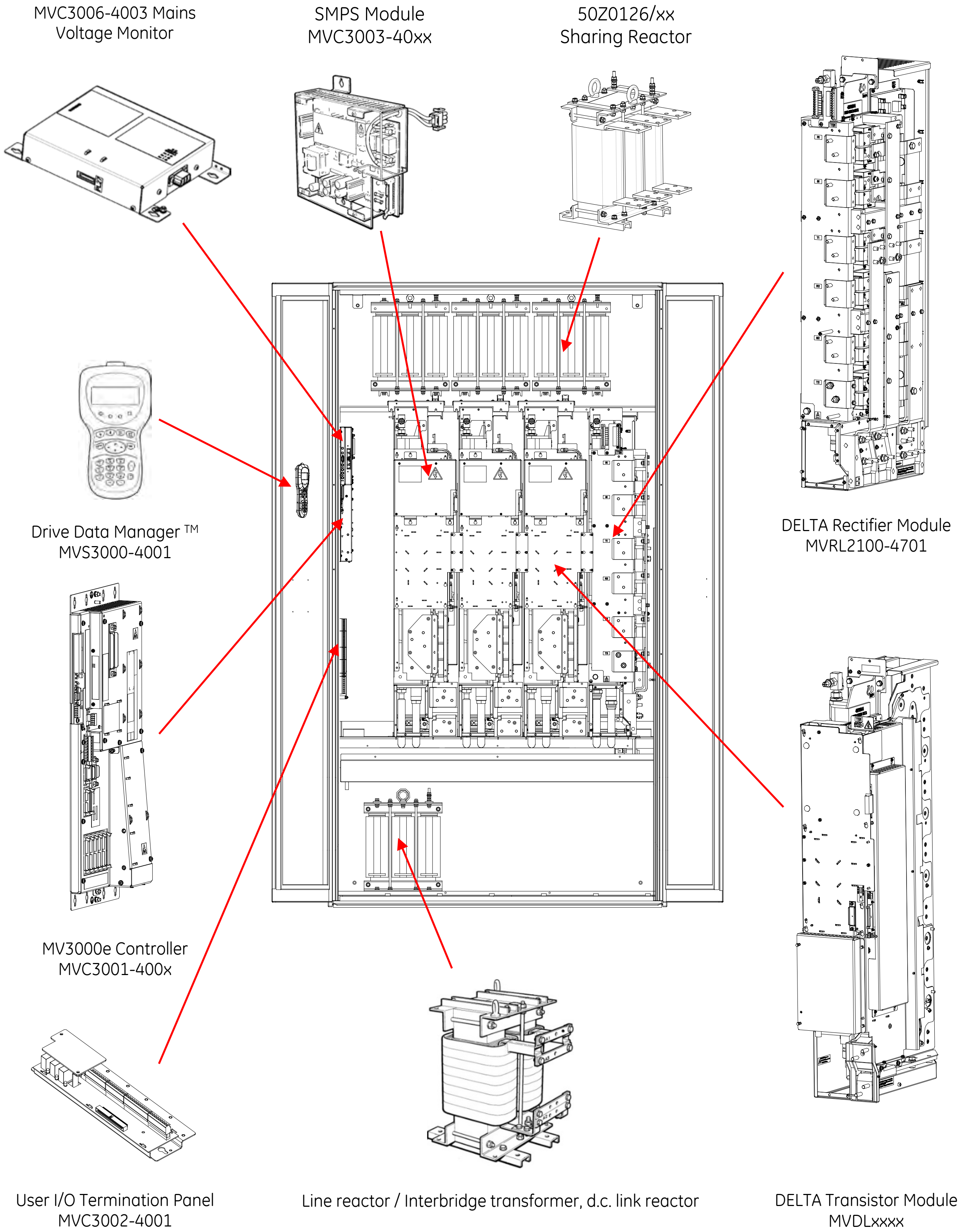


Figure 1–3. – Typical layout of CDM

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2. SPECIFICATION

2.1 INTRODUCTION

The specifications provided in this section are for the individual DELTA components. These components are the transistor and rectifier modules, the MV3000e Controller, the Switched Mode Power Supply (SMPS), the User I/O Termination Panel, associated reactors and transformers and the installation accessories (for use in enclosures). Consideration should be given to the rating of individual components when they are included in a CDM as derating for parallel applications may apply.

2.2 DELTA COMPONENTS (GENERAL ENVIRONMENT)

All DELTA components are designed to comply with the common specifications in Table 2–1 to Table 2–6 unless otherwise detailed in the individual component specification. Drive performance data for an MV3000e based DELTA drive is included in Table 2–7.

2.2.1 Electrical Supply

DELTA modules are intended to be used in a drive connected to an electrical supply with the following characteristics:

FUNCTION	SPECIFICATION
Electrical Supply	
Network Type	TN or TT (i.e. earthed/grounded neutral). Can also be connected to IT network (i.e. isolated or high impedance neutral) if IT network separated from public mains supply by an isolating transformer (see Section 4.5.1: Protection Against Transients).
Voltage Range	575 V - 690 V (600 V nominal)
Voltage Variation (on voltage range)	±10% long term, ±15% for 0.5 to 30 cycles with loss of performance but no trip
Voltage Unbalance	Negative sequence voltage not to exceed 3%
Frequency (optimised)	50 Hz, 60 Hz
Operational Frequency Range	45 Hz to 63 Hz. With frequencies outside the optimised values, extra d.c. link ripple may be apparent and may impair motor control performance.
Insulation Coordination	
Overvoltage Category (line to earth)	EN 50178, IEC 61800-5-1, UL 840, CSA C22.2 No. 0.2 TN or TT network : Overvoltage Category III IT network : Overvoltage Category II For full compliance with UL 508C, transient suppressers complying with UL 1449 must be fitted between line and earth. These must be fitted as close as possible to the point where the electrical supply enters the drive enclosure.

Table 2–1. – Electrical Specification

2.2.2 Switching Frequency

The switching frequency is set by parameter P35.00 in the MV3000e controller (see MV3000e Software Manual T1679). The range of possible switching frequencies is given in Table 2–2.

	Default	Alternatives Available
Network Bridge (AEM only)	2.5 kHz	5 kHz
Machine Bridge	1.25 kHz	2.5 kHz, 5 kHz

Notes:

1. If one of the alternative switching frequencies is selected, it may be necessary to reduce the power rating of the drive, particularly at higher ambient temperatures.

2. If the switching frequency of the network bridge is altered, the effects on the PWM filter must be assessed. The change of PWM frequency will affect the power dissipation in the filter and will also affect the emissions onto the electricity supply.

Table 2–2. – Switching Frequency

2.2.3 Temperature & Humidity

DELTA modules and associated components (including the controller) are intended to be installed in a local ambient (inside the enclosure) with the following characteristics:

FUNCTION	SPECIFICATION
Environmental	
Operating	
Ambient air temperature range	0 to 50°C (32°F to 122°F)
Relative humidity	5 to 95% (non-condensing)
Altitude	Normal operating altitude up to 1000m above sea level. From 1000 m (3280 ft.) to a maximum of 2000 m (6551 ft.) derate by 7.3% per 1000 m (3280 ft.).
Cooling air	Pollution Degree 2 (IEC 60664-1, UL 840 and CSA C22.2 No. 0.2-93) i.e. clean, free from dust, condensation and conductive or corrosive gases. If conductive pollution or condensation are expected (Pollution Degree 3), the drive must be placed in an enclosure which achieves Pollution Degree 2 by: - excluding the conductive pollution e.g. by the use of filtered air; - preventing condensation e.g. by use of anti-condensation heaters. In extreme environments dual circuit heat exchangers are recommended.
Atmospheric chemicals (max)	15 ppm H_2S 25 ppm NO_2 25 ppm SO_2
Liquid coolant temperature	DELTA Inlet temperature: 0°C (32°F) minimum 60°C (140°F) maximum
Storage	
Temperature range	-25°C to +55°C (-13°F to 131°F) – without coolant
Relative humidity	5 to 95% non-condensing
Altitude	Up to 3000 m (9842 ft.) above sea level
Transport	
Temperature range	-25°C to +70°C (-13°F to 158°F) – without coolant
Relative humidity	≤ 95% (non-condensing)
Altitude	Will withstand air transport

Table 2–3. – Temperature & Humidity

2.2.4 Ingress Protection

According to IEC 60529, EN 60529:

IP00 (not protected).

The DELTA modules and associated components must always be installed in an appropriate enclosure with restricted access.

2.2.5 Vibration

2.2.5.1 Operational

The product complies with the vibration requirements in Table 2–4. This meets or exceeds the requirements of the following standards:

- EN 50178;
- IEC 61800-2 (this standard uses class 3M1 of IEC 60721-3-3);
- IEC 61800-5-1;
- DNV Rules for Ships, Pt. 4 Ch.8 Sec. 3.

Frequency	Vibration Level
2 Hz to 5 Hz	0.3 mm displacement
5 Hz to 42.4 Hz	20 mm/s velocity
42.4 Hz to 57 Hz	0.075 mm displacement
57 Hz to 150 Hz	10 m/s^2 acceleration
9 Hz to 200 Hz	1 m/s^2 acceleration

Table 2–4. – Vibration Withstand Levels

The above vibration levels are used as an accelerated life test. For reliable operation, it is recommended that the vibration levels in operation do not exceed the levels of class 3M1 according to IEC 60721-3-3. These are given in Table 2–5 below:

Frequency	Vibration Level
2 Hz to 9 Hz	0.3 mm displacement
9 Hz to 200 Hz	1 m/s^2 acceleration

Table 2–5. – Recommended Maximum Operational Vibration Levels

2.2.5.2 Transport & Storage

The levels in Table 2–6 are permitted only when the modules are packed for transport.

Vibration - Storage and transport	To IEC 61800-2 which specifies Class 2M1 of IEC 60721-3-2 when equipment is packed for transport: 2 to 9 Hz 3.5mm amplitude 9 to 200 Hz 10m/s^2 acceleration 200 to 500 Hz 15m/s^2 acceleration
Drop - Transport	To IEC 61800-2 which specifies Class 2M1 of IEC 60721-3-2 when equipment is packed for transport: mass < 100kg 0.25m; 100kg ≤ mass 0.10m

Table 2–6. – Transportation & Storage Vibration Levels

2.3 DRIVE PERFORMANCE WITH MV3000E CONTROLLER

Table 2–7 includes the drive performance data.

FREQUENCY			
Resolution	0.01%	Control Accuracy	0.1%
SPEED			
Resolution	0.01%	Accuracy (absolute)	0.01%
SPEED CONTROL			
	FREQUENCY CONTROL (VVVF)	**ENCODERLESS FLUX VECTOR**	**FLUX VECTOR WITH ENCODER**
Range	50 : 1	50 : 1	>1000 : 1
Bandwidth	N/A	20 rad/s	100 rad/s
Accuracy	≅ 1%	≅ 0.5%	≅ 0.02%
TORQUE CONTROL			
Bandwidth	< 1 rad/s	> 500 rad/s	> 500 rad/s
Accuracy	≅ 10%	≅ 10%	≅ 5%

Table 2–7. – Drive Performance Data

2.4 MV3000E CONTROLLER

Units covered: MVC3001-400x.

The MV3000e controller, shown in Figure 2–1, provides all control and monitoring functions for the transistor and rectifier bridges in a DELTA drive (to a maximum of 6 transistor modules and 2 rectifier modules).

The controller is supplied in a 'stand-alone' chassis for mounting within an enclosure.

The controller derives an electrical supply from the SMPS of an associated DELTA transistor module. The controller includes facilities for communication with both the transistor and rectifier bridge modules, and external equipment.

The controller can be mounted at various locations in an enclosure. Section 3: Drive (CDM) Design includes the requirements for determining the position of a controller in an enclosure.

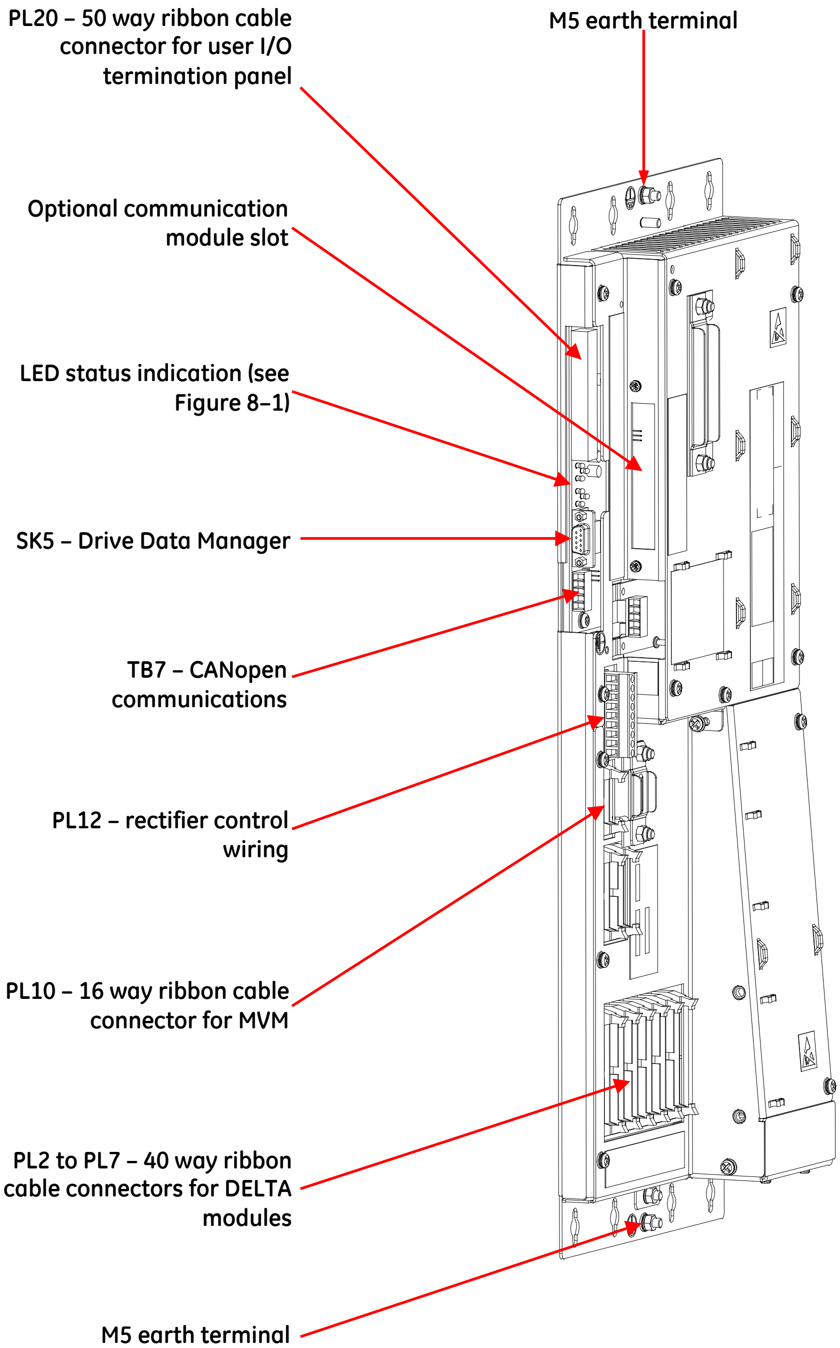


Figure 2–1. – MVC3003-400x Controller Electrical Connections

2.4.1 Electrical Connections

The connections from the MV3000e controller to other equipment in a DELTA drive are as follows:

- Six 40 way ribbon cable connectors for transistor modules, see Table 2–8;
- One 50 Way ribbon cable connector for a user I/O termination panel;
- One 16 way ribbon cable connector for an Mains Voltage Monitor unit;
- One D-type connector for a Drive Data Manager™ keypad;
- One 9 way connector for wiring to the rectifier module, see Table 2–9;
- One 5 way connector for wiring CANopen communications, see Table 2–10.

PL2 to PL7 carry the control signals to and from the DELTA transistor modules. Each DELTA transistor module is identified by the connector position it occupies, as shown in Table 2–8:

Controller Connector	DELTA Designation
PL2	DELTA 1, PL1
PL3	DELTA 2, PL1
PL4	DELTA 3, PL1
PL5	DELTA 4, PL1
PL6	DELTA 5, PL1
PL7	DELTA 6, PL1

Table 2–8. – DELTA Ribbon Connector Identities

The connection arrangement for the modules at the controller is shown in the connection diagrams in Appendix B: Electrical Connection Diagrams.

The rectifier module control connections are made to PL12, as listed in Table 2–9. Rectifier control wiring should have a cross sectional area between limits of:

Minimum 0.5 mm^2 or 20 AWG (use a consolidating crimp)
Maximum 2.5 mm^2 or 14 AWG

Terminal Number	Function
1	NTC Temperature Monitor - Thermistor
2	NTC Temperature Monitor - Thermistor
3	Thermostat (+24 V = HEALTHY)
4	+24 V
5	+24 V
6	0 V
7	+24 V
8	Pre-charge Relay +24 V
9	Pre-charge Acknowledge (+24 V = HEALTHY)

Table 2–9. – PL12 Connection Functions For Rectifier Modules

CAN communications are made available on TB7. The pin assignments are shown in Table 2–10. The CAN port connector wiring should have a cross sectional area between limits of:

Minimum 0.25 mm^2 or 23 AWG (use a consolidating crimp)
Maximum 1.5 mm^2 or 16 AWG

TB7 Pin Number	Function
1	Comms GND
2	CAN_LO
3	Screen
4	CAN_HI
5	N/C

Table 2–10. – TB7 Connection Functions For The CANport

2.4.2 Weight

The MV3000e controller weighs approximately 4 kg (8.8 lb.).

2.4.3 Optional Modules

Several optional communication modules are available for retrofit to the standard MV3000e controller:

- MVC3007-4002 Profibus field coupler 12 Mb/s;
- MVS3011-4001 2nd CAN port communications module;
- MVS3012-4001 Ethernet interface, single channel;
- MVS3012-4002 Ethernet interface, dual channel.

Installation and operation instructions are supplied with each module, see Section 1: Introduction.

2.5 USER I/O TERMINATION PANEL

Unit covered: MVC3002-4001

The user termination panel, shown in Figure 2–2, provides connection facilities for I/O signals to and from the MV3000e drive.

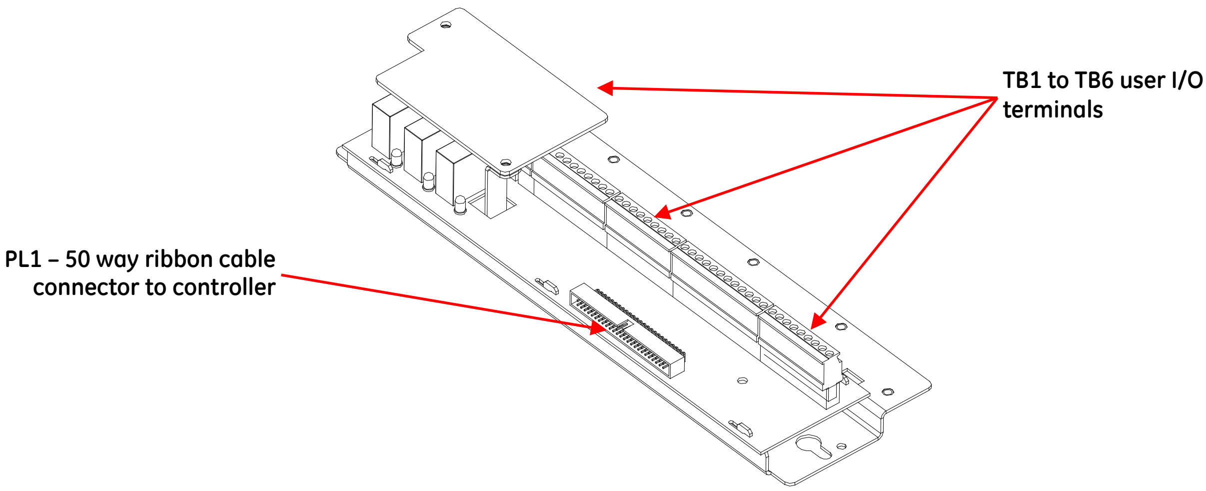


Figure 2–2. – User I/O Termination Panel

Except for connections to TB1, TB2 and TB3, multicore screened cables should always be used. For each screened cable, crimp the braid to an M4 (No. 8 or 3/16 in) ring crimp and secure it to the panel with the M4 screws provided.

The user connectors on the user I/O termination panel are suitable for 0.5 mm^2 - 2.5mm^2 (20 to 14 AWG) single core or flexible cable. A consolidating crimp should be used for the minimum size. Refer to table below for a specification of each terminal function.

Refer to the Commissioning section of T1676 or T2002 MV3000 Getting Started Manuals for basic I/O configuration.

Plant I/O is configured by Menu 7 of the MV3000 firmware. Refer to T1679 MV3000 Software Manual for details of Menu 7.

There are two DIP switches on the module (see Figure 2–3) that configure the analogue I/O for current or voltage operation. Further parameterisation is done through Menu 7 of the MV3000 firmware.

NOTE: **TB4 and TB6 are each 9 way terminal blocks of the same connector pitch and so it is important that wiring for these blocks is connected to the correct terminal block. TB1 is also a 9 way terminal block but this has a different connector pitch to TB4 and TB6.**

2.5.1 Electrical Connections

The connections from the I/O panel to other equipment in the DELTA drive are as follows:

- One 50 way ribbon cable (925 mm [36.4 in] long), supplied with the I/O termination panel, connects to the controller.

The user connections made available by the I/O panel are:

- TB1 - Digital outputs (three);
- TB2 - 24 V d.c. auxiliary input;
- TB3 - Digital inputs (six), interlock, 24 V peripheral supply;
- TB4 - Communications (RS485, HSIO);
- TB5 - Encoder / PTC (Thermistor, positive temperature coefficient);
- TB6 - Analogue I/O (2 inputs, 2 outputs).

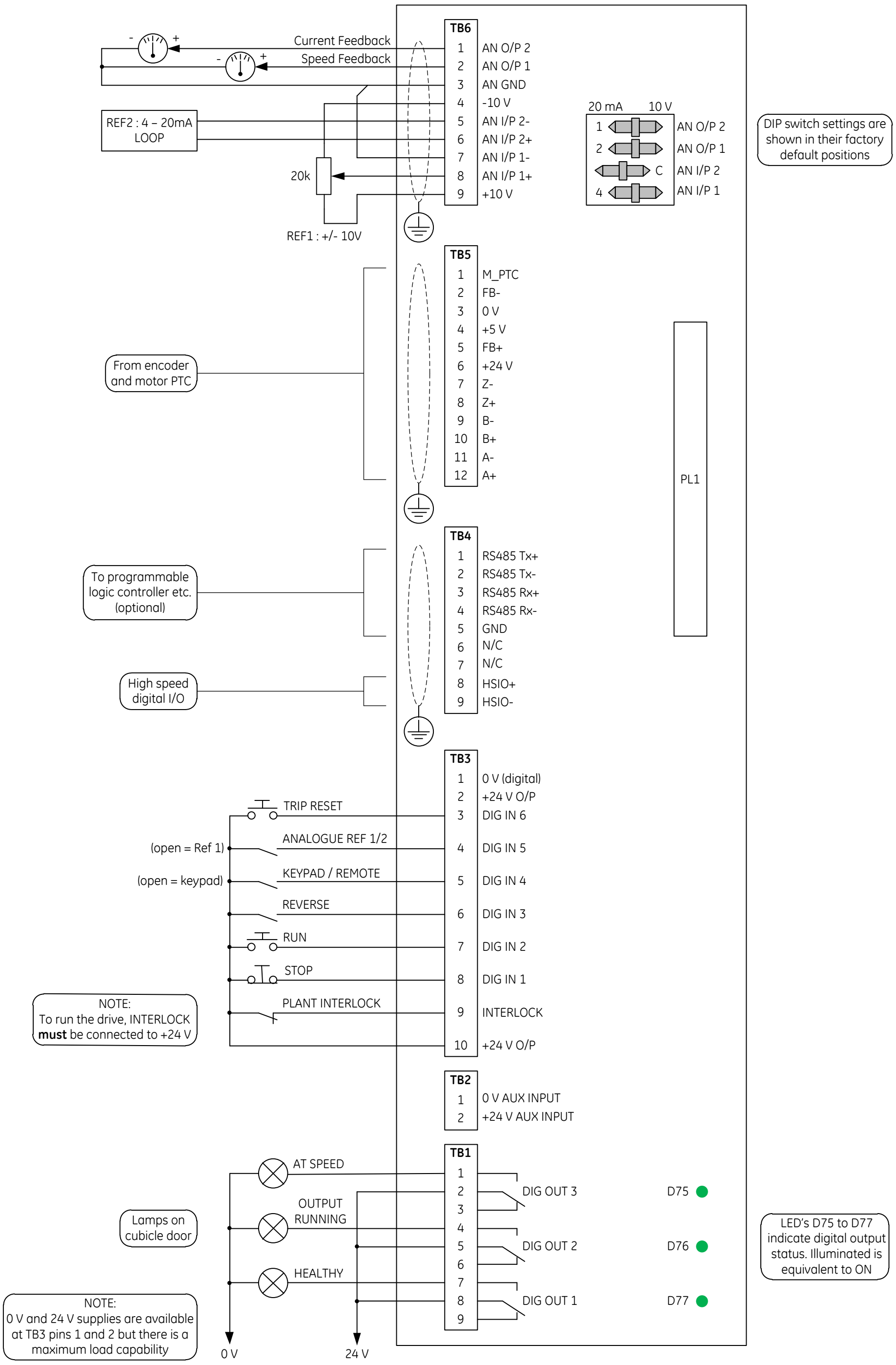


Figure 2–3. – Wiring Diagram For User I/O Termination Panel

TB6		Analogue Inputs/Outputs (Menu 7)	Specifications
Pin	Signal		
1/2	AN O/P 1 and 2	Analogue outputs 1 and 2 Voltage (V) or Current (I) as selected by SW1	V or I: (11 bit + sign), ±5% full scale accuracy, update time 5 ms V: −10 V to +10 V, ≤ 5 mA load I: −20 mA to +20 mA, ≤ 500 Ω load
3	AN GND	Analogue earth / ground for i/p and o/p	Connected to earth/ground internally
4/9	−10.5 V/+10.5V	Reference supplies for analogue inputs	Maximum Load: 5 mA, current limited
5/6 7/8	AN I/P 2 −/2 + AN I/P 1 −/1 +	Differential analogue input 2 Differential analogue input 1 Voltage (V) or Current (I) as selected by SW1	V or I: (11 bit + sign), ±5% full scale accuracy: V: −10 V to +10 V, 100 kΩ load input Z I: −20 mA to +20 mA, 235 Ω load input Z Common mode volts = ±2.5 V maximum
TB5		**Encoder/PTC (Menu 13)**	**Specifications**
1	M_PTC	Input from motor PTC	Resistive:Trip: P2.13 (0 Ω to 7 kΩ) Reset: P2.13 – 0.1 kΩ
2/5	FB −/FB+	Encoder power supply feedback for accurate setting	
4/6	+5 V/+24 V	Power supply outputs for the encoder	+5 V: Adjustable, 350 mA maximum 4.5 - 6.5 V, +24 V : Fixed, 350 mA maximum
3	0 V	Common return line for encoder power supply and the PTC	Connected to earth/ground internally
7/8 9 - 12	Z−/Z+ B−/B+, A−/A+	Marker signal from encoder Encoder position signals	EIA RS422A, Max edge frequency 1.5 MHz EIA RS422A, Max edge frequency 1.5 MHz
TB4		**Communications**	**Specifications**
1/2 3/4	RS485 Tx +/Tx− RS485 Rx +/Rx−	Differential link for improved noise immunity (Menu 32)	0 - 2 km range. Update time 10 ms.
5	GND	Common ground for communications links	Connected to earth / ground internally
6/7	No function	No connection	-
8/9	HSIO +/−	High speed digital link (Menu 20) Common mode volts ≅ 15 V	RS422 protocol, ± signal differential wrt GND pin.
TB3		**Digital Inputs (Menu 7)**	**Specifications**
1	0 V (digital)	0 V reference of digital inputs	Connected to earth / ground internally
2 & 10	+24 V O/P	User supply for peripheral equipment	Volts range: +22.8 V to +25.3 V Max load: 500 mA
3 to 8	DIGIN 1-6	For remote control of drive – default functions are shown in wiring diagram	Impedance: 15 kΩ Active: +12 V to +50 V Inactive: Open circuit or < 7 V
9	INTERLOCK	Hardware interlock – must be made to enable drive	Impedance: 15 kΩ Healthy: +12 V to +50 V Unhealthy: Open circuit or < 7 V
TB2		**Auxiliary Input Supply**	**Specifications**
1 2	0 V Aux Input +24 V Aux Input	Allows monitoring and programming with main power switched off	Current, nominal (Keypad + CDC): 500 mA Current, max (all versions): 2.2 A
TB1		**Digital Outputs**	**Specifications**
DIGOUT 1 to 3		Volt-free changeover relay outputs	Max volts: 250 Vac, 30 V d.c. Max current: 3 A (resistive load)

Table 2–11. – User I/O Termination Panel Connections

2.5.2 Weight

The user I/O termination panel weighs approximately 1 kg (2.2 lb.).

2.6 MAINS VOLTAGE MONITOR (MVM)

Unit covered: MVC3006-4003.

The Mains Voltage Monitor unit, shown in Figure 2–4, is used to precisely monitor the mains voltage and phase angle, to allow an MV3000e to operate as an AEM drive. The full specification is given on the datasheet provided with the unit.

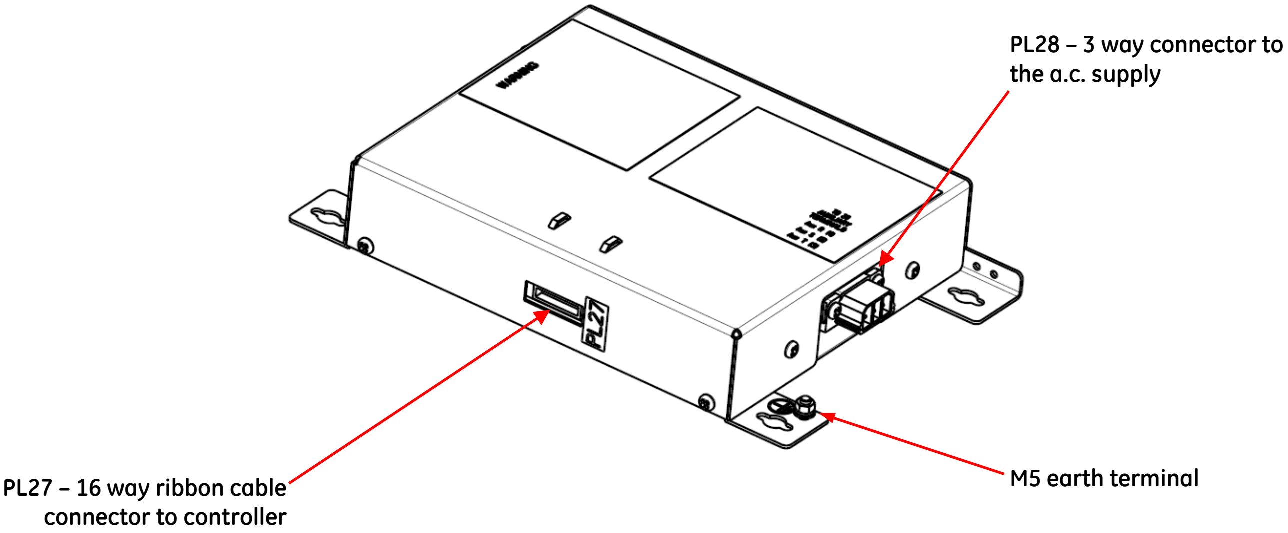


Figure 2–4. – Mains Voltage Monitor Unit (MVM)

2.6.1 Electrical Connections

The terminations from the MVM module to other equipment in the DELTA drive are as follows:

- One 16 way ribbon cable (360 mm [14.2 in] long) supplied with the MVM unit, connects to the controller;
- One 3 pin connector to a.c. input.

Wiring to PL28 should have a cross sectional area between limits of:

Minimum	0.5 mm^2 or 20 AWG (use a consolidating crimp)
Maximum	2.5 mm^2 or 14 AWG

2.6.2 Weight

The MVM module weighs approximately 1.75 kg (3.85 lb.).

2.7 SWITCHED MODE POWER SUPPLIES (SMPS)

Units covered: See Table 2–12.

The DELTA SMPS, shown in Figure 2–5, is mounted on the front of each transistor module. It provides power to the control electronics of the transistor module and for the MV3000e controller. The SMPS derives a supply from the drive d.c. link, via a connector on the associated transistor module.

There are several versions, offering different operating voltages, or enhanced d.c. link monitoring.

Power to the control electronics is maintained during a temporary loss of supply.

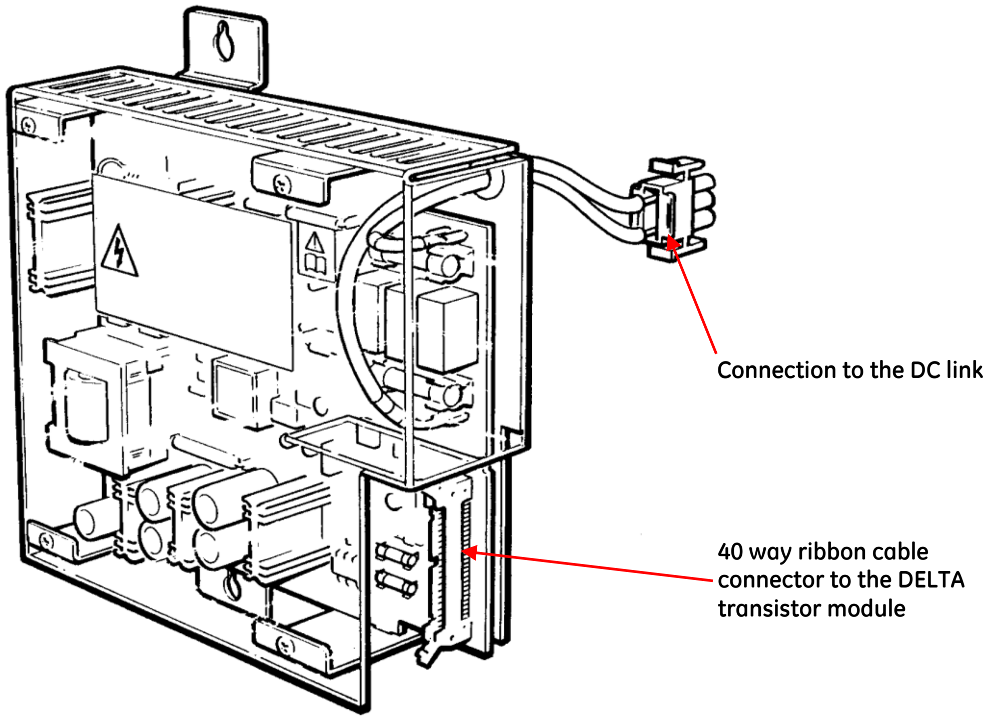


Figure 2–5. – MVC3003 SMPS Module

	SMPS Type					
Parameter	**MVC3003-4001**	**MVC3003-4002**	**MVC3003-4003**	**MVC3003-4020**	**MVC3003-4025**	**MVC3003-4030**
Nominal drive supply voltage	380 – 440 V a.c. (400 V nominal)	460 – 525 V a.c. (480 V nominal)	575 - 690 V a.c. (600 V nominal)			
SMPS supply	Fed from d.c. link of DELTA transistor module					
Start up voltage	450 V d.c.		550 V d.c.			
Instantaneous Overvoltage Trip	784 V d.c.	882 V d.c.	1172 V d.c.	1188 V d.c.	1290 V .d.c.	1262 V d.c.
Timed Overvoltage Trip	Not available			1188 V d.c.	Not available	1188 V d.c.
Undervoltage Trip	400 V d.c.	450 V d.c.	560 V d.c.			
Output power	110 W					
Maximum ambient	50°C					
Weight	1.5 (3.3 lbs.)			1.8 (4 lbs.)	1.5 (3.3 lbs.)	1.8 (4 lbs.)

Table 2–12. - SMPS Specifications

NOTE: See Section 3: Drive (CDM) Design for SMPS selection guidance.

2.7.1 Electrical Connections

The connections from the SMPS unit to other equipment in the DELTA drive are as follows:

- One 40 way ribbon cable, supplied as part of the DELTA transistor module;
- A two pin connector plugs into the d.c. link of the associated DELTA transistor module.

2.8 MV3000E DRIVE DATA MANAGER™ (KEYPAD)

Units covered: MVS3000-4001 (DDM)

MVS3001-4001 (Installation kit)

The Drive Data Manager™, shown in Figure 2–6, is an ergonomically designed keypad which provides the functionality to configure a drive system. It also provides motor control and diagnostic functions.

The Drive Data Manager™ derives its power supply from the MV3000e Controller.

Figure 2–6. – Drive Data Manager™ (Keypad)

An installation kit containing a waterproof gasket and a lead is available separately. The lead for connection from the Keypad to the MV3000e controller has a maximum length of 3 m (9.8 ft.). This lead length determines the relative positions of the Drive Data Manager™ and the controller. When supplied with a waterproof gasket, it can be mounted on an enclosure door to meet IP 65 enclosure protection.

The specification for the Drive Data Manager™ and its electrical connections, are included in the T1915 Instruction Sheet which is supplied with the Drive Data Manager™.

2.9 DELTA RECTIFIER MODULE

Unit covered: MVRL2100-4601.
MVRL2100-4602.

In a DELTA drive system, rectifier modules shown in Figure 2–7, are used in network bridges to convert an a.c. supply into a rectified, unsmoothed d.c. supply.

The rectifier module is available in a single rating. Larger rectifier power ratings can be achieved by connecting the modules in parallel (derating will be necessary, see Section 2.9.4.1: Parallel Ratings).

Each module has a pair of three-phase, six pulse rectifiers, with individual a.c. input terminals. Two d.c. positive terminals and a single d.c. negative output terminal are provided.

The rectifier module may be operated as a 12-pulse network bridge. This configuration is achieved by connecting the d.c. positive outputs together through an interbridge transformer and one a.c. input being phase-shifted in relation to the other by an external supply transformer.

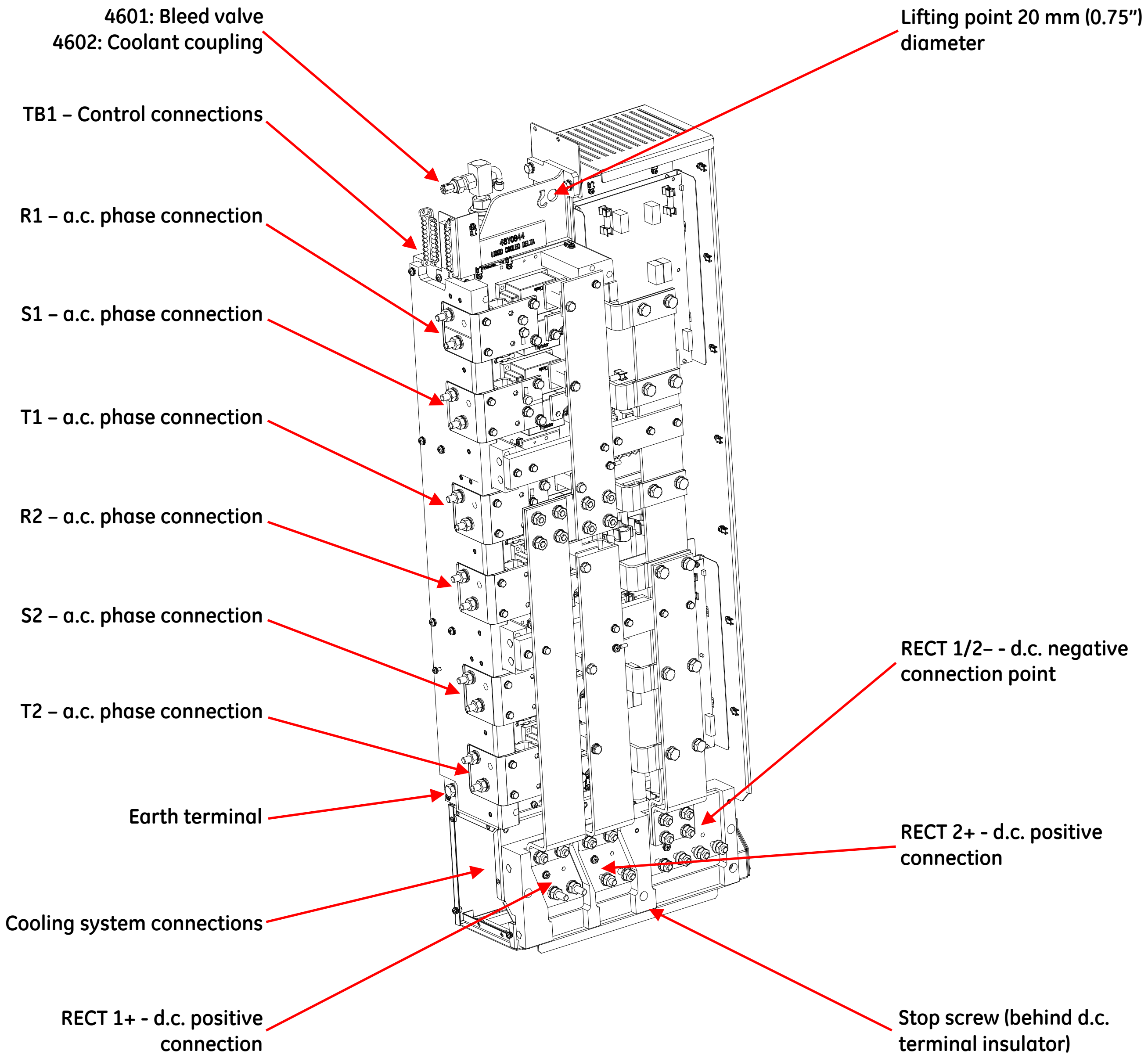


Figure 2–7. – DELTA Rectifier Module

2.9.1 Features

- The rectifier module includes a circuit which is capable of pre-charging the transistor modules. This circuit charges the d.c. link capacitors of the transistor modules via current limiting resistors in the rectifier module;
- Modules fit in the standard DELTA mounting frames;
- Metal oxide varistors are included to absorb surge energy from the mains. Supply impedance is necessary for this to function correctly;
- Protection against d.c. link short circuits is by the use of recommended semi-conductor fuses;
- Modules carry thermostat and thermistor temperature sensing devices, which are monitored by the MV3000e controller to provide over-temperature protection.

2.9.2 Interfaces

- Signals between the controller and rectifier module are by individual wires;
- The a.c. and d.c. power connections have stud terminals and are designed for cable connection, however maximum sizes for busbar connections to d.c. terminals are provided in this manual.

2.9.3 External Requirements

- For parallel operation of rectifier modules, external sharing reactors must be fitted;
- Similarly, for parallel operation of the two six-pulse rectifiers within a MVRL2100-4601 module, external sharing reactors must be fitted;
- For 12-pulse operation, the two supplies must be phase shifted by 30° to each other, and be of balanced voltage. The d.c. output must be through an interbridge transformer;
- Protection of the main input rectifier devices is by the addition of external semi-conductor fuses. For recommended fuses, see Section 2.9.4.2: Fusing;
- The a.c. and d.c. terminals on the modules are not suitable to support the weight of any attached cables. These cables must have additional mechanical support;
- These liquid cooled modules must be cooled by an externally derived cooling system.

2.9.4 Current Ratings and Recommended Fuses

Overloads are for 60 seconds, 6 times per hour equally spaced.

All ratings assume standard drive configurations using the recommended interbridge transformers.

2.9.4.1 Parallel Ratings

Output current should be de-rated by 10% in the following circumstances:

- Two separate rectifier modules connected in parallel;
- Two halves of the same rectifier connected in parallel (6 pulse).

In systems with parallel rectifiers, a.c. line reactors will be required.

2.9.4.2 Fusing

To protect a DELTA rectifier module from d.c. link side short circuits it is recommended that semi-conductor fuses be fitted in the a.c. supply. The current rating of the rectifier module with the recommended fuses is given in Table 2–13. Other manufacturers' fuses may be used but they should be equivalent to the types specified in this manual. Appendix B: Electrical Connection Diagrams includes details of the input power circuits and the fusing arrangements.

MVRL2100-4601/2 Voltage Rating 500 - 690 V a.c. Current Rating of 2100 A d.c. + 10% for 60 s in 600 s			
Manufacturer	**Part Number**	**Microswitch**	**Quantity of fuses**
Cooper Bussmann	170M6117	170H0069	6

MVRL2100-4601/2 Voltage Rating 500 - 690 V a.c. Current Rating of 1600 A d.c. + 50% for 60 s in 600 s			
Manufacturer	**Part Number**	**Microswitch**	**Quantity of fuses**
Cooper Bussmann	170M6118	170H0069	6

Table 2–13. – Recommended Fuses For Rectifier Module Input Protection

NOTES: Semi-conductor fuses of the correct rating must be fitted to each of the three phases of the a.c. supply input to protect against catastrophic failure of the input rectifiers.

The fuses should be fitted remotely from the rectifier;

All ratings are calculated assuming a 31 MVA supply (fault level), no added impedance.

All incoming mains cables should be protected with fuses according to local wiring regulations, for example, in Europe (or any other countries that use IEC standards) using fuses type gG and in USA and Canada using Class L fuses.

2.9.5 Phase Rotation

Rectifier modules are not sensitive to phase rotation.

2.9.6 Phase Voltage

The Input Phase Voltage is detailed in Table 2–14.

Nominal voltage is a.c. r.m.s, 3 phase, 3-wire and earth/ground.

The equipment will operate with a variation of ±10% of the nominal supply voltage. For supply voltages below the nominal, there will be a corresponding reduction in maximum output power. The equipment can operate up to a maximum of +15% variation on the nominal supplies for a maximum of 30 cycles duration without the equipment tripping though reduced performance may be observed.

Supply frequency : 45 Hz to 63 Hz.

	Input AC Voltage	**Output DC Link Voltage**	
Module	**Nominal AC Input Voltage (V r.m.s.)**	**Maximum Output (V d.c.)**	**Maximum Allowed Regenerative Voltage (V d.c.)**
MVRL2100-4601/2	575 - 690	1122	1250

Table 2–14. – Input a.c. Voltage & Output d.c. Link Voltage Ratings

2.9.7 D.C. Link Voltage

The Output d.c. Link Voltage is detailed in Table 2–14.

Typical d.c. output: 1.35 x supply voltage (r.m.s).

2.9.8 Pre-Charge

Pre-charge requirements are listed in Table 2–15. The pre-charge control signal switches in the main rectifiers when the d.c. link has finished pre-charging. The drive controller determines when the charging period is complete. The MVRL2100-4601/2 DELTA rectifier module is capable of pre-charging:

- Up to three MVDL643 DELTA transistor modules;
- Up to three MVDL800 DELTA transistor modules;
- Up to two MVDL1000 DELTA transistor modules.

The rectifier pre-charge acknowledge signal must be connected to the MV3000e controller at PL12, to allow drive operation. See Table 2–9.

Module	Internal Pre-charge Resistor (Ohm)	Control Signal Voltage (V d.c.)	Control Signal Load (mA)
MVRL2100-4601/2	72	24 V	10 mA

Table 2–15. – Pre-Charge Requirements

2.9.9 Thermal Protection

Thermal protection is provided on each rectifier module by a thermistor on the upper heatplate and a thermostat located on each heatplate. Connection details are given in Table 2–9. The thermostat contact is a normally closed contact and opens at 90°C ±3°C.

2.9.10 Electrical Connections

2.9.10.1 Control Connections

The rectifier control terminals are mounted at the top of the front face of the Rectifier module - see Figure 2–7. The customer terminals are the left half of a 10-pin plug and socket, referenced TB1, and may be unplugged for ease of wiring. See Figure 2–8 for the terminal layouts and functions.

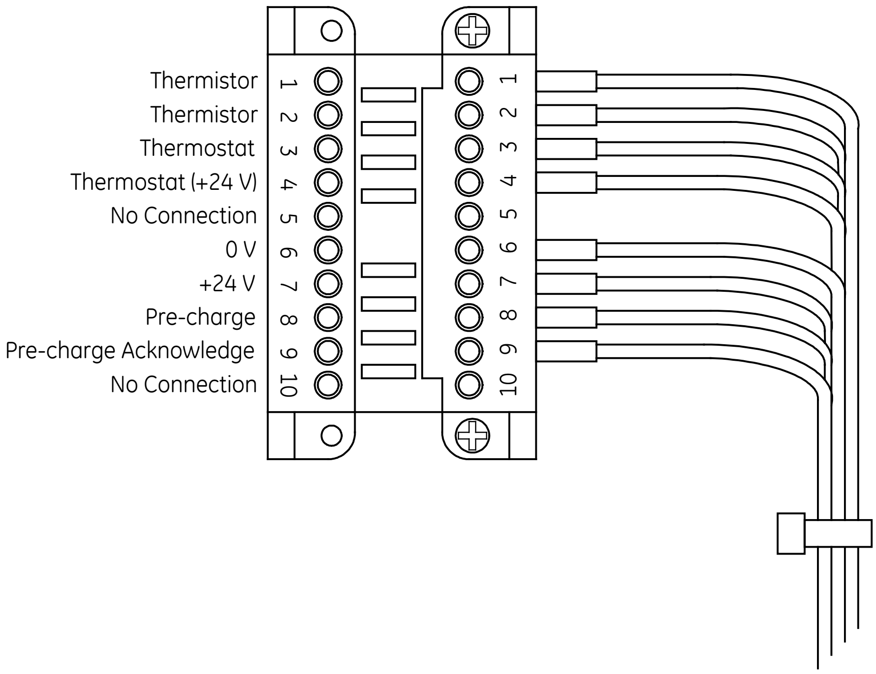


Figure 2–8. – Rectifier Module Control Terminals At TB1

Terminals will accept up to 2.5 mm² (12 AWG) flexible cables. To prevent failure of the Rectifier module pre-charge components, the rectifier pre-charge acknowledge signal (TB1/9) must be connected to the control module. If this signal is not healthy the control module will not allow the drive to run.

2.9.10.2 Power Connections

Terminations for the 3-phase supply, the d.c. output and earth/ground are detailed in Table 2–16.

Termination	Stud Size	Crimp Size
a.c.. terminals	2 x M10 stud connections per phase.	M10 (or 3/8 in) ring crimps
d.c. terminals	2 x M10 stud connections for each positive output and 4 x M10 stud connections for the single negative output	M10 (or 3/8 in) ring crimps
Earth Terminal	1 x M10 bolt	M10 (or 3/8 in) ring crimps

Table 2–16. – Terminations For 3-Phase a.c. Supply, d.c. Output & Earth

The a.c. terminals are suitable for a maximum of 2 x 150 mm^2 cables (2 x 300 MCM in North America).

To achieve the full current rating of the product, it may be necessary to use high temperature cable. See Section 3: Drive (CDM) Design.

NOTE: **Do not allow the temperature of the cable to exceed 125°C (257°F).**

The d.c. positive terminals are suitable for a maximum size of busbar at 76 mm x 6.3 mm wide (= 3 in x ¼ in). The d.c. negative terminals are suitable for a maximum size of busbar at 140 mm x 6.3 mm wide (≈ 5.1/2 in x 1/4 in). Ratings and sizes of busbars are application dependent.

2.9.11 Heat Dissipation

The heat dissipation for a DELTA rectifier module will vary depending upon the drive in which it is used (a typical dissipation from module to coolant is 6 kW). The total heat dissipation will include heat dissipated from the module into the coolant and into the enclosure environment. As an approximation, it can be assumed that 90% of module losses will be into the liquid coolant, with the remaining 10% into the enclosure air. As these dissipation figures are all application-dependent, refer to GE Power Conversion for advice.

2.9.12 Weight

The dry weight of the MVRL2100 DELTA rectifier module is 85 kg (187 lb.). Each module increases in weight by 1.5kg (3.3 lb.) when filled with coolant.

2.9.13 Acoustic Noise

The acoustic noise generated by the DELTA rectifier module is negligible. The majority of any noise generated will be from the wound components and heat exchanger system and this will be specific to each application.

2.10 DELTA TRANSISTOR MODULE

Units covered: MVDL643-4702
MVDL800 range
MVDL1000 range

In a DELTA drive, transistor modules shown in Figure 2–9, are used in both machine bridges and AEM network bridges, to convert between variable frequency a.c. and d.c. voltages.

Transistor modules are available in three current ratings. Larger power ratings can be achieved by connecting modules of the same rating in parallel (derating will be necessary).

When operated in parallel, sharing reactance will be required.

Each module has three a.c. phase, one d.c. negative, and one d.c. positive terminal.

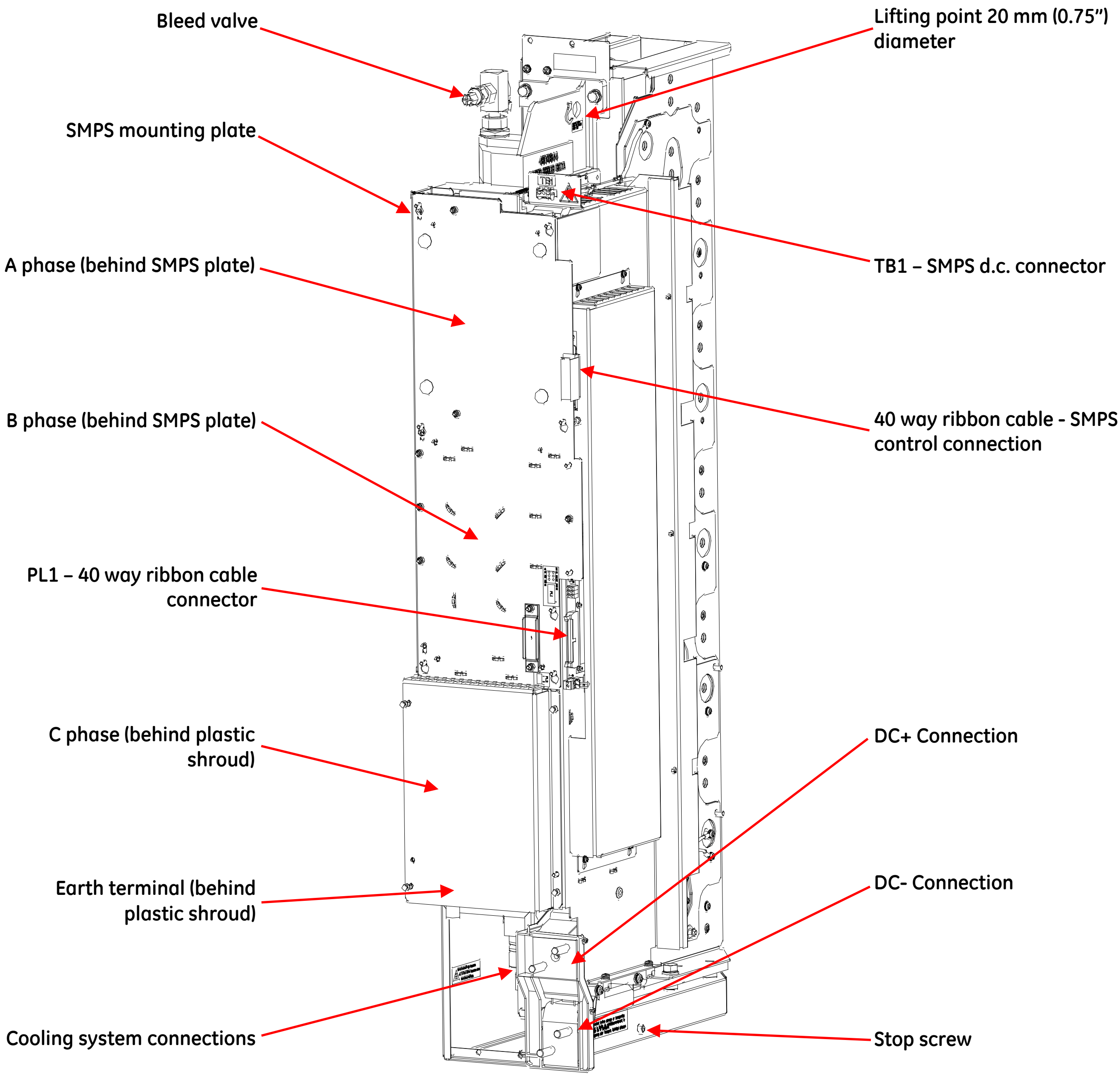
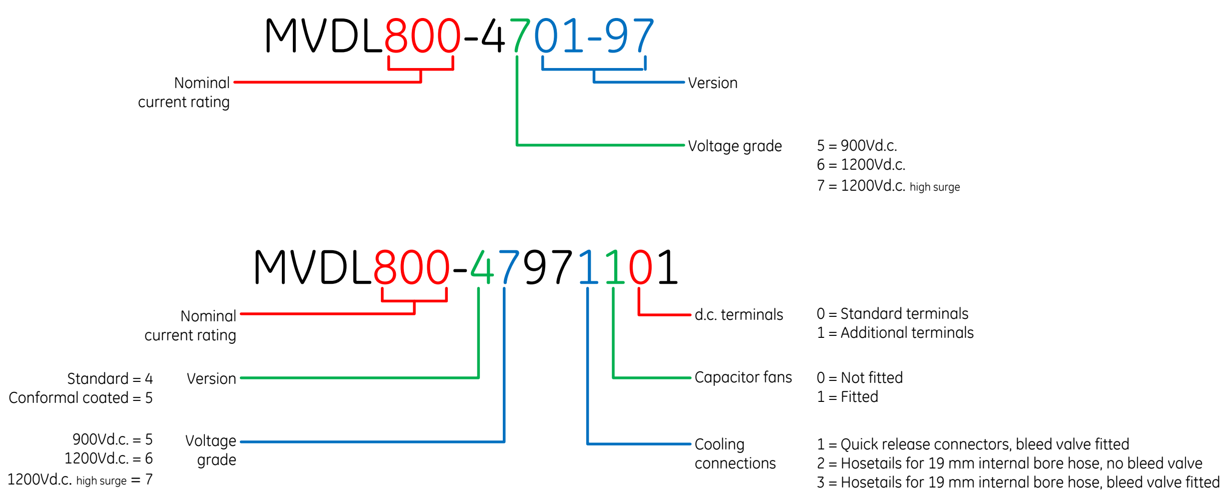


Figure 2–9. – DELTA Transistor Module

The values given in this section are the absolute maximum ratings for the DELTA transistor modules. As other components (i.e. controller) are required to form a complete drive circuit, then the ratings arising from the combined components should be used when sizing a drive.

2.10.1 Transistor Module Part Numbering

Two types of part number exist for DELTA transistor modules, the formats of which are described below:



NOTE: All part number combinations may not be available. Refer to GE Power Conversion for further details.

2.10.2 Features

- Wide range of optional features can be configured;
- Modules fit in the standard DELTA mounting frames;
- DELTA transistor modules use insulated-gate, bipolar transistors (IGBTs) to provide low distortion output;
- Smoothing capacitors provide filtering for the drive d.c. link, in addition to local energy storage for IGBT switching;
- Output protection against short circuits;
- Auxiliary d.c. link connection plug for connection to the SMPS. The SMPS unit is mounted on the transistor module;
- Each module includes thermistor protection. When connected to the MV3000e controller the module is protected against excessive temperature;
- As an option, modules can include d.c. link capacitor cooling fans, which are automatically monitored to ensure correct performance.

2.10.3 Interfaces

- Signals between the controller and transistor module are by a single 40 way, ribbon cable per module. This cable also carries the supplies for the electronics in the controller;
- An SMPS unit is connected to the transistor module with a 40 way, ribbon cable and a 2 pin, d.c. connection;
- The a.c. and d.c. power connections have stud terminals and are designed for cable connection, however maximum sizes for busbar connections to d.c. terminals are provided in this manual.

2.10.4 External Requirements

- Transistor modules contain smoothing capacitors, which when used in both network and machine bridge applications, must be 'pre-charged'. These modules do not have inbuilt pre-charge circuits. Pre-charge is either via a DELTA rectifier module or external circuitry. Refer to Section 3: Drive (CDM) Design for external pre-charge guidance;
- The d.c. supply to the transistor module must be within appropriate voltage, current and ripple limits, and must be 'pre-charged';
- The a.c. and d.c. terminals on the modules are not suitable to support the weight of any attached cables. These cables must have additional mechanical support;
- These liquid cooled modules must be cooled by an externally derived cooling system;
- When transistor modules are used as network bridges, it is recommended that semi-conductor fuses are fitted on the a.c. supply on a per module basis.

2.10.5 A.C. Phase Current Ratings

The a.c. phase current ratings, detailed in Table 2–17, are limited by the system design. The cooling system, number of parallel DELTA transistor modules, plus type and configuration of controller, will limit the system rating. It is NOT possible to achieve these absolute ratings under all operating conditions. Most combinations of ambient temperature, supply voltage, and switching frequencies will result in a reduced rating. Refer to GE Power Conversion for specific ratings for different configurations.

Conditions	MVDL643	MVDL800	MVDL1000
Continuous a.c. r.m.s. current allowing for a 1.5 x overload	471 A	587 A	733 A
Continuous a.c. r.m.s. current allowing for a 1.1 x overload	643 A	800 A	1000 A

Table 2–17. – Absolute Maximum a.c. Phase Current Ratings (network or machine mode)

2.10.6 Phase Voltage

The maximum output phase to phase r.m.s voltage is V d.c./√2 for sinusoidal waveforms.

2.10.7 D.C. Link Voltage

DELTA transistor module d.c. voltage ratings are given in Table 2–18. For instance, when a motor is braked power is returned to the drive and the d.c. link voltage rises. To protect the DELTA transistor modules the drive is programmed to trip if the d.c. link voltage rises to an excessive level. The overvoltage trip level is determined by the type of SMPS units fitted, See Table 2–12.

<table>
<tr><th>Module</th><th>Maximum Continuous Working Voltage</th><th>Maximum Voltage (Surge) *</th><th>Maximum Silicon Voltage (V_{CES})</th><th>Overvoltage Trip Level for 600 V & 690 V Nominal Supply Voltage</th></tr>
<tr><td>MVDL 643-4702</td><td>1165 V</td><td>1200 V</td><td rowspan="3">1700 V</td><td rowspan="3">See note**</td></tr>
<tr><td>MVDL800 range</td><td rowspan="2">1200 V</td><td rowspan="2">1275 V</td></tr>
<tr><td>MVDL1000 range</td></tr>
</table>

Table 2–18. – DC Link Voltage & Overvoltage Trip Level

NOTES: * : the maximum surge level is the lesser of the d.c. link capacitor rating and the short circuit test rating for the IGBT (Insulated-gate Bipolar Transistor).
**** : overvoltage trip level is determined by the type of SMPS unit fitted. See Section 3: Drive (CDM) Design for selection instructions.**
Refer to Section 2.10.9 for additional fuse details concerning protection of the d.c. link.

2.10.8 D.C. Link Capacitors

Table 2–19 gives the capacitance values for single DELTA transistor modules.

<table>
<tr><th>Product Type</th><th>Voltage rating of each capacitor (V d.c.)</th><th>Value of Capacitor (μF)</th><th>Number in Series</th><th>Total Quantity</th><th>Total Capacitance (μF)</th><th>Discharge Time (< 50 V d.c.)*</th></tr>
<tr><td>MVDL643-4702</td><td>450</td><td rowspan="2">2900</td><td rowspan="3">3
(12 parallel paths)</td><td rowspan="3">36</td><td rowspan="2">11600</td><td rowspan="2">5 minutes</td></tr>
<tr><td>MVDL800 range</td><td>450</td></tr>
<tr><td>MVDL1000 range</td><td>450</td><td>4200</td><td>16800</td><td>8 minutes</td></tr>
</table>

*** The quoted d.c. link discharge times assume maximum d.c. link operating voltage.**

Table 2–19. – DC Link Capacitors For A Single DELTA Transistor Module

2.10.9 DELTA Transistor Module DC Link Fuse Protection

For multiple transistor bridge applications, it is recommended that each module is fused at both the d.c. + and d.c. - terminals. Fuses must be rated for the d.c. link operating voltage. Refer to Table 2–20 for recommended fuse types and Appendix B: Electrical Connection Diagrams for connection details.

<table>
<tr><th colspan="4">MVDL643-4702 Voltage Rating 1165 V d.c.
Current Rating of 643 A + 10% for 60 s in 600 s</th></tr>
<tr><th>Manufacturer</th><th>Part Number</th><th>Microswitch</th><th>Quantity of fuses</th></tr>
<tr><td>Cooper Bussmann</td><td>170M6114</td><td>170H0069</td><td>2</td></tr>
</table>

<table>
<tr><th colspan="4">MVDL643-4702 Voltage Rating 1165 V d.c.
Current Rating of 471 A + 50% for 60 s in 600 s</th></tr>
<tr><th>Manufacturer</th><th>Part Number</th><th>Microswitch</th><th>Quantity of fuses</th></tr>
<tr><td>Cooper Bussmann</td><td>170M6114</td><td>170H0069</td><td>2</td></tr>
</table>

<table>
<tr><th colspan="4">MVDL800-47xx / MVDL800-xxxxxxxx
Voltage Rating 1200 V d.c.
Current Rating of 800 A + 10% for 60 s in 600 s</th></tr>
<tr><th>Manufacturer</th><th>Part Number</th><th>Microswitch</th><th>Quantity of fuses</th></tr>
<tr><td>Cooper Bussmann</td><td>170M6114</td><td>170H0069</td><td>2</td></tr>
</table>

<table>
<tr><th colspan="4">MVDL800-47xx / MVDL800-xxxxxxxx
Voltage Rating 1200 V d.c.
Current Rating of 587 A + 50% for 60 s in 600 s</th></tr>
<tr><th>Manufacturer</th><th>Part Number</th><th>Microswitch</th><th>Quantity of fuses</th></tr>
<tr><td>Cooper Bussmann</td><td>170M6116</td><td>170H0069</td><td>2</td></tr>
</table>

<table>
<tr><th colspan="4">MVDL1000-47xx / MVDL1000-xxxxxxxx
Voltage Rating 1200 V d.c.
Current Rating of 1000 A + 10% for 60 s in 600 s</th></tr>
<tr><th>Manufacturer</th><th>Part Number</th><th>Microswitch</th><th>Quantity of fuses</th></tr>
<tr><td>Cooper Bussmann</td><td>170M6116</td><td>170H0069</td><td>2</td></tr>
</table>

<table>
<tr><th colspan="4">MVDL1000-47xx / MVDL1000-xxxxxxxx
Voltage Rating 1200 V d.c.
Current Rating of 733 A + 50% for 60 s in 600 s</th></tr>
<tr><th>Manufacturer</th><th>Part Number</th><th>Microswitch</th><th>Quantity of fuses</th></tr>
<tr><td>Cooper Bussmann</td><td>170M6116</td><td>170H0069</td><td>2</td></tr>
</table>

Table 2–20. - Recommended Fuses For Transistor Module Input Protection

2.10.10 Thermal Protection

Thermal protection is provided on DELTA transistor modules by a thermistor embedded within each IGBT module.

2.10.11 Electrical Connections

2.10.11.1 Control Connections

The control terminations for the DELTA transistor module are detailed in Table 2–21. The connectors are supplied with the product.

Termination	Connection Type
SMPS supply / d.c. feedback	2 pin connector
Control signals	1 x 40 way ribbon cable

Table 2–21. – Terminations For Control Circuits On DELTA Transistor Modules

2.10.11.2 Power Connections

Terminations for 3-phase, d.c. outputs and earth/ground are detailed in Table 2–22.

<table>
<tr><th>Terminations</th><th colspan="2">Stud Size</th><th>Crimp Size</th></tr>
<tr><td rowspan="3">a.c. terminals</td><td>MVDL643-4702</td><td rowspan="2">2 x M10 stud connections per phase</td><td rowspan="7">M10 (or 3/8 in) ring crimps</td></tr>
<tr><td>MVDL800 range</td></tr>
<tr><td>MVDL1000 range</td><td>3 x M10 stud connections per phase</td></tr>
<tr><td rowspan="3">d.c. terminals</td><td>MVDL643-4702</td><td rowspan="2">2 x M10 stud connections per position</td></tr>
<tr><td>MVDL800 range</td></tr>
<tr><td>MVDL1000 range</td><td>3 x M10 stud connections per phase</td></tr>
<tr><td>Earth terminal</td><td colspan="2">1 x M10 threaded insert</td></tr>
</table>

Table 2–22. – Terminations For 3-Phase & d.c.

The a.c. terminals are suitable for a maximum of 2 (or 3) x 120 mm^2 cables (250 MCM in North America).

To achieve the full current rating of the product, it may be necessary to use high temperature cable, see Section 3: Drive (CDM) Design.

NOTE: Do not allow the temperature of the cable to exceed 125°C (257°F).

The d.c. terminals are suitable for a maximum size of busbar at 6.3 mm x 70 mm wide (≈ 1/4 in x 2. 3/4 in). Ratings and sizes of busbars are application dependent.

2.10.12 Heat Dissipation

The heat dissipation for a DELTA transistor module will vary depending upon the drive system in which it is used. A typical dissipation and power losses is shown below.

- Active Energy Management drive, single DELTA module, machine bridge;
- 690Va.c. supply, 1100Vd.c. link;
- 1.1 overload, 1.25 kHz switching frequency;
- 40°C coolant inlet temperature;
- Power flow from d.c. link to motor, motor power factor = 0.9.

DELTA Transistor Module	Losses (kW)
MVDL643-4702	10.84
MVDL800 family	6.15
MVDL1000 family	8.25

The total heat dissipation will include heat dissipated from the module into the coolant and into the enclosure environment. As an approximation, it can be assumed that 90% of module losses will be into the liquid coolant, with the remaining 10% into the enclosure air. As these dissipation figures are all application-dependent, refer to GE Power Conversion for assistance.

2.10.13 Weight

The dry weight of the DELTA transistor module is dependent upon the type, but will be in the range of 88 kg to 101 kg (194 lbs. to 225 lbs.). The module increases in weight by 1.5 kg (3.3 lb.) when filled with coolant.

2.10.14 Acoustic Noise

Acoustic noise is negligible for the DELTA transistor module. The cooling fan assembly for the d.c. link capacitor bank produces 52dB(A). These fans are not fitted to all versions of DELTA transistor module. The majority of any noise generated will be from the wound components and heat exchanger system and this will be specific to each application.

2.11 DELTA POWER MODULES - LIQUID COOLING SYSTEM INTERFACE

2.11.1 Introduction

Each DELTA rectifier and transistor module is principally cooled by a pumped liquid system. Heat generated within a module is removed by the coolant flow to an external heat exchanger. Refer to Section 3: Drive (CDM) Design, for further details.

2.11.2 Cooling System Connection Options

Three cooling system connection options for DELTA power modules are available:

- Spring-loaded, self-sealing connections (Staubli RMI16) – flow and return at the bottom of the module. See Figure 2–10.
- Hosetails - flow and return at the bottom of the module. See Figure 2–11.
- Hosetails – flow at the bottom of the module, return at the top. See Figure 2–12.

Mating parts for the Staubli RMI16 style connectors are available, see Section 2.14.3: Coolant Connections. These are suitable for 19 mm (3/4 in) internal bore hose.

Hosetail connections are suitable for 19mm (3/4 in) internal bore hose.

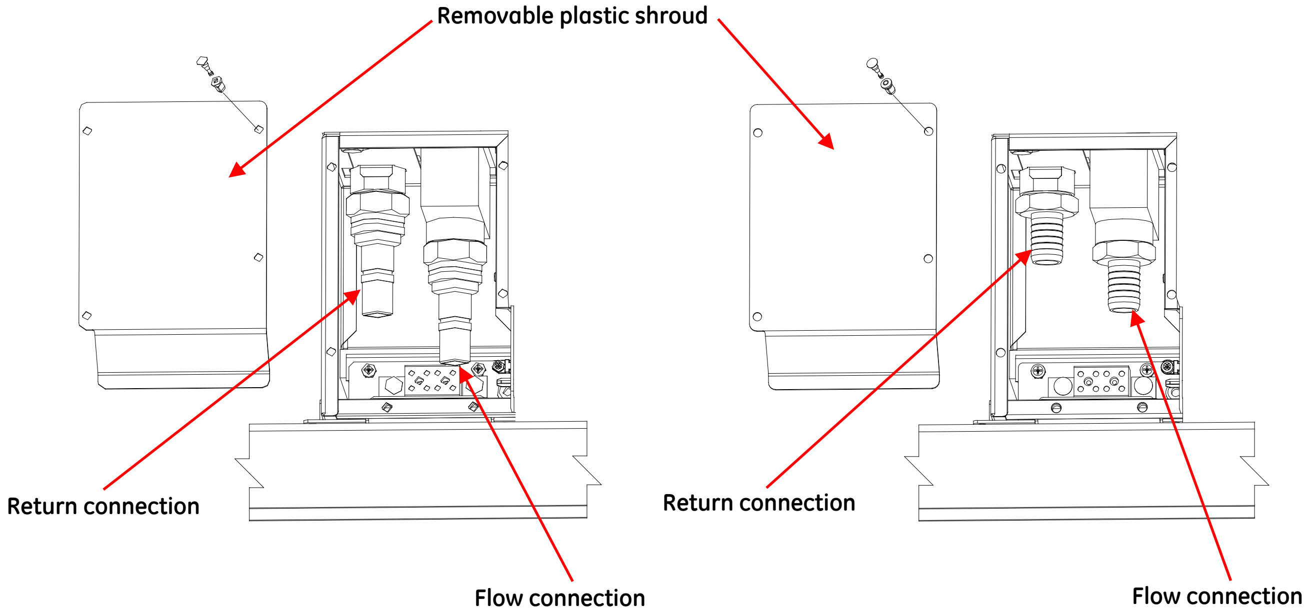


Figure 2–10. – Spring Loaded, Self-Sealing Connectors (Staubli RMI 16)

Figure 2–11. – Hosetail Connectors

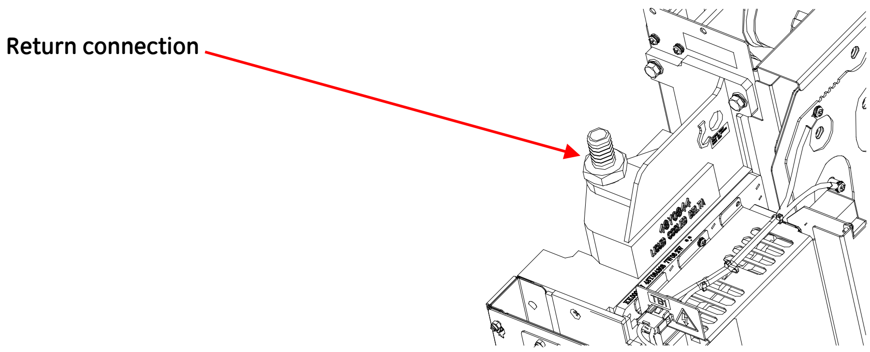


Figure 2–12. – Hosetail Connection (flow connection as Figure 2–11)

2.11.3 Bleed Valves

When both coolant connections are at the bottom of the DELTA power module a valve is fitted at the top to bleed air from the liquid cooling system. The valve is operated by turning the 12.7 mm (1/2 in) A/F hex shaft. Figure 2–7 and Figure 2–9 show the position of the bleed valve.

2.11.4 Operating Pressure

The maximum working pressure for the cooling system is 3 bar (0.3 MPa).

The maximum pressure for testing purposes only is 6 bar (0.6 MPa) for short durations.

See also Section 3: Drive (CDM) Design.

2.11.5 Flow Rate

The rated coolant flow is 25 litres/minute (5.5 UK gallons, 6.6 US gallons), per DELTA power module.

2.11.6 Differential (Flow) Pressure Drop

The pressure drop across a DELTA power module is dependent on the coolant temperature and anti-freeze concentration. Figure 2–13 shows the pressure drop variation with flow rate at the following conditions:

- Staubli RMI16 cooling system connections;
- Coolant temperature = 20°C;
- Anti-freeze concentration = 40%.

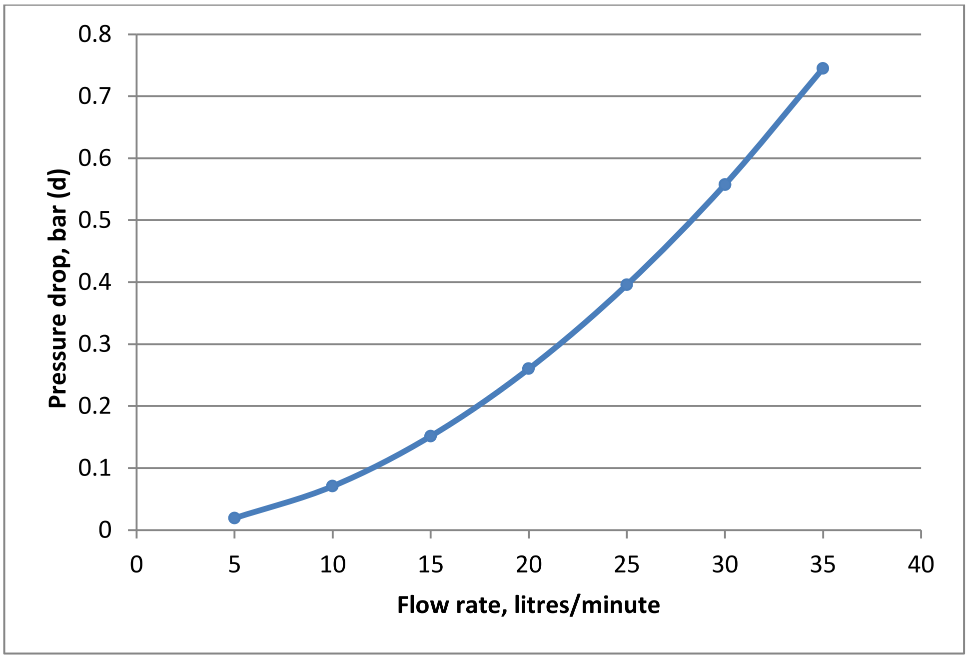


Figure 2–13. – DELTA Module Pressure Drop

NOTE: 1 litre/minute = 0.22 UK gallon/minute = 0.264 US gallon/minute.

2.11.7 Material Compatibility

See Section 3: Drive (CDM) Design.

2.12 REACTORS, INDUCTORS & TRANSFORMERS

2.12.1 General Description

A variety of reactors, inductors and transformers are available for use in conjunction with DELTA drives. Further information is given in Section 3: Drive (CDM) Design. With the exception of the DELTA transistor module sharing reactors, these components are application specific.

2.12.2 Input Reactor For DFE Drives

The input reactor provides impedance between the a.c. supply and the rectifier module(s). This helps to reduce the input current ripple, peak currents, harmonics, aids transient voltage protection and fuse protection.

2.12.3 Input Sharing Reactor For DFE Drives

To allow equal load sharing between DELTA rectifier modules which are connected in parallel, it is always necessary to fit additional reactance in the three-phase connection of each parallel module.

Reactor Part Number	Nominal Supply Voltage (V a.c.)	Current Rating (A r.m.s)	Phase Inductance (mH)	$R_{reactor}$ (mΩ)	Weight (kg)	(lbs.)
50Z0081/01	690	986	0.385	0.85	1050	2310

2.12.4 Input Reactor For AEM Drives

The input reactor provides the impedance between the a.c. supply and the PWM generated voltage of the network bridge. This impedance is required to allow the network bridge to provide the correct voltage vector output that will generate a sinusoidal current with a very low harmonic content to the supply voltage.

2.12.5 Shunt PWM Filter For AEM Drives

The PWM filter provides the correct shunt path to attenuate the PWM harmonics generated by the transistor bridge. These filters are tuned to the switching frequency of the network bridge, with a combination of resistance, capacitance and inductance.

2.12.6 D.C. Link Inductor

This inductor is used in conjunction with the DFE input reactor, to provide a more continuous current into the machine bridge and reduce the harmonics that the drive imposes on the supply.

2.12.7 Interbridge Transformer For DFE Drives

When using DELTA rectifier modules in a 12-pulse DFE drive, it is mandatory that an interbridge transformer replaces the d.c. link inductor. In addition to performing the same functions as a d.c. link inductor, the interbridge transformer forces sharing between the two rectifier bridges (one supply phase-shifted by 30°).

2.12.8 AEM & Machine Bridge Sharing Reactors

To allow equal load sharing between DELTA transistor modules which are connected in parallel, it is always necessary to fit additional reactance in the three-phase connection of each parallel module. Dimensioned drawings of these reactors are included in Appendix A: Dimensioned Mechanical Drawings.

Reactor Part Number	Accompanying DELTA Module	Current Rating (A)	Losses to Air	Reactance (μH)	Weight (kg)	(lbs.)
50Z0126/01	MVDL643-4702	645	320 W	10 / phase	30	66
50Z0126/02	MVDL800 family	800	400 W		38	84
50Z0126/03	MVDL1000 family	1000	450 W		60	132

Table 2–23. – Sharing Reactor Details

2.13 INSTALLATION ACCESSORIES (ELECTRICAL)

2.13.1 Screened Ribbon Cables

Units covered: MVS3020-40xx.

Most control connections in the DELTA drive are made with screened ribbon cables. The 16 way and 50 way ribbon cables for connecting the mains Voltage Monitor and I/O termination panel respectively are supplied with those units.

The length of the 40 way ribbon cables to connect the DELTA transistor modules to the controller are application specific, and should be determined during the enclosure design stage (see Section 3: Drive (CDM) Design).

NOTE: Only ribbon cables supplied by GE Power Conversion must be used. This is to ensure that the screen is of a suitable construction and performance, enabling the clamps described in Section 2.13.2: Ribbon Cable Clamps to correctly secure the ribbon cables.

These cables are available pre-terminated in a range of lengths - from 0.7 m to 3.0 m, (27.5 in to 118.1 in) in increments of 0.1 m (4 in).

Part Number	Length
MVS3020-4007	0.7 m (27.5 in)
MVS3020-4008	0.8 m (31.5 in)
MVS3020-4009	0.9 m (35.5 in)
MVS3020-4010	1.0 m (39.4 in)
MVS3020-4011	1.1 m (43.3 in)
MVS3020-4012	1.2 m (47.3 in)
MVS3020-4013	1.3 m (51.2 in)
MVS3020-4014	1.4 m (55.2 in)
MVS3020-4015	1.5 m (59.0 in)
MVS3020-4016	1.6 m (63.0 in)
MVS3020-4017	1.7 m (66.9 in)
MVS3020-4018	1.8 m (70.9 in)

Part Number	Length
MVS3020-4019	1.9 m (74.8 in)
MVS3020-4020	2.0 m (78.7 in)
MVS3020-4021	2.1 m (82.7 in)
MVS3020-4022	2.2 m (86.6 in)
MVS3020-4023	2.3 m (90.6 in)
MVS3020-4024	2.4 m (94.5 in)
MVS3020-4025	2.5 m (98.4 in)
MVS3020-4026	2.6 m (102.4 in)
MVS3020-4027	2.7 m (106.3 in)
MVS3020-4028	2.8 m (110.2 in)
MVS3020-4029	2.9 m (114.2 in)
MVS3020-4030	3.0 m (118.1 in)

Table 2–24. – 40-Way Screened Ribbon Cable Range

2.13.2 Ribbon Cable Clamps

Units covered: MVS3017-4001
MVS3018-400x
MVS3019-4001

To ensure good signal integrity, the screen of each ribbon cable should be clamped at both ends to the component / drive chassis or enclosure steelwork. 16 way and 50 way ribbon cable clamps are only available to clamp single ribbon cables. 40 way ribbon cable clamps are available to clamp up to six ribbon cables.

Part Number	Description
MVS3017-4001	16 way ribbon cable clamp, one cable
MVS3018-4001	40 way ribbon cable clamp, one cable
MVS3018-4002	40 way ribbon cable clamp, two cables
MVS3018-4003	40 way ribbon cable clamp, three cables
MVS3018-4004	40 way ribbon cable clamp, four cables
MVS3018-4005	40 way ribbon cable clamp, five cables
MVS3018-4006	40 way ribbon cable clamp, six cables
MVS3019-4001	50 way ribbon cable clamp, one cable

Table 2–25. – Ribbon Clamp Range

2.13.3 Keypad Mounting Kit

Unit covered: MVS3001-4001

This kit allows the Drive Data Manager ™ to be mounted to the vertical face of the drive enclosure. Information is provided with the kit, detailing its specification and fitting instructions.

2.14 INSTALLATION ACCESSORIES (MECHANICAL)

2.14.1 DELTA Module Mounting Frames

The DELTA module mounting kit is a framework of cross members and brackets, which when installed in an enclosure, provide support and fixing points for the modules. It is suitable for installation into standard Rittal TS8 series enclosures.

The DELTA module mounting frames include four side supports and three cross members, complete with fixing screws. Four frame widths are listed. The frames are supplied in a kit form. Lower guide plates are also included with the kits.

2.14.2 Variations

The mounting kits are based on 600 mm (23.6 in) and 800 mm (31.5 in) deep enclosures. For each of these depths there are four widths available:

- 600 mm (23.6 in) - to support up to two DELTA modules;
- 800 mm (31.5 in) - to support up to two DELTA modules;
- 1000 mm (39.4 in) - to support up to three DELTA modules;
- 1200 mm (47.2 in) – to support up to four DELTA modules.

The detailed part references for the DELTA module mounting frames for installation in Rittal TS8 enclosures are listed in

Table 2–26.

Order Number	Number of DELTA Modules	Enclosure Width (mm)	Enclosure Depth (mm)	Frame Weight	
				kg	lb.
MVDL-TS-4001	2	600	800	15	33
MVDL-TS-4002	2	800	800	17	37
MVDL-TS-4003	3	1000	800	19	43
MVDL-TS-4004	4	1200	800	22	48
MVDL-TS-4005	2	600	600	13	29
MVDL-TS-4006	2	800	600	15	33
MVDL-TS-4007	3	1000	600	17	38
MVDL-TS-4008	4	1200	600	20	44

Table 2–26. – DELTA Module Mounting Frame Specifications

2.14.3 Coolant Connections

Unit covered: MVS3010-4001

This kit is required for connecting DELTA rectifier and some DELTA transistor modules with Staubli RMI 16 self-sealing couplings, to the cooling system. It contains a pair of couplings suitable for connection to 19 mm (3/4 in) internal bore hose.

2.15 STANDARDS

When installed in a CDM, in accordance with this manual, the DELTA components are designed to comply with the standards listed below.

2.15.1 Safety

EN 50178	Electronic equipment for use in power installations.
EN 61800-5-1 (IEC 61800-5-1)	Adjustable speed electrical power drive systems: Part 5-1-Safety requirements – Electrical, thermal and energy.
ANSI / UL508C	Power conversion equipment.
CAN / CSA C22.2-14	Industrial control equipment, industrial products.

2.15.2 Electromagnetic Compatibility (EMC)

EN 61800-3 (IEC 61800-3)	Adjustable speed electrical power drive systems: Part 3 – EMC product standard including specific test methods.

In particular, this includes the following immunity requirements:

IEC 61000-4-2	Electrostatic discharge	6 kV contact discharge 8 kV air discharge
IEC 61000-4-3	Electromagnetic field	80 MHz – 2 GHz, 10 V/m 2 GHz – 2.7 GHz, 1 V/m
IEC 61000-4-4	Electrical fast transient/burst	2 kV
IEC 61000-4-5	Surge	1 kV line-line 2 kV line-earth
IEC 61000-4-6	Conducted radio-frequency	150 kHz – 80 MHz, 10 V

2.15.3 Ratings/Performance

EN 61800-2 (IEC 61800-2)	Adjustable speed electrical power drive systems: Part 2 – General requirements - Rating specifications for low voltage adjustable frequency power drive systems.
EN 60146-1-1 (IEC 60146-1-1)	Semiconductor converters. General requirements and line commutated converters.

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3. DRIVE (CDM) DESIGN

WARNING

- **Ensure that access to rotating arts of fans is prevented.**
- **Air used to cool the product is unfiltered. Air ejected from the product may contain foreign particles. Air outlets should be arranged to deflect the air away from the eyes.**
- **The combined audible noise emitted by fans in an installation can be greater than 70 dB(A), dependent on the air flow path.**
  Measure the audible noise in the installation.
  When the audible noise level exceeds 70 dB(A), appropriate warning notices should be displayed.

3.1 INTRODUCTION

This section is aimed primarily at the designer of the 'Complete Drive Module' (CDM). The design requires detailed Engineering knowledge and circuit design experience. The data given here cannot replace that knowledge, but is intended to give additional information for particular requirements for the MV3000 DELTA products.

Design data for other parts of the Power drive system can be found in Section 4: PDS Design.

If the drive (CDM) has been supplied as a complete item of cubicalised equipment, then this chapter can be ignored.

3.1.1 How To Use This Section

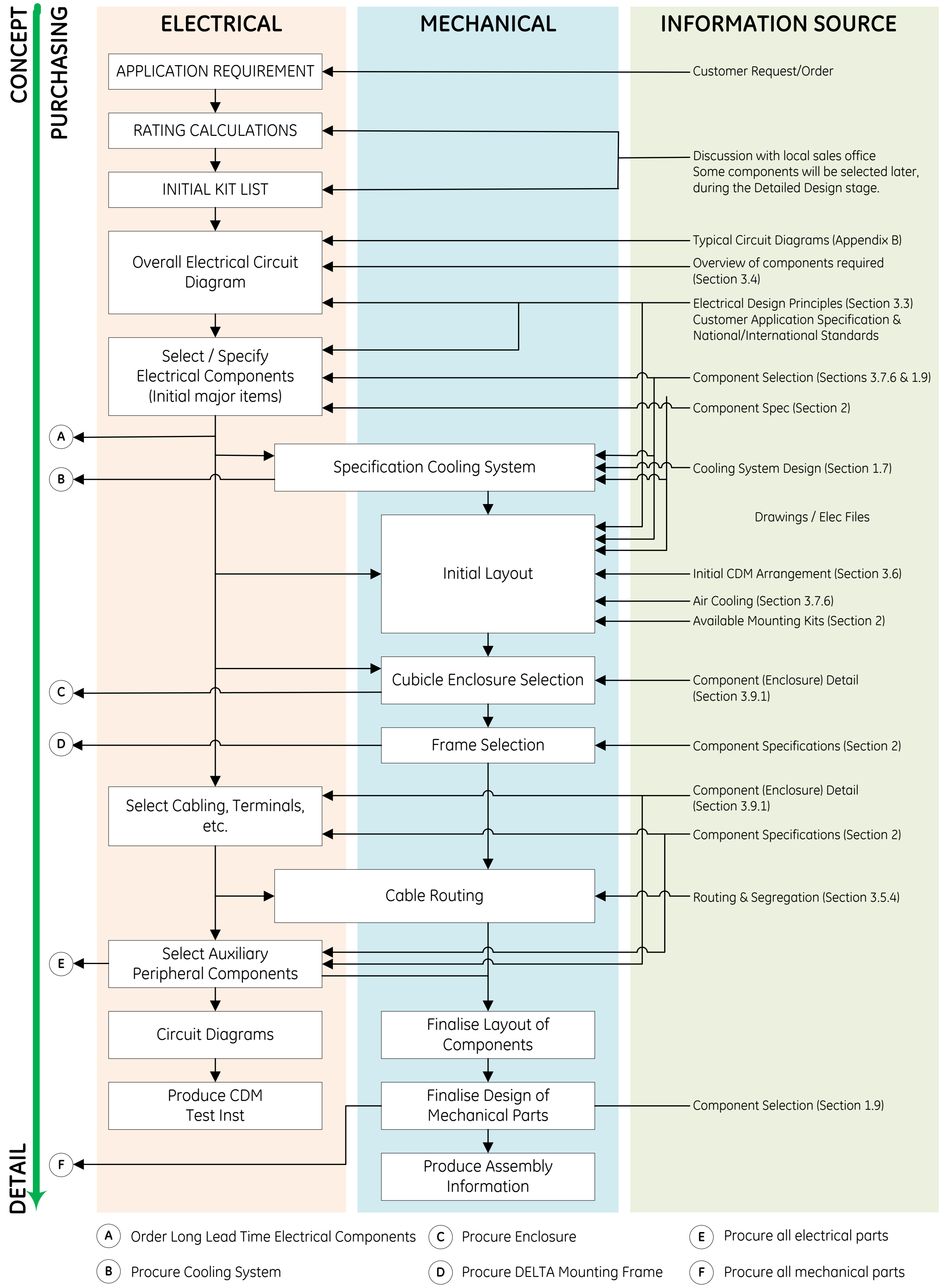


Figure 3–1. – Organisation Of Drive (CDM) Design Section

The sequence for this section is based on the recommended work flow shown in Figure 3–1.

3.2 INITIAL DELTA KIT LIST

The customer's requirements and initial discussions with the local supplier's Sales Office should have established:

- The overall configuration of the drive;
- The ratings;
- An initial list of the DELTA modules and associated components;
  - This initial list may need to be modified during the design of the drive,
  - Additional components will have to be specified and purchased to complete the CDM.

3.3 ELECTRICAL DESIGN PRINCIPLES

Using the DELTA modular components allows many different configurations. Some typical circuit diagrams are shown in Appendix B: Electrical Connection Diagrams for both power and control connections.

In addition to following good electrical design practice, the following sections give details on specific requirements for the DELTA power and control modules.

See Figure 3–1 for the location of detailed design information and recommended work flow.

3.3.1 Electrical Safety

3.3.1.1 CDM Over-Current Protection

The CDM will be connected to hazardous voltages and high energy supplies. In common with all high power electrical installations, the available short circuit power of the final installation must be considered when designing the CDM.

The breaking capacity of over-current protective devices (e.g. fuses and breakers), the short-circuit current rating of cables and components, and the layout and strength of the enclosure must be co-ordinated and be capable of protecting personnel under normal and fault conditions.

The CDM must be protected against over-current from all energy sources. These sources are usually:

- The main supply (network);
- Machines (e.g. generators or motors regenerating energy);
- Auxiliary power supplies;
- Control power supplies;
- I/O signals.

Over-Current Protection Of DELTA Modules

DELTA modules use solid state (semi-conductor) transistors to regulate the a.c. current. In common with all products using semiconductor devices, it is possible for two series transistors to fail and create a short-circuit. This short-circuit will be fed from both the supply and the CDM's d.c. link capacitors. To limit consequential damage to other parts of the DELTA module and CDM, external protection is required. This protective device will be unable to prevent the failure of the short circuit device.

The DELTA modules have been assessed against "breakdown of components" to IEC61800-5-1 and UL508C when used with high speed fuses (also called semiconductor fuses). These recommended fuses are given in the specification section for each module.

3.3.1.2 Segregation Of Persons From Hazardous Voltages

The CDM must be designed in such a manner that persons are not exposed to hazardous voltages during normal or fault conditions.

The control connections in the DELTA modules and the controller are designed with "protective separation" from hazardous voltages. The construction of the CDM must be done in such a manner that this protective separation is not invalidated.

Therefore:

- Separate extra low voltage wiring and components from:
  - high voltage components and cabling;
  - high power components and cabling (separation still required during arc-faults);

- Design the CDM so that items that need to be monitored or adjusted while the equipment is live can be accessed without risk.

- To ensure safe access during commissioning, maintenance and fault finding:
  - The points of electrical isolation/disconnection of all sources of supply must be clearly identified;
  - Ensure segregation of wiring on the live side of such points from all other items in the CDM;
  - Cover (to the required IP rating) and label all circuits that are permanently live;
  - Where it is necessary to measure hazardous voltages during commissioning or fault finding, ensure that this can be done without risk;
  - When the CDM is isolated (electrically safe work condition) from the electrical supplies, ensure there is access to points that require measurement to prove the absence of voltage. In addition to supply connections, this must include the d.c. link connections to the transistor modules as these contain stored charge.

3.3.1.3 Protection Against Arcing Faults (arc-flash)

Catastrophic failure of equipment fed from high power supplies may cause arcs. This arcing can result in the ejection of air and particles at high pressure and high temperature. Therefore, arc containment should be taken into account in the design of the enclosure. Refer to the relevant national or international standards for further data.

3.3.1.4 Electrical Interference / Electromagnetic Compatibility (EMC)

The CDM has high power, high speed switching devices and sensitive electronic controllers in close proximity. Care must be taken to avoid these interfering with each other, adjacent equipment or installations.

The adjacent equipment or installations must also be prevented from interfering with the CDM or DELTA modules.

Immunity Level Of The DELTA Modules & The CDM

The individual DELTA modules and MV3000 control components comply with the immunity requirements for an industrial environment ('also known as 'second environment') according to IEC 61800-3 or IEC 61000-6-2.

When all of the equipment used in the CDM also meets this immunity requirement (see also Section 2.15.2: Electromagnetic Compatibility (EMC)) and after a relevant assessment of the complete CDM, this should also comply with the requirements for the industrial environment.

Emission Levels From The CDM

DELTA modules are open frame units that contain electrically noisy waveforms. The actual emission levels from the CDM will be heavily dependent on the selection and layout of all the components in the CDM. Some general guidance is given here:

If no special measures are taken, the drive may have to be classified as Category C4 according to IEC 61800-3.

Compliance with IEC 61800-3 will require radio-frequency filtering on the main supply of AEM drives and may be required on the DFE drives. If an auxiliary supply is used, it is likely to require some filtering because this emission category has a lower emission limit for ports with rated current below 100 A. Some care with shielding and segregation will also be required. An “EMC style” enclosure may be required.

The “industrial” limit of IEC 61000-6-4 / EN 61000-6-4 is identical to IEC 61800-3 Category C2. This will require filters with high attenuation on both main power and auxiliary connections. It will also require significant care with shielding and segregation within the enclosure, which is beyond the scope of this manual.

Due to the very high power rating, it is extremely unlikely that the CDM would be used in an environment that requires compliance with the residential emission limits of IEC 61000-6-3 / EN 61000-6-3 or IEC 61800-3 Category C1. Compliance with such a limit is very difficult to achieve on equipment with such high power rating.

3.3.1.5 Designing The CDM To Comply With International Standards

The DELTA modules have been designed and evaluated against the international standards shown in the specification section. The designer of the CDM is responsible to ensure that the design, assembly and testing of the CDM complies with the relevant standards.

The following data has been provided where the individual module depends on particular features of the CDM for compliance against the named standard.

System Design Requirements To Satisfy UL 508C

UL 508C has a number of requirements that must be satisfied when designing the CDM. The following have been highlighted as they may be easily be missed when designing the CDM to comply with UL508C:

- Motor over-temperature monitoring is required. See the data on the User I/O panel for available inputs for the CDM;
- Semiconductor fuses should be located within the same enclosure as the DELTA module;
- The integral short circuit protection provided by the DELTA module does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the National Electric Code and any additional local codes.

3.3.2 Electrical Design For Reliability

3.3.2.1 Bonding

In additional to electrical safety bonding, functional bonding of the enclosure/s and components is mandatory see Section 3.3.2.1: Bonding.

3.4 OVERVIEW OF COMPONENTS REQUIRED

The DELTA product range is a modular component sub-system that requires installation into an enclosure with additional components to form a Complete Drive System (CDM). These additional components are specified and purchased by the CDM designer / builder in addition to the parts supplied by GE Power Conversion.

3.4.1 DELTA Modules & Associated Components (DELTA Kit List)

A typical list will include:

Item	Drive Type	Component Description	Notes
Power modules	All versions	Liquid cooled transistor modules	Required
		Dynamic Braking Units (DBs)	Optional
	Rectifier fed (DFE)	Liquid cooled rectifier modules	Optional
Wound components	All versions	Transistor module current sharing reactor	Required for parallel modules
		Filter reactors (see Filters)	Required
	Rectifier fed (DFE)	d.c. link reactor	Optional
		Rectifier inter-bridge transformer	Required for parallel rectifiers
		Rectifier current sharing reactor	Required for parallel modules
	All versions	Input line reactor	Required
Control components	All versions	MV3000e Controller	Required
		MV3000e User I/O Termination Panel	
		MV3000e Switch Mode Power Supply(s) (SMPS)	
		Drive Data Manager (Keypad)	Optional
	Rectifier fed (DFE)	Mains Voltage Monitor (MVM)	Optional
	AEM		Required
Accessories	All versions	Ribbon cables	Required
		Ribbon cable clamps	
Mechanical	All versions	DELTA power module mounting frame	Required
		Module Cooling Fans	Optional
Filters	All versions	Machine protection DV/DT Filter	Optional
	AEM	AEM PWM Filter	Required
		Common mode filter	Optional

3.4.2 Items To Be Supplied By The CDM Designer / Builder

The following parts are also typically necessary to assemble the CDM:

Enclosure(s)	All versions	To include gland plates, baying brackets, panel earth continuity, apertures for cables/vents etc. (Rittal TS8 enclosures are recommended)
Internal Panels and Brackets	All versions	For mounting: • control components; • auxiliary components. Mounting frame interface brackets (if Rittal TS8 enclosure is not used). Additional panels for earthed ribbon cable highway. Drip tray, or drip protection.
Power Connections	All versions	Cables Bus ways (busbars) Customer terminals Gland plates
Control	All versions	Auxiliary supplies Internal discrete wiring Control supplies (In addition to SMPS if required) Terminal blocks (In addition to I/O panel if required)
Filters	All versions	Options include: • PWM filter; • DV/DT filter.
Cooling system	All versions	Liquid cooling system, see section 3.7 (including the heat exchanger, pump, manifold, connection flanges, filter, pipe-work, coolant and monitoring Air cooling system, see Section 3.7.8 (including enclosure ventilation fans, air-to-water heat exchangers etc.
Wound Components (other than sharing reactors)	All versions	Options include: • AFE main reactor; • Filter reactors; • Control supply transformers.
Control cables	All versions	All cables and wiring other than the ribbon cables supplied with the DELTA components, or separately supplied by GE Power Conversion.
Fuses / circuit breakers / isolators	All versions	To provide protection for: • AC power; • DC power; • Auxiliary supplies.
DC link Pre-charge circuit	For DC Fed & AEM	Required for drives that do not use DELTA Rectifier modules.
DB resistors	All versions	
Fixings / labels / crimps	All versions	To include, for example: • All screws, bolts and washers that are not provided with the DELTA products; • User connection identification; • All crimps for power and control wiring.
24 V d.c. power supply	All versions	To maintain communication with the controller in the absence of the main power supply. (optional)
Enclosure Heaters	All versions	Low temperature and/or anti-condensation.
Transient protection	All versions	
Earth Fault monitoring	AEM	
Temperature monitoring / protection	All versions	To include: • Enclosure ambient; • Cooling system.
Test equipment	All versions	To test and commission the CDM

3.4.3 Items To Be Supplied By The PDS Designer / Builder

To complete the power drive system, examples of these are:

Machine (motor or generator) or controlled load/source	For all versions	To include machine monitoring, such as an encoder
Interconnection / supply cables	For all versions	
Transient / over-voltage protection	For all versions	
Earth fault protection	For AEM	
Supply over-current protection, etc.	For all versions	

Where there is a specific requirement for any of these items to be used with DELTA modules, some guidance on the design of these components is given in Section 4: PDS Design. The design and specification of these components is the responsibility of the PDS designer.

3.5 MECHANICAL DESIGN PRINCIPLES

After the selection of the electrical components the mechanical arrangement into an enclosure is required.

3.5.1 The Equipment Must Be Enclosed

The DELTA modules and associated components are usually 'open type' products (IP00) for installation into an enclosure.

- The front of the DELTA power module is supplied with terminal shrouds. These provide limited protection for personnel against accidental direct electrical contact;
- The transistor power modules contain a d.c. link capacitor bank. This capacitor has resistors fitted to discharge it to below 50V in less than 8 minutes (see specification for the times for individual modules) after the isolation of the supply;
- The electrical components on rear and side of the power modules are not shrouded. They will need to be enclosed to prevent accidental contact.

All wound components (e.g. d.c. link reactor, inter-bridge transformer, input line reactors) must be installed in a steel enclosure to prevent:

- Contact of persons against hazardous voltages and temperatures. These are usually supplied as IP00 (open components);
- Emission of magnet and electrical noise.

3.5.1.1 Essential Requirements For The Enclosure

- Protection of personnel against direct contact of hazardous parts:
  - Electrical – all hazardous live parts, e.g. the DELTA module power terminals;
  - Thermal - hot parts - on the DELTA module, the heatsink and busbars. For the system these plus high temperature cables, reactors etc.;
  - Moving parts – in the DELTA none; in the CDM the impellers of the cooling fans;
  - Energy hazards – Electrical (including the stored energy in the dc capacitor bank, which takes up to eight minutes to discharge), the rotational mechanical energy in the fans (this stops within a few seconds) and the energy that could be supplied into the enclosure during catastrophic failure of any part of the system 'arc-containment'.
- The enclosure strength, over-current protection and supply fault levels must be co-ordinated and sufficiently robust to contain the arc-fault energy. Of sufficient strength to support the combined weight of items inside, also contain faults and provide protection.
- Protection of the enclosed equipment against the environmental conditions:
  - Mechanical impact against the enclosure;
  - Shock and vibration;
  - Environmental control against the ingress of water, dust and solid objects;
  - Condensation and pollution control to meet the requirements of Pollution Degree 2 (see Section 2: Specification);
  - Sufficient strength of supports and enclosure (and lifting arrangement) for environment of the final installation and transport.
- Reduction of electrical radiated emissions from the drive and protection of the drive from radiating sources (see Section 3.3.1.4: Electrical Interference / Electromagnetic Compatibility (EMC))
- Allow access in a safe way for operation, adjustment and maintenance:
  - This must also allow access to prove 'absence of voltage' (proving dead) after safe isolation (e.g. Lock-out, Tag-out).

3.5.2 Impact of Electrical Safety On Mechanical Design

The mechanical design must not be detrimental to the electrical safety or electrical function of the CDM.

Follow the instructions on electrical design given in Sections 3.3.1: Electrical Safety to 3.3.2: Electrical Design For Reliability and 3.5.3: Electrical Bonding to 3.5.4: Routing & Segregation Of Cables.

3.5.3 Electrical Bonding

In additional to electrical safety bonding, functional bonding of the enclosure/s and the components located in these is mandatory to ensure that the CDM performs correctly.

This bonding is especially important between the control components and the DELTA power modules.

- A continuous bond of earthed metal is required from all the DELTA transistor modules to the controller:
  - This is usually achieved by a wide steel plate that provides a low inductance path between modules and to the controller. The high frequency currents creating a small voltage difference across this bond.
  - Also bond the DELTA power modules together using the bonding plate supplied with the DELTA modules to form a single metal highway across the front of the DELTAs. This arrangement forms a ground plane (low resistive and low inductive path) against which the control ribbon cables must be run (see Section 5.13: Fitting Earth Bonding Plates).
  - It is unnecessary to extend this bonding highway to the rectifier modules.
  - Additional low inductance paths are beneficial.
  - The DELTA mounting frames when directly fastened (metal-to-metal) to the unpainted enclosure frame also aid this bonding.
  - Screened control cables also provide a low inductance path, but without adequate parallel metal-to-metal component bonding, the signals carried will be disrupted by noise currents.
  - The installer of the modules must complete the bonding path (and cable routing) to the controller. These parts are not supplied with the modules as the exact position of the controller is not fixed.
- The control enclosure must also be bonded to the power modules enclosure:
  - Use high frequency techniques.
  - Use multiple paths.
- Bond all of the enclosures together.
  - Converters contain high leakage current equipment so currents will flow between adjacent enclosures.
    - To minimise the voltage created by these currents, a low impedance, low inductance path (some of these currents are at high frequency) must be provided. This is usually in addition to any safety bonding.
    - This bonding must be by direct metal-to-metal contact, not by braids or cables to make a ‘continuous enclosure’.
- Bond all of the enclosure’s panels together.
  - This bonding must be by direct metal-to-metal contact, not by braids or cables to make a ‘continuous enclosure’.
- Bond all the cable gland plates to the enclosure.
  - To continue the screening effectiveness of screened or armoured cables, you must bond to the ground plate by a 360° degree connection.
  - The gland plate must then be connected directly to the enclosure walls, or to metal framework to which the outer walls are electrically bonded.
    - Gland plates must not be spaced off, even on metal pillars or bars.
    - Direct metal-to-metal contact across a large surface area must be achieved for low inductance continuity.
    - This bonding is required in addition to any electrical safety bonding.
    - Both control and power cabling gland plates must be directly bonded.

- Provide a return path for noisy electrical components.
  - EMC filters (if fitted) shunt the noise current from the power connection to the local ground. A low inductance path to the noise source e.g. DELTA transistor module must be provided. So should be mounted to a metal panel which is bonded to the metal framework of the DELTA power modules.
- Bond control components together.
  - For best EMC practice the MV3000 controller, I/O panel and MVM unit (if fitted) are fitted to the same conductive panel.
  - A low inductance, direct electrical bond is required and so an unpainted panel (e.g. plated or galvanised,) must be used.
  - See Section 3.6.8: Position Of Control Components for the recommended layout.

3.5.3.1 DELTA Module Earthing/Grounding Requirements

The steel mounting frame into which DELTA Rectifier or Transistor modules are mounted can be used as the earthing method provided that:

- The earth continuity is checked between the module earth terminal and the main enclosure earth point.
  - The earth continuity must be equal to or less than 0.02 Ω (as stated by IEC 61800-5-1 clause 4.3.5.3), with at least 10 A supplied from a source of not more than 24 V, measured between the M10 earth terminal and the enclosure earth stud.
  - If this value is not achieved then the module must be separately earthed via the M10 earth terminal at the lower front face of the modules. The M10 earth terminal is identified on the module by the symbol shown in Figure 3–2.

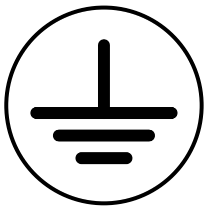


Figure 3–2. – Protective Earth (ground) Symbol to IEC 60417 (Symbol 5019)

3.5.4 Routing & Segregation Of Cables

3.5.4.1 Segregation Of High Current Or Electrically Noisy Cables To Other Circuits

- Screen the control ribbon cables;
  - Bond the screen at both ends;
    - See Section 2.13.1: Screened Ribbon Cables for ribbon cables;
    - The ribbon cable bonding clamp at the DELTA transistor module end is provided with the transistor module;
    - The ribbon clamp for the controller end must be separately ordered. See Section 2: Specification.
- All Analogue I/O and communications cables must use screened cable. The screen must be connected to earthed metalwork using an uninsulated, metal ‘p-clip’;
- Keep apart sensitive control wiring and power cables;
  - Maximise the distance between control and power cables;
  - Do not run the control wiring in parallel with power cables;
  - a.c. power cables between DELTA transistor modules and filters are especially noisy.

3.5.4.2 Routing Of Control Cables

Ribbon cables between control components and between control components and the DELTA modules must be:

- Run along earthed metal, not through 'mid-air'.
  - Select the cable lengths to allow this routing, refer to Section 2: Specification for available lengths.
- Segregated from power cables and from external plant wiring.
- Not extended. If the ribbons are too long, fold the excess length backward and forward (do not roll) to make a low-inductance bundle.

3.5.4.3 Routing Of Power Cables

Minimise large current loops e.g. High current components close together, cables should be arranged in tri-foil, and DC+ run immediately against DC-.

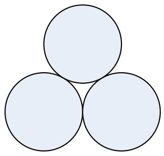


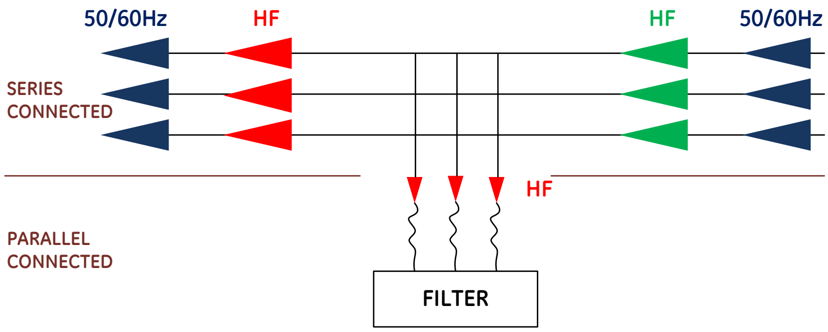
Figure 3–3 Trefoil Cable

Avoid eddy currents in metal work by passing the current flow and return conductors through the same hole e.g. DC+ with DC-, or R and S with T for 3phase cabling.

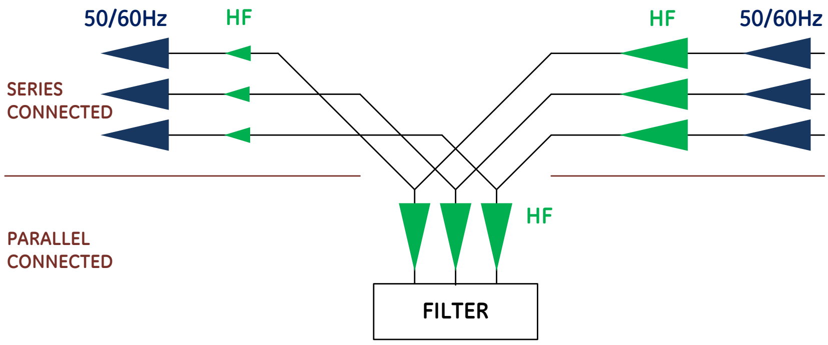
Position high power components together to minimise interconnection cable lengths to reduce cable power loss, radiated (RF) noise and cable costs.

Ensure that the power cabling to high frequency (hf) shunt filters (e.g. PWM filter) does not cause the hf current to bypass that component:

- Run the series current path through the filter, see Figure 3–4. Any parallel connections must use low inductance techniques such as flat and wide busbars, short trefoil cables or parallel cables.



Poor filtering as HF Current bypasses filter.



Good filter performance.

Figure 3–4 Cable Routing Effect On Filter Performance

3.6 INITIAL CDM ARRANGEMENT

This section provides guidance for:

- Enclosure sizing;
- Positioning of DELTA components within the enclosure.

Specifications of individual DELTA components can be found in Section 2: Specification.

Further details relating to the assembly processes can be found in Section 5: CDM Assembly.

3.6.1 General Design Considerations

The CDM layout should include sufficient clearance to fit each component. Consideration should be given to servicing access.

Ensure positions allow removal and replacement of all required modules/components.

- Do not obstruct the DELTA power modules or control components by installing other equipment in front of them.

When a 600 mm (23.6 in) deep enclosure is used, careful planning is required as there is limited space in front of the modules for interconnections, door flanges and ventilation.

3.6.1.1 Component Weight

The weight of components must be considered in the CDM design. Most heavy components would be best located at the base of the cabinet. An exception to this would be sharing reactors fitted above a transistor bridge where cable access was through the top of the cabinet.

3.6.1.2 Thermal Considerations

Position the components with the lowest temperature rating and those dissipating small air losses in the lowest temperature airflow, e.g.:

- adjacent to the air inlet of the enclosure in an IP21 application;
- adjacent to the air outlet from an air-to-liquid heat exchanger for an IP54 enclosure.

Allow space throughout the enclosure for adequate airflow.

3.6.1.3 Cable Routing

Consider the power cable entry and exit points as this will determine the enclosure's internal arrangement.

Mechanical support will be required for all cables. Ensure that features are designed into the enclosure to support cables.

The bend radii of all cables must be respected. Space must be allowed in the design for cables to change direction.

Access is required to main and control connections of the modules.

For cable segregation, see Section 3.5.4: Routing & Segregation Of Cables.

3.6.1.4 Cooling System

Ensure that joints in the liquid cooling system are not located above vulnerable components or circuits to prevent damage caused by leaks or lost coolant when removing modules. If necessary fit drip protection covers / trays.

For DELTA power modules that have a bleed valve fitted, ensure that access is available for the operation of this valve. The bleed valve drain hose must be routed so that any fluid that is released when bleeding the DELTA is drained from the enclosure.

When using the standard DELTA mounting frame there is no space inside the frame to run pipework and manifolds. These must be fitted either above or below the cross members, or located outside the enclosure.

The method of fitting and retaining both flexible and rigid pipes should not restrict access to electronic equipment which may have to be removed for servicing.

3.6.2 Enclosure Size

See Section 3.9.1: Enclosure (/s) for other enclosure requirements.

3.6.2.1 Depth

DELTA drives require a minimum enclosure depth of 600 mm. Standard DELTA mounting frames are available for use in 600 mm and 800 mm (23.6 or 31.5 in) deep Rittal TS8 style enclosures.
See Section 2: Specification.

The mounting frames position the DELTA power modules close to the rear of the enclosure. This maximises the space at the front of the DELTA power modules for interconnections and for mounting SMPS modules and CDM shrouding.

3.6.2.2 Height

It is usual for DELTA drives to be installed into 1600 mm to 2400 mm tall enclosures. The enclosure height is application specific and depends on the other equipment fitted around the DELTA modules and the final installation space requirement. The DELTA module mounting frame may be fitted at any height within the enclosure, but the height is determined by the following constraints:

- Position of cooling system manifolds;
- Location and type of reactors;
- Cable entry;
- Position of auxiliary equipment.

3.6.2.3 Width

The width of the enclosure is predominantly determined by the number of DELTA power modules (up to a maximum of four).

DELTA power modules are mounted side by side, on a pitch of 250 mm. If the control components are mounted into the same enclosure ensure there is sufficient width for these, to the side of the power modules.

The horizontal position of the DELTA power modules is determined by the mounting frame.

3.6.3 CDM Installation In Multiple Enclosures

If a CDM is to be installed into multiple enclosures, these must be electrical bonded as detailed in Section 3.3.2.1: Bonding.

3.6.4 Position Of DELTA Rectifier Modules

It is recommended that the DELTA rectifier module(s) is mounted on the right hand side of the enclosure (front view), with enough space to the right of the module for the following:

- Access to d.c. positive and d.c. negative connections;
- Access to the d.c. link pre-charge fuses which are located on the printed circuit board at the rear of the module;
- Access for tidy routing of cables from the d.c. connections;
- Most enclosure doors are hinged on the left, so door interlocked isolators are mounted on the right of the enclosure.

3.6.5 Position Of DELTA Transistor Modules

DELTA transistor modules are identified by the 40 way connector position they occupy on the controller. Table 2–8 gives the DELTA designations. For ease of identification, it is recommended that the DELTA transistor modules are fitted in the same sequence into the enclosure.

3.6.6 Position Of Reactors & Filtering Components

Reactors and other iron-cored components emit strong magnetic fields. When installing these components ensure that:

- Air-cored reactors have a minimum segregation of 300 mm (12 in) from sensitive components and control electronics;
- All wound components have an air gap to adjacent steel components to prevent eddy currents. The minimum recommended gap is 100mm (4") but smaller distances may be acceptable if evaluated by the CDM designer).

Iron-cored components (for example an inter-bridge transformer), will usually be mounted on the floor of the enclosure due to their size and weight.

Sharing reactors are usually fitted adjacent to the DELTA transistor module either:

- Above the DELTA power modules for top cable entry

or

- Below the DELTA power modules for bottom cable entry.

Filters are designed to absorb high frequency currents. They must be positioned to have low inductance connections to the source of the noise and to ensure that the hf current does not bypass the filter. The effect of cable routing is shown in Figure 3–4.

3.6.7 Position Of Switched Mode Power Supply (SMPS)

An SMPS module is required for each DELTA transistor module.

The SMPS is mounted on the upper front face of the DELTA transistor module, from which it derives a d.c. power supply.

3.6.8 Position Of Control Components

The control assembly must comply with the requirements for electrical bonding given in Section 3.3.2.1: Bonding. It is also recommended that the components are arranged as shown in Figure 3–5. This will give good electrical noise immunity and ensure that the ribbon interconnection cables supplied will be of sufficient length. A dimensioned version of this drawing is included in in Appendix A: Dimensioned Mechanical Drawings.

The controller should be positioned towards the front of the enclosure to aid access.

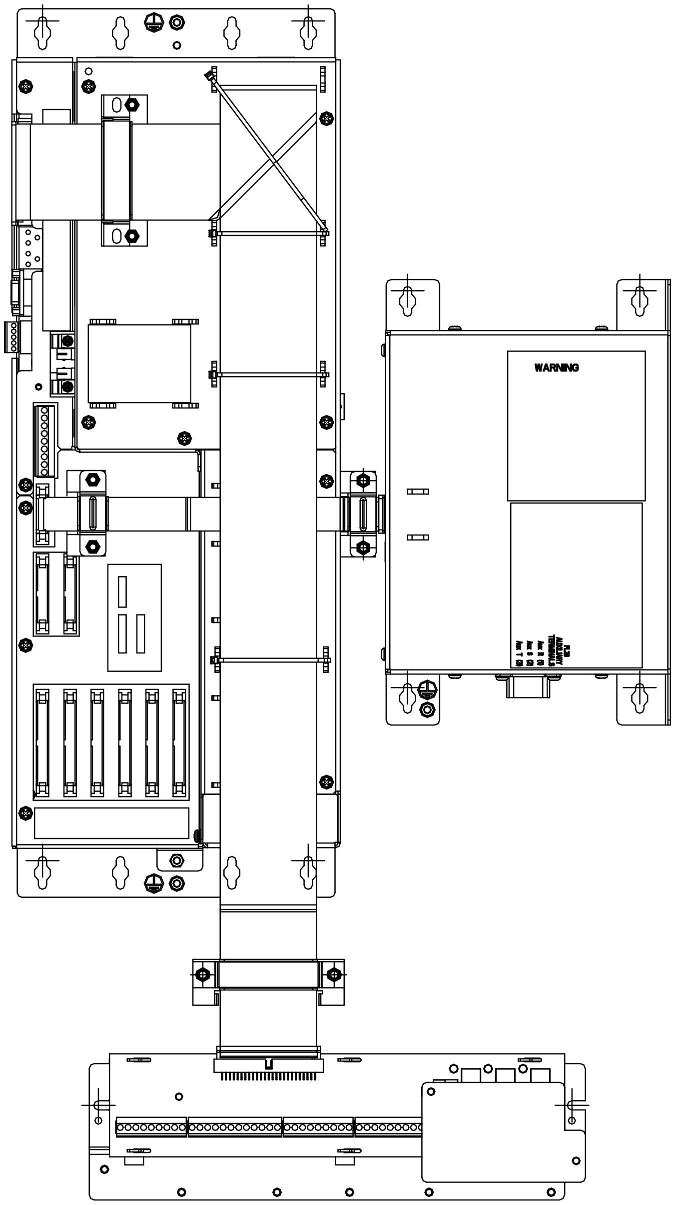


Figure 3–5. – Control Component Arrangement

The following should be observed when locating the control components:

- Allow 50 mm (2 in) ventilation space above and below the controller;
- The status LEDs on the controller and I/O panel should be visible;
- Allow access to the plugs, sockets and terminals on the control components;
- Allow sufficient space around the components for the routing and retention of all associated cables;
- The interconnection ribbon cables available with these units have limited lengths – see Section 3.6.8.1: Control Cabling Requirements.

3.6.8.1 Control Cabling Requirements

There are limits to the cable lengths allowed in a DELTA drive. When calculating the lengths of cable routes, remember the requirements for routing given in Section 3.5.4: Routing & Segregation Of Cables.

To ensure that the maximum cable lengths are not exceeded:

- Ensure that the cable routing distances for the 40 way ribbon cables from the controller to the DELTA transistor modules do not exceed 3 m (9.8 ft.). Available ribbon cable lengths are given in Section 2: Specification;
- When used, an optional Drive Data Manager™ (Keypad) will have to be mounted in a position which is within the 3 metre (9.8 ft.) cable length of the cable provided. This dimension will influence controller and DDM position;
- Ensure that the cable routing distance of the wiring from PL12 to the DELTA rectifier module (or modules) does not exceed 25 m (82 ft.);
- Ensure that the cable routing distance for the 50 way ribbon cable from PL20 on the controller, to the user I/O termination panel does not exceed 2 m (6.5 ft.). The ribbon cable provided with the I/O panel is 925 mm (36.4 in) long;
- The ribbon cable provided with the MVM unit is 360 mm (14.2 in) long.

3.6.9 Typical CDM Arrangement

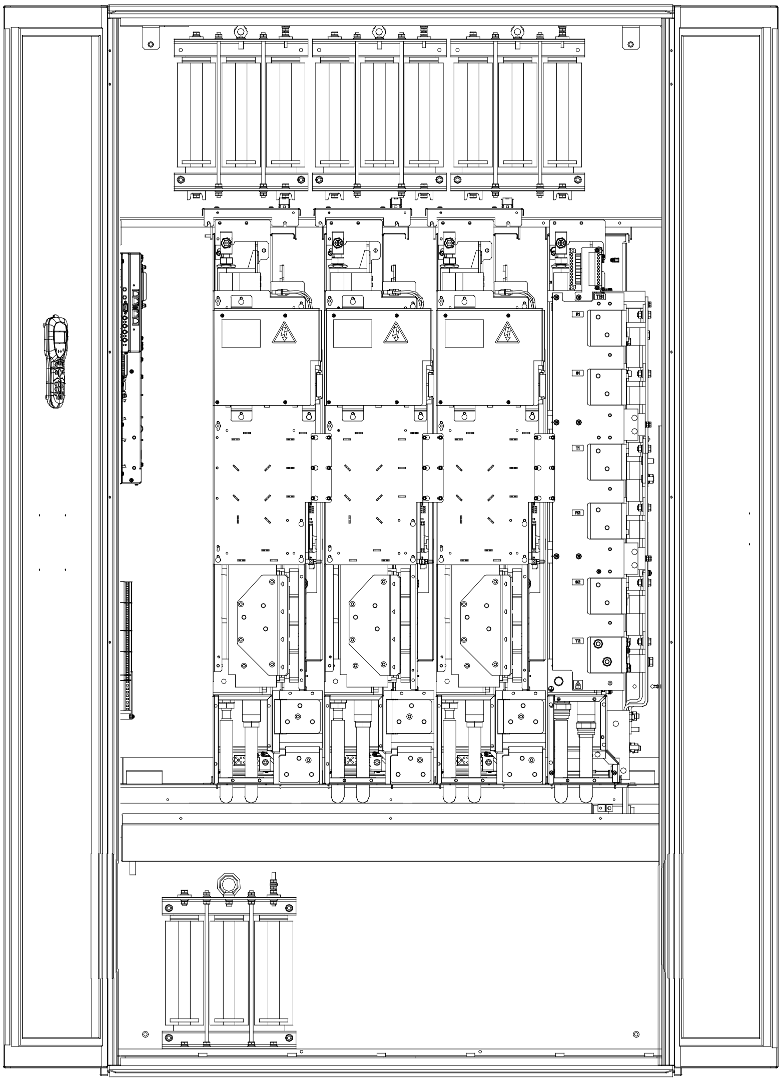


Figure 3–6. – Typical Layout Of CDM (DFE Drive)

3.7 COMPONENT SELECTION – COOLING SYSTEM DESIGN

3.7.1 Introduction To Cooling System

3.7.1.1 DELTA Power Modules:

- Have the majority of the power losses removed by the liquid coolant system.
- Require some forced air flow to provide ventilation for any components that are not directly liquid cooled.

The liquid coolant system:

- Dissipates these losses to the environment via a heat exchanger.
- Is usually specified and supplied by the CDM/PDS integrator.

3.7.1.2 DELTA Control Components

- Air cooled, with low power losses.

3.7.1.3 DELTA Wound Components

- Cooling depends on the individual component (see specification chapter).
  - Some components e.g. sharing reactors are usually air-cooled.

- Wound components usually have high temperature rating (class H is up to 180°C). When these components are liquid cooled there will also be significant losses to the local air due to this high temperature difference.

3.7.2 Objective Of This Section

To provide a safe and reliable coolant system is a complex job that requires expert knowledge.

- This section does not replace the knowledge of an experienced cooling system designer, but does:
- Give detailed, specific requirements for the DELTA modules.
- Guidance on the general design of the cooling system by:
  - Showing a typical cooling system ‘hydraulic’ diagram;
  - Describing the components in this typical system;
  - Giving details of important coolant control functions;
  - Giving an overall coolant system specification;
  - Showing typical system design calculations;
  - Summary data for air cooling?

3.7.3 Specific Requirements For A Liquid Cooled DELTA

The limit values are given for the individual components in Section 2: Specification. Additional guidance is given below:

Flow rate	Each liquid cooled DELTA module or component (for example, reactors, filter resistors, air-to-liquid heat exchangers for IP54 enclosures) must have at least minimum flow as shown in their specification to achieve full rating. A significantly higher flow rate above the module/component's rated flow is not recommended as it does not increase the module rating, but increases the power required in the coolant pump and may ultimately lead to erosion of the internal coolant channels.
Inlet temperature	The inlet coolant temperature to each component must be within the temperature limits specified for that component. In addition the coolant system and the individual modules/components must protected against freezing and condensation, see also: Section 3.7.4.12: Coolant, Section 3.7.4.4: Heater [H 01]. Section 3.7.4.4: 3 Way Valve [VT 01], Section 3.7.4.17: Control, Section 3.7.4.20: Prevention Of Condensation.
Pressure Limits	The Maximum System Pressure during filling, testing and continuous operation must not be exceeded. See also: Section 3.7.7.2: Pressure (for definitions) Section 3.7.4.6: Expansion Reservoir (vessel, tank) [RE 01] Section 3.7.4.7: Pressure Relief Means (Over-pressure relief valve) [VN 01]
Coolant type and quality	Suitable coolant (clean water, corrosion inhibiter and antifreeze chemical composition, particle size, scale prevention, filters and separation from other systems) must be provided, see: Section 3.7.4.12: Coolant, Section 3.7.5: Material Compatibility Section 3.7.4.5: Filter (strainer) [F 01]
Coolant connection	When the DELTA module is fitted with the 19mm (¾ inch) connector compatible hoses and clamps must be used see: Section 3.7.4.13: Flexible Hoses / Clamps & Connectors. Section 3.7.4.14: Joints / Seals Section 3.7.4.15: Manifolds

3.7.4 Typical Liquid Cooling System

A stand-alone liquid cooling system will typically comprise the following items:

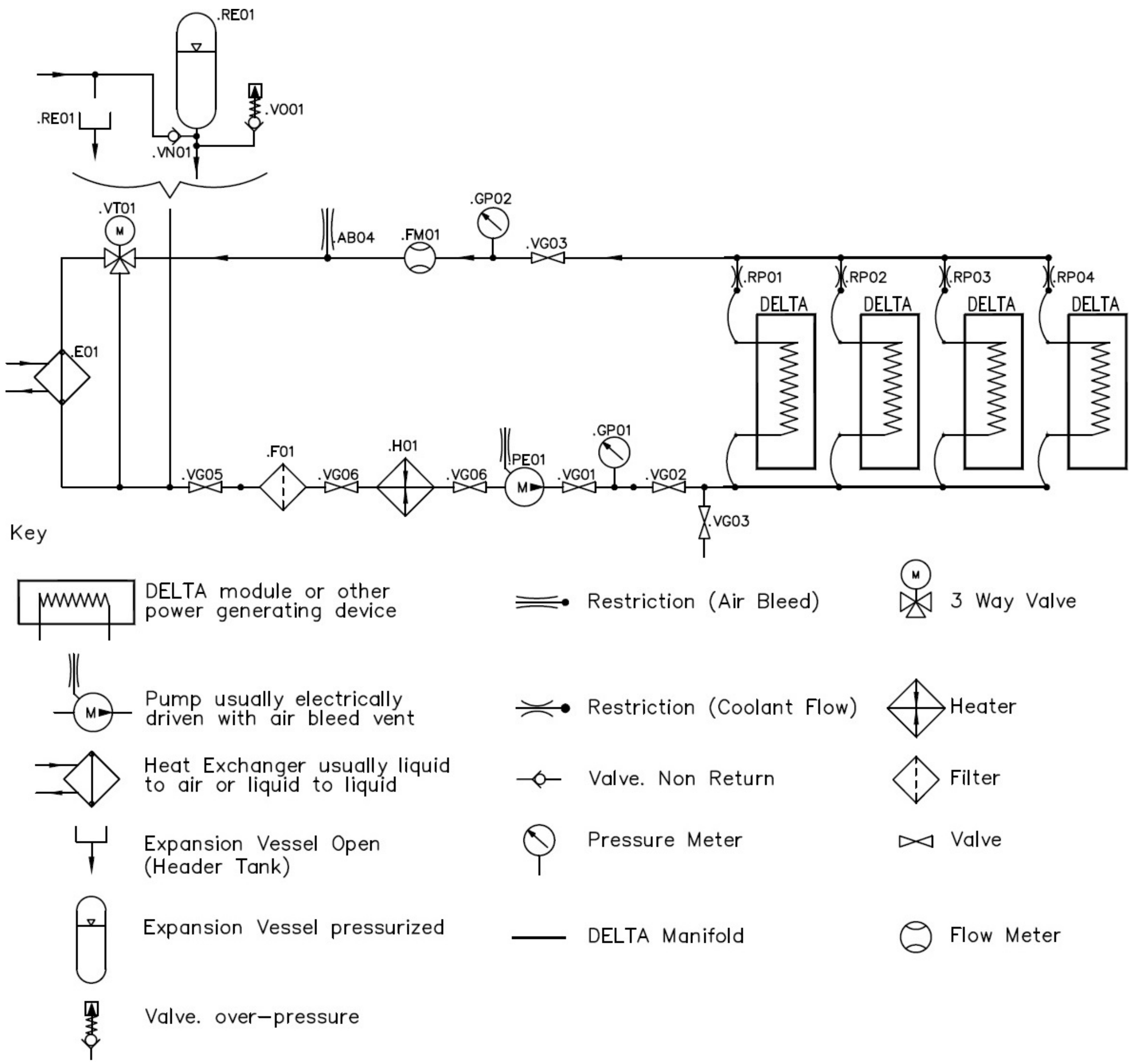


Figure 3–7. – Typical DELTA System Hydraulic (Liquid Cooled) Diagram

3.7.4.1 DELTA Power Module Or Other Liquid Cooled Components [PM 01 to PM n]

These are the main devices to be cooled by the system.

Other power devices may be connected in parallel if their differential pressure matches and the cooling system is rated to dissipate the total heat energy produced.

The energy to be removed from the power modules will usually be given as part of the drive quote from the local sales office. If not, an indication of the losses is usually given in the specification section.

NOTE: The actual losses vary as a result of the electrical system and the operating environment. So an adequate allowance must be allowed for predicted-to-actual loss performance.

3.7.4.2 Pump [PE 01]

This must provide the total flow of all the parallel DELTA modules (and other parallel connected heat loads) against the differential pressure drop (see Section 3.7.6: Cooling System - Tests for calculations).

- The maximum pressure provided by this pump must be below the maximum working pressure specified for the DELTA module.
- The pump motor's supply voltage and power must be compatible with the available auxiliary supply.
- The required flow rate must be specified at the working (differential) system pressure.
- Consider how the pump is protected (for example thermal overload).

NOTE: **The DELTA modules have over-temperature protection and so interlocking is not mandatory.**

- Is there a requirement for a standby pump?

3.7.4.3 Heat Exchanger [E 01]

The selection of either a liquid-to-air or liquid-to-liquid version depends on the final site installation.

A liquid-to-air exchanger is typically used unless the installation site already has a large general coolant system.

A Liquid-to-liquid heat exchanger is used to separate the site's coolant from the DELTA modules. This is important if the site coolant does not comply with the DELTA's coolant quality requirement e.g. particle size, contaminants, corrosive substances, temperature range.

- If the heat-exchanger electrical power is supplied from the CDM, then supply voltage and power must be compatible with an auxiliary supply available.
- Consider the protection of the heat exchanger's fans /pumps.

NOTE: **The DELTA modules have over-temperature protection and so interlocking is not mandatory.**

- If the exchanger is installed external to the building, use a 3 way valve and heaters if the external temperature can drop below 0°C.

3.7.4.4 Heater [H 01] & 3 Way Valve [VT 01]

These are required when the ambient conditions would allow the local DELTA environment to be outside of the allowed range. The heater is used with the 3 way valve to prevent the coolant temperature dropping below +5°C, or to prevent condensation on the CDM components.

NOTE: **The pump losses contribute to the total heating input.**

3.7.4.5 Filter (strainer) [F 01]

This prevents solid particles from entering the DELTA, pump, heat-exchanger, etc. that may block the coolant path.

- The mesh size must be smaller than the maximum particle size allowed for any component in the system. For DELTA modules see coolant quality Section 3.7.5.1: Maximum Particle Size.
- The filter should be specified to have a low pressure drop for the rated system coolant flow.
- Fit service valves on the filter's inlet and outlet, allow access space for tools and a container (to catch any lost coolant) when cleaning the mesh.

3.7.4.6 Expansion Reservoir (vessel, tank) [RE 01]

This is used to allow for the expansion and contraction of the coolant over the operating temperature range. It should be sized to ensure that the pressure (gauge) is kept within the allowed limits. A sufficient size margin is required for air-bleeding and for loss of coolant between service intervals.

For open systems the expansion reservoir is a header tank located at sufficient height above the coolant system to provide the required working pressure (gauge). It will also require low coolant level and coolant leak monitoring, and a refill system (this must have the correct combination of water, glycol and corrosion inhibiters).

For closed (sealed, pressurized) systems then an expansion reservoir (receiver) is fitted. It will also require an over-pressure release, low pressure monitor and a refill system. Ensure that the pressure x volume of air in the expansion vessel does not exceed the safety requirement, e.g. in the EU the Pressure Equipment Directive.

The decision on which type of system used is dependent on the site installation. Sealed systems are used when open header tanks are not acceptable due to risk of spillage, contamination or where a remote header tank is non-preferred.

3.7.4.7 Pressure Relief Means (Over-pressure relief valve) [VN 01]

The DELTA modules do not contain an integral pressure relief means. Therefore, on the coolant systems where there is a possibility of the pressure exceeding the specified maximum, a means must be provided to limit the pressure to below the maximum limit (see Section 3.7.7.2: Pressure). This must also work if the electrical power is off, e.g. when the system is being filled to too a high a pressure.

3.7.4.8 Service Valves [VG 01 to VG 08]

Any item that requires draining for servicing or replacement should be fitted with local isolation valves on the inlet and outlet to limit the coolant that needs to be removed. These are normally fitted for both the filter and pump. If the DELTA modules are not fitted with disconnect, self-sealing connectors (Staubli) then local isolation should also be fitted close to the DELTAs.

3.7.4.9 Air Bleed [AB 04]

The coolant system must be designed to incorporate an air bleeding device at any high points.

When both coolant connections (flow & return) are fitted to the bottom of the DELTA modules a manual bleed valve is also fitted to the top. This then allows the air to be bled from this point during commissioning and maintenance. The bleed valve outlet hose must be connected to a suitable drain.

3.7.4.10 Coolant Drain Point [VG 03]

A suitable drain should be fitted at any low points in the coolant system. Where sections are isolated by service valves, these also require a drain and de-pressurisation point.

3.7.4.11 Restriction For Coolant Flow (RP 01 to RPn)

Any device connected in parallel with the DELTA modules coolant must have a compatible pressure at the nominal flow rate. When the connected device has a different pressure characteristic then a flow restrictor must be fitted to either the device or the DELTA modules to balance the pressures at the designed flow rate.

3.7.4.12 Coolant

The recommended coolant is a mixture of water, anti-freeze and corrosion inhibiters and should meet the performance specification of BS 6580 "Specification for corrosion inhibiting, engine coolant concentrate ("antifreeze")" or the equivalent national standard.

The coolant must provide:

- Corrosion protection, scale inhibitors (against hard water);
- Frost protection if there is any risk of the coolant freezing.

NOTE: Heat-exchangers located external to a building usually require anti-freeze protection.

Do not mix antifreeze or corrosion inhibitors of different types or from different manufacturer's.

In unfavourable conditions this causes an increase in corrosions.

Water

Do not use water as the only coolant. If mixing coolant, use pure or de-mineralised water. Coolant must contain corrosion inhibitors.

NOTES: Corrosion and scale Inhibiters types vary according to the local region's water mineral content (phosphates, calcium, magnesium, etc.). The inhibiters are optimised to prevent harmful chemical reactions with these minerals. The use of de-mineralised water avoids these additional reactions. Other containments in the water may cause blockages, erosion from solid particles, biological growth or accelerated corrosion.

Anti-Freeze

Type: Monoethylene Glycol (see also corrosion inhibiters).

Concentration: Sufficient to prevent freezing (for the minimum external temperature –Figure 3–8).

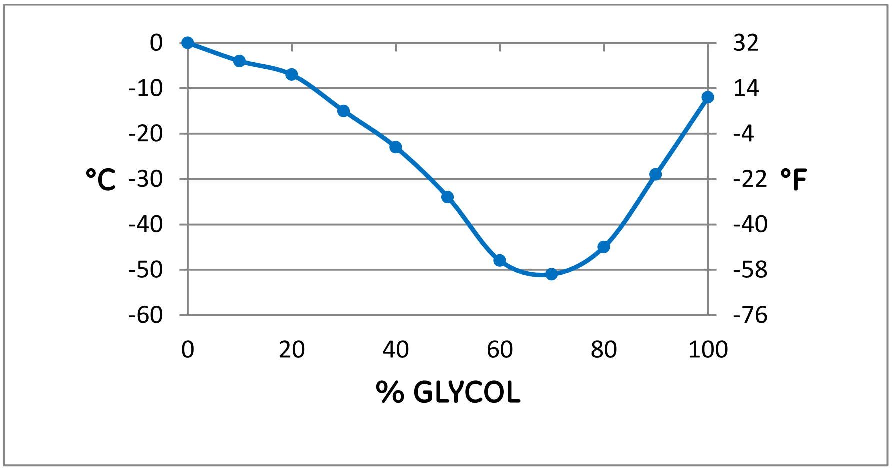


Figure 3–8 Freezing Point of Glycol / Water

Figure 3–8 shows the freezing point of Monoethylene Glycol water mixture.

NOTE: The actual 'freeze protection' level is not as low as this figure, refer to manufacturer's data.

- Maximum freeze protection is obtained at 50 – 70% glycol concentration.
- Neat glycol freezes at -12°C (10.4°F).
- Increasing the glycol above 50% does not give a significant increase in freeze protection; above 75% this protection is reduced. Water is more efficient at cooling than glycol, so the minimum concentration that will give the required freeze protection should be used.
- If corrosion inhibiters are included in the anti-freeze mixture it is usual for this to have maximum protection at 50% anti-freeze mixture to match the maximum freeze protection. Do not use concentrations below 33% for corrosion protection.

Corrosion & Scale Inhibiters

The coolant must contain a corrosion inhibitor additive, suitable for the materials specified in Section 3.7.5: Material Compatibility.

This inhibiter is included in the anti-freeze mixture by some manufacturers and must be to the necessary concentration recommended by the manufacturer.

Example Coolants

A local supplier of coolant (antifreeze) can be used, providing the product complies with the requirements listed above and is compatible with the materials specified in Section 3.7.5: Material Compatibility.

Type	Manufacturer	
Eskimo Universal Antifreeze	FUCHS LUBRICANTS (UK) PLC	www.fuchslubricants.com
Comma Supercoldmaster Antifreeze	COMMA OIL & CHEMICALS LIMITED	www.commaoil.com
Glysantin® G 30	BASF Aktiengesellschaft	www.glysantin.de

WARNING

- **This coolant is harmful. Follow the manufacturer's safety instructions.**

3.7.4.13 Flexible Hoses / Clamps & Connectors

Hoses

The DELTA modules are fitted with hose tails for connection by flexible 19 mm (3/4 in) internal bore hoses. It is usual to join these hoses to a coolant manifold adjacent to the DELTA modules.

The flexible hose allows for differential movement between the rigid coolant pipe-work and the DELTA module due to thermal expansion or vibration. It also allows the coolant connection to be bent to allow the extraction of the DELTA module.

Ensure that the flexible hose is compatible with the coolant mixture (Section 3.7.4.12: Coolant) and other materials in the coolant system see in Section 3.7.5: Material Compatibility.

- Ensure equal flows to parallel modules by keeping hoses equal lengths.
- The hose end should be firmly attached by a clamp and adequately restrained along its length to prevent abrasion or high stress.
- Ethylene Glycol based coolants are NOT normally compatible with polyurethane hoses.

When the DELTA module is supplied with the quick disconnect, low loss, 'auto shut-off' couplings (option) then the mating parts are supplied loose with each module. These are also to be connected by a 19 mm (3/4 in) flexible hose. The loose part is Staubli Unimation RMI 16 socket hose GE Power Conversion Part Number: MVS3010-4001.

Internal / Outside Diameter mm (in)	Type	Manufacturer	Temperature Range	Working Pressure			Minimum Bending Radius mm (in)
				bar	psi	MPa	
19.1 (3/4 in) / 27mm ($1^{1}/_{16}$ in)	Codan Type 4801, Rubber hose, EPDM lining, polyester reinforcement	Codan Rubber A/S, Denmark www. codan.com/codan_dk/	+110 °C to -40 °C	6	87	0.6	100 (3.9 in)
19.0 (3/4 in) / 26.9mm ($1^{1}/_{16}$ in)	FLEXOR 6, Part no: 8T9AA0200	Alfagomma S.p.A www.alfagomma.com	+100 °C to -40 °C	21	300	2.1	178 (7.0 in)

Table 3–1. – Examples for Flexible Coolant Pipe

Clamps

The hose clamp must be suitable for the hose used. It must tighten uniformly around the hose with uniform compression and a 360° seal. The inside edge must be smooth and completely free of sharp edges.

Screw band (worm-gear) clamps frequently leave a small section of hose adjacent to the screw without compression and so are not recommended. If a unitary clamp is used, it should additionally be specified with the band edge rolled to eliminate steps in the contact area.

Examples of Hose Clamps

Suitable clamps are step-less 2-Ear-Clamps (no steps or gaps on the inner circumference of the clamp) from **www.oetiker.com.**

3.7.4.14 Joints / Seals

The number of joints should be minimised. The most reliable are of a welded construction. Any seals used should be suitable for the coolant. The DELTA modules use EPDM seals.

3.7.4.15 Manifolds / External Pipes

The main purpose of the manifold is to give equal pressure and therefore equal flow through all of the parallel coolant connected DELTA modules. It also provides a distributed, local connection point for the DELTA modules.

- Ensure that there are no significant pressure drops across the manifold(s) by the use of suitably sized pipes. If this is not possible, arrange the flows to equalise the pressure drop by using a diagonal principal so that the flow and return pipes are positioned diagonally opposite across the modules.
- Ensure that the manifold is sufficiently supported for the forces applied e.g. due to vibration and the attachment of external pipe-work. Allow some ‘float’ (movement) in the pipe-work to allow for the manufacturing tolerances of the various parts.

When the return manifold is fitted above the DELTA modules:

- Fit an air-bleed to this manifold If it is the high point in the system.
- Ensure that the DELTA modules are protected against any coolant leakage, e.g.:
  - Use welded joints on the manifold.
  - Position the flexible hose connection so that they are not directly above the DELTA modules or add a drip tray under these joints.
  - Route the outlet of the air-bleed valves away from any vulnerable components.

External pipework may be hot, so assess precautions to prevent contact by personnel including warning labels.

3.7.4.16 Fill Point

Filter

During filling, some coolant does not pass though filter F 01. This can be prevented by fitting an additional filter at the fill point.

For A Sealed System:

The fluid is pumped into the coolant system using a separate fill pump fed from a container. The flexible hoses connecting the pump to the drive fill point will be pressurised and so suitable hose retention (clips/clamps) are necessary.

On the drive coolant system it is usual to fit a hose tail, a manual fill valve, non-return valve and a filter.

When the fill valve is open the pressurised coolant in the drive will flow out. This can be prevented by ensuring that the fill pump is always running when this valve is open or by fitting a non-return valve.

3.7.4.17 Control

During warm-up of the cooling system or when the main supply is off, the following may need to be operated independently to the drive controller:

- Pump to circulate heating water;
- 3 way valve position (usually bypass of external heat exchanger);
- Heaters.

These items also need protection against overheating (e.g. loss of coolant, jamming, or overload).

A temperature sensor should be used to control the inlet temperature to the DELTA when the 3-way valve and, heater are used.

The drive controller contains configurable logic functions and a limited amount of I/O (see software manual) and so some of the coolant system's control and protection may be integrated into the drive controller.

The DELTA module, when connected to the MV3000 controller has a monitor that trips the drive at high temperature and will not permit the drive to start at low temperature.

The following are normally required:

- Continuous operation of the pump during coolant heating or drive operation;
- The economic use (and noise reduction) of the heat exchanger fan/s. by (variable or on/off) speed control;
- The co-ordination of coolant pump, 3-way valve, heater and heat exchanger fans to keep the DELTA module's inlet temperature within limits and to prevent condensation;
  - Use the lowest inlet temperature to the DELTA module that prevents condensation. These modules are more efficient and have a longer life at lower temperatures.
  - The heater off at higher temperatures and low humidity.

3.7.4.18 Protection

In addition to the built in protection (described in Section 3.7.4.17:Control) the following must also be included:

- Over-temperature protection of liquid cooled reactors (if fitted). These may have PT100s, thermostats or thermistor fitted (check the specification for the particular component). Thermostats may be fed directly to a digital input but will not provide a warning unless two temperature thermostats are used. When using the drive controller a signal conditioner is usually required to converter this to a compatible analogue input;
- Over-pressure protection (see Section 3.7.4.7: Pressure Relief Means (Over-pressure relief valve) [VN 01]).

3.7.4.19 Control Monitoring & Indication [GP 01, GP 02, FM 01]

To provide early fault protection and to aid fault finding the following may be required:

- Coolant level too low (in an open system) or low pressure (in a closed system)
- Pump ON, e.g. feedback from the overload protection relay and pump control contactor
- Filter blocked
- Coolant leakage
- Coolant flow inadequate, e.g. flow meter or flow switch
- Coolant temperature too high for safe operation (at either the outlet from heat-exchanger or inlet to DELTA)
- Heat exchanger fan/s not running, e.g. from the overload protection relay or control contactor
- Inlet and outlet pressure;
- Outlet temperature.

Minimum Indication

The flow meter is not normally used on volume systems, due to its cost. It is frequently fitted to pre-production and evaluation systems to check that the flow rate is adequate.

Note: **For the initial first build, it is recommended to have temporary flow-meters fitted to each different type of parallel module path, to check that each path has the correct flow.**

3.7.4.20 Prevention Of Condensation

Condensation forms when moist air is cooled or comes into contact with a cool surface that is at or below its dew point (saturation point). At this temperature air is unable to hold all the moisture, and water vapour condenses into moisture droplets on available surfaces. Below freezing the vapour condenses into frost.

Various problems result when condensation forms on electrical devices including the reduction of resistance of insulation and the corrosion of critical parts. This can cause a reduction in the life expectancy of components and in severe cases an immediate failure.

To prevent condensation on critical components, the surface temperature of the component must be kept above the dew point of the air (see Figure 3–9).

NOTE: To reduce the effect of corrosion it is recommended that the long term humidity is limited to below 60%.

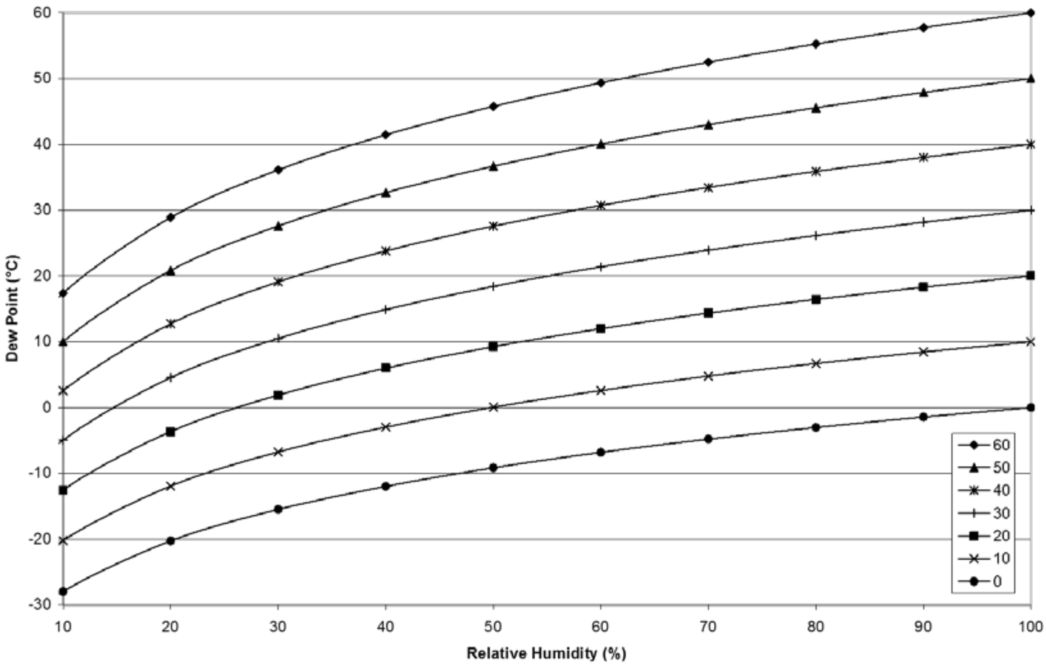


Figure 3–9. – Dew Point (Condensation occurs) For Various Air Temperatures

In the case of liquid cooled components this requires the coolant temperature to be above the dew point of the component's local air temperature. Components must be kept above the dew point even when switched-off and during low night temperatures. The use of coolant, anti-condensation heaters and/or dehumidifiers is recommended.

3.7.5 Material Compatibility

It is important that all materials in the cooling path are compatible with each other and with the type of coolant in use (see Section 3.7.4.12: Coolant). This compatibility must be maintained in the requirements for any external cooling path component.

Material In Contact DELTA Module's Cooling Path (Quick disconnect versions)

COMPONENT	MATERIAL AND SPECIFICATION
All versions	
Coolant Duct	Aluminium LM25 to BS 1490
Heatplate	Aluminium LM25 to BS 1490
Heatplate Seal	EPDM 60 / 5053M-027 (Ethylene Propylene)
Versions fitted with Quick disconnect	
Quick Release Hose Couplings Staubli: RMI16 N007 117 96 (socket) and RMI16 N007 153 98 (plug)	Main Parts in brass CuZn40Pb3 - Nickel plated Release Sleeve in Stainless Steel Z30 CF13 Plug Body in hardened Chromium Steel Z30 CF13 Locking Balls in Stainless Steel Z2 CN18.09 Seals in EPDM Springs in Stainless Steel Z10 CN18.09
Return Pipe	Stainless steel 316L, seal EPDM 70
Vent (Bleed) Valve Assembly	Stainless Steel Grade 316L, seals EPDM 70
Versions fitted with Hose-tails (at bottom)	
Hose-tail	Aluminium 6082, seal EPDM 70
Return Pipe	Stainless steel 316L, seal EPDM 70
Vent (Bleed) Valve Assembly	Stainless Steel Grade 316L, seals EPDM 70
Versions fitted with Hose-tails (at top)	
Hose-tail	Aluminium 6082, seal EPDM 70
Blanking plug	Stainless steel 316L, seal EPDM 70

Table 3–2. – Materials Used In The DELTA Module Cooling Path

Typical Materials Used In The Cooling Path That Are External To The DELTA Modules

Table 3–2 lists materials which are usually acceptable for the external coolant circuit. These are internally corrosion inhibited by the correct coolant mixture, but the external surfaces should be protected against the local ambient conditions.

Note: **The final customer often has their own rules on compatible materials e.g. do not use copper/brass, or use only stainless steel.**

COMPONENT	MATERIAL AND SPECIFICATION
Flexible Pipes from DELTA module to Manifold	Section 3.7.4.13: Flexible Hoses / Clamps & Connectors.
Rigid Pipes from Manifold to External Cooling System	Light Carbon Steel Tube to BS 1387#, stainless steel 316L or 304L to EN 10312#.
Manifold	Carbon Steel, stainless steel 316L or 304L.
Header Tank	Polypropylene or stainless Steel 316L or 304L.
Heat Exchanger	Tube material – copper, stainless steel 316L or 304L.
Coolant Pump	Brass body and bronze impeller, cast iron body and stainless steel impeller.
Coolant	Section 3.7.4.12: Coolant.

Table 3–3. – Typical Materials Used In The External Cooling Path

Note: **EN 10255 "Non-alloy steel tubes suitable for welding and threading" and EN 10312 "Welded stainless steel tubes for the conveyance of aqueous liquids" or the equivalent national standard may be used.**

Non-Compatible Materials For The Cooling Path

This list is not fully inclusive; the system integrator must check for any material inter-compatibility.

NON-COMPATIBLE MATERIAL	Where frequently found, (but not to be used with water / glycol coolant!)
Polyurethane	Flexible hoses (wetted surface)
Nitrile rubber (also known as Buna-N, NBR)	Seals, O-rings

Table 3–4. – Non-Compatible Materials For The Cooling Path

3.7.5.1 Maximum Particle Size

The DELTA power modules have large diameter internal coolant paths. So a large filter mesh size may be used on the coolant path. This largest recommended mesh is 0.7mm (28 thou').

3.7.6 Cooling System - Tests

Any leakages of the coolant system in the enclosure may damage the connected electronic components. Test as much of the system as possible before the installation of the electronic components.

3.7.7 Liquid Cooling System Calculations

3.7.7.1 Flow Rate

Calculate the total flow to be delivered by the pump by summing all of the parallel heat generating modules.

The nominal flow is 25l/min (5.5 UK or 6.6 US gallons/minute) per transistor or rectifier module and 15l/min per liquid cooled reactor (check the specification for each particular item for a special flow rate), e.g. six LCDs (25l/min each) + one reactor (15l/min) = 165l/min.

Include a margin for miss-match in parallel connected components due to pressure compatibility e.g. 10%.

3.7.7.2 Pressure

Working System (gauge) Pressure

This is the coolant pressure compared to atmospheric pressure measured at the maximum pressure point in the system. It is usually measured by a pressure gauge so is also known as gauge pressure.

When the pump is stopped, the system pressure is the same as the fill pressure. The running pump creates a differential (flow) pressure between inlet and outlet, with the outlet pressure rising higher and the inlet below the fill pressure. As the system pressure is the maximum pressure (at any point in the system) then the system pressure is also higher than the fill pressure. This gauge pressure measured at the inlet or outlet to a DELTA module must not exceed the specified working pressure. See Section 2.11.4 - Operating Pressure.

See also:

- Fill (Static) Pressure / Header Tank (height) Location,
- Section 3.7.4.6 Expansion Reservoir (vessel, tank) [RE 01],
- Section 3.7.4.7 Pressure Relief Means (Over-pressure relief valve) [VN 01].

Test Pressure

During testing the system pressure may be increased for short durations to ensure that the system is robust and that leakages will not occur during normal operation; this is equivalent in electrical terms to an insulation withstand (flash) test. During the pressure test the converter must not have electrical supplies applied in case of coolant leakage.

Testing must be restricted to the components specified pressure and time. For repeated testing the pressure / time must be below these values.

Fill (Static) Pressure / Header Tank (height) Location

When the system is filled, it is necessary to pressurise the coolant. This is either through the fill pump for a closed system or by the height of the header tank for an open system. This fill pressure is usually sufficient to prevent any point in the coolant system dropping below atmospheric pressure when the pump is running. A negative pressure allows air to be drawn into any joints that are liquid tight, but not gas tight. It is usual to leave at least 0.5 bar (7.3 psi) margin.

If the pump has been selected to deliver 1 bar (14.5 psi), then the fill pressure should be approximately 1.5 bar. This then ensures that the maximum pressure in the system is below the limit for the DELTA module even if there is a blockage in the system.

Note: With care and the correct use of over-pressure devices it is acceptable to use different fill and pump pressures, but the detail of this is beyond the scope of this document.

The pressure due to the height of the header tank is given by:

$$P_{\text{static fluid}} = \rho g h \quad \text{where} \quad \begin{array}{l} \rho = \text{fluid density} \\ g = \text{acceleration of gravity} \\ h = \text{depth of fluid} \end{array}$$

For only water at 20°C, $\rho = 1$ kg/m², $g = 9.81$ m/s², so to obtain 1.5 bar = 1.5/(1x9.81) = 15.3 m (50.2 ft.).

For 50:50 water glycol mixture at 20°C, $\rho = 1.07$ kg/m², so to obtain 1.5 bar requires a depth of fluid of 14.3 m (47 ft.).

Note: The glycol density changes as the coolant temperature changes. The internet has several sites illustrating the specific gravity of ethylene glycol water mixtures.

Dynamic (flow) Pressure Drop

The pump has to provide the total pressure around the coolant system for all series connected components at the specified flow rate

Figure 3–10 is a simple example of a coolant system to illustrate pressure drops. This shows two DELTA modules plus one reactor, connected in parallel. The actual pressure drop will have to be obtained for the components, system and conditions used for the actual application.

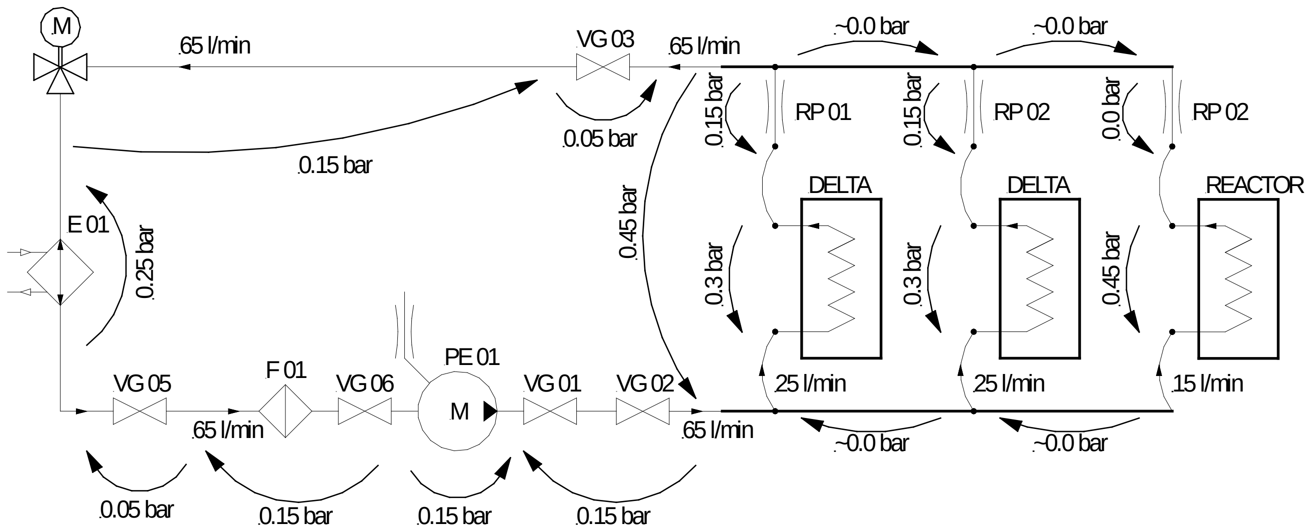


Figure 3–10 Example Of Dynamic Pressure Drops

The total coolant flow required through the pump and heat-exchanger is at least 65 l/min (2x25 per DELTA +15 for the reactor). The pressure drops represented by each component / section of the coolant system are shown. These are added together for the series connected components. The pressure drop across the parallel components must be equal at the nominal flow rate for each component and so restrictors are shown to balance these pressures. It will also be necessary to oversize the pump if the pressures are not completely balanced so that at least the nominal flow is achieved for each parallel path.

The pump must supply the pressure of 1.25 bar, from 0.15 + 0.45 (LCD + restrictor = reactor + no restrictor) + 0.05+0.15+0.25+0.05+0.15 = 1.25 bar

When measuring the pressures in an actual system, the gauges will show the effect of both the dynamic and static pressure.

Note: The pump rating does not have to include the static pressure as the weight of the water flowing uphill is balanced by the weight of water returning downhill in return path.

3.7.7.3 Volume Of Coolant In A System

The volume of coolant required includes the filling of all the liquid cooled components and the leakage / evaporation loss between planned maintenance.

Volume & Weight Of Coolant In Each DELTA Module

The volume of coolant in each DELTA module (Rectifier or Transistor), is 1.75 litres (≈ 0.38 UK gallon or ≈ 0.46 US gallon); weight of coolant is 1.75 kg (4 lb.).

3.7.7.4 Coolant System Component Temperatures

All of the components must be rated for the local coolant and air temperatures. The temperature will vary through the coolant system (low at the heat-exchanger outlet and high at the heat loads outlet).

The maximum allowed coolant into the DELTA module is 60°C (140°F) although a lower temperature will give benefits in component lifetime, reduction in power losses and improvement in drive rating. Check the specification for other components.

3.7.8 Air Cooling

The liquid cooled components have a proportion of losses that are removed by the local airflow. The proportion of losses depends on the ratio of temperatures (liquid-to-air), surface area and the velocity of air flow. In addition to these stray losses, there is also the power loss from any component that is not directly liquid cooled. These losses and any localised hotspots need to be removed by the air cooling.

Typical losses for individual DELTA assemblies are given in the Specification, section 2. (These are for indication only as the exact losses depend on the environmental conditions).

The cooling air temperature and quality should also ensure operation within the environmental conditions given in Section 2: Specification.

This cooling may be by ventilation through the enclosure or by recirculating the air through a heat-exchanger.

3.7.8.1 'Through Enclosure' Air Cooling

- Usually more cost effective than fitting heat-exchangers.
- Generally give lower enclosure and component temperatures than fitting heat-exchangers.
- It is easier to achieve an adequate design as the airflow can be increased by additional fans.
- Should only be used when the environment complies with the air quality requirement for the components used.
- Air inlet is usually located at the bottom of the enclosure and outlet at the top.
  - These openings must be located and constructed to avoid hazards to personnel from ejected debris picked-up by the airflow or from arc flash.
  - Avoid locating air inlets or outlets where persons may be present when the drive is operating, e.g. the front door of the enclosure.

3.7.8.2 Re-Circulation Air Cooling

For higher Ingress Protection (IP) enclosures, the cooling of the air may be supplied by air-to-liquid (or air-to-air) heat exchangers.

Great care must be used when determining the rating; they must dissipate all the air losses some of which may be unknown.

3.8 COMPONENT SELECTION – ELECTRICAL

3.8.1 DELTA Power & Control Modules

These are selected as part of the initial kit list (Section 3.2: initial DELTA Kit list), with the description and specification for these units shown in Section 2: Specification. Some units have a small amount of additional selection information shown below.

3.8.1.1 Switch Mode Power Supply (SMPS)

Several variants are available as shown in Table 2–12. - SMPS Specifications. These variants allow for different voltage supplies and different voltage transients on these supplies. Higher voltage transient SMPS must only be used with higher transient capable DELTA power modules as the SMPS provides the under- and over-voltage protection for that power module.

Standard Tolerance a.c. Supplies

Table 3–5 shows compatible DELTAs for the standard a.c. supply voltage (as shown in Table 2–1. – Electrical Specification) of the CDM. This SMPS supply voltage rating must also match the DELTA Transistor module voltage (except for the MVDLxxxx-x5xxxxxx which may be used with the MVC3003-4001 on 380 – 440V supplies).

SMPS Version	AC Supply Voltage	Compatible DELTA module
MVC3003-4001	380 – 440 V a.c. (400 V nominal	MVDLxxxx-x5xxxxxx
MVC3003-4002	460 – 525 V a.c. (480 V nominal	MVDLxxxx-x5xxxxxx
MVC3003-4003	575 - 690 V a.c. (600 / 690 V nominal)	MVDLxxxx-x6xxxxxx
See below for MVDLxxxx-x7xxxxxx		

Table 3–5: SMPS Units For Standard Supplies

Poor Tolerance a.c. Supplies

The following variants have been designed specifically for use in systems with poor supply regulation. These units are more complex, expensive and are only to be fitted to DELTA modules with higher withstand voltage.

The sequence of SMPS connections to the controller is important:

MVC3003-4020

To allow the highest d.c. voltage rating for an MVDLxxxx-x6xx by fitting a high tolerance over-voltage feedback circuit. The other (if fitted) parallel DELTA transistor modules are then fitted with an SMPS (MVC3003-4025) where the over-voltage trip is set above this trip level.

The MVC3003-4020 must be connected to the controller PL2 (DELTA 1 position) only. The -4025 version is fitted in DELTA 2 – 6 positions (PL3 – 7 on the controller).

MVC3003-4030

The MVDLxxxx-x7xx has a higher short-time voltage rating than other DELTAs. This SMPS is designed to maximise the achievable system voltage by allowing a time delay on the over-voltage trip. The Timed Overvoltage is user configurable for up to 7.5s.

The unit is fitted with another higher voltage trip circuit. If this voltage threshold is reached the drive is tripped instantly.

If other parallel DELTA transistor modules are fitted then these require an SMPS (MVC3003-4025) where the over-voltage trip is set above these levels.

MVC3003-4030 must be installed in DELTA position 1 only. The -4025 version is fitted in DELTA 2 – 6 positions.

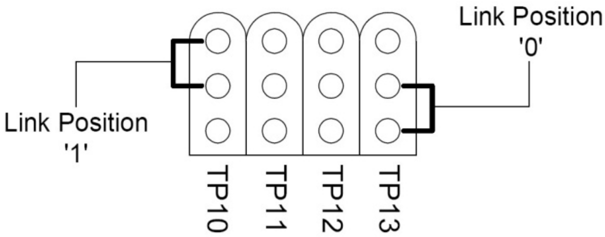
MVC3003-4025

These units are to be installed in DELTA positions 2 to 6 in multi bridge DELTA systems. Their overvoltage trip level is set to 1290V nominal, and is intended to be a back-up for the master trip circuitry in MVC3003-4020 and MVC3003-4030. The analogue volts feedback is disabled in this variant.

If the MVC3003-4025 is fitted in the controller PL2 (DELTA 1 position) the system will trip on DC Link Under-voltage.

Configuring The Timed Overvoltage Trip Duration

MVC3003-4020 and MVC3003-4030 are both fitted with 20X4344 daughter boards. This board contains the configuration links for the Timed Overvoltage trip duration. The table below shows the link settings and their corresponding duration.



20X4344 Configuration Links				Duration (seconds)
TP10	TP11	TP12	TP14	
0	0	0	0	0.0
0	0	0	1	0.5
0	0	1	0	1.0
0	0	1	1	1.5
0	1	0	0	2.0
0	1	0	1	2.5
0	1	1	0	3.0
0	1	1	1	3.5
1	0	0	0	4.0
1	0	0	1	4.5
1	0	1	0	5.0
1	0	1	1	5.5
1	1	-	-	6.0
1	1	0	1	6.5
1	1	1	0	7.0
1	1	1	1	7.5

Table 3–6. – Link Settings & Durations

DC Overvoltage – Origin Discrimination

By monitoring the AC supply and the DC Link voltage it is possible to discriminate between a supply induced overvoltage and a motor/load derived overvoltage (for example regeneration of power through the output bridge beyond the braking capacity connected to the DC Link).

For this discrimination a MVC3006-4001 Mains Voltage Monitor unit and the appropriate firmware are required.

With this hardware and software arrangement, the following actions will occur:

Mains Induced Overvoltage

In this case both the mains voltage and the DC Link will have reached predefined threshold levels. The PWM will be inhibited until the DC Link falls below 1188V (±1%) when the software will perform an auto restart operation and flycatch the load.

Motor/Load Induced Overvoltage

A DC Link transient without an accompanying AC supply transient will be treated in the normal way and the drive will trip.

3.8.2 Control Circuit – Auxiliary Components

Additional components to those shown in the typical circuit diagrams will be required. Typically these are:

- Pre-charge circuits for AEM / DC feeder schemes (see Section 3.8.6: Pre-Charge For AEM Systems).
- Cooling system supplies and controls (see Section 3.7: Component Selection – Cooling System Design).
- Air ventilation supplies and controls.
  - Enclosure fans or air heat-exchanger.
  - Temperature monitoring and protection of component and enclosure.
    - Check in specification chapter which items already have internal monitoring and protection.
    - For those not monitored, decide on protection strategy and add monitoring as appropriate.

NOTE: The internal fan (option) in DELTA transistor module is also supplied by the SMPS.

- Auxiliary control supplies.
  - The power supplies for the MV3000 controller are supplied by the SMPS unit.
    - A 24V d.c. auxiliary input connection on TB2 (pin 2 =24V, Pin 1 = 0V) is also available for monitoring and programming the controller when the main supply is switched off.
    - 24V d.c. output is available for digital inputs.
      See Table 2–11. – User I/O Termination Panel Connections for details.
  - Customer interfaces may use other supplies these must be protected against over-current and voltage transients.
  - Additional devices added to the CDM e.g. contactors or heaters may require 110V a.c. supplies.

3.8.2.1 Line Contactors & Relays

When installing line contactors and relays in close proximity to, or connected to, the DELTA modules the coils must be fitted with suppression devices.

Suppression will normally take the form of a suitably sized series connected capacitor and resistor connected across the contactor/relay coil.

3.8.3 Filters

3.8.3.1 PWM Filter

This must be fitted to an AEM drive to filter the PWM harmonics.

- Sized for the application, depends on:
  - PWM frequency;
  - Supply reactance;
  - Impedance of the input reactor;
  - Drive rating;
  - Attenuation required (acceptable level of harmonics).

Due to the large variation of applications, standard versions are unavailable.

- Electrical location shown in Figure 11–7.

3.8.3.2 EMC Filters

Used as part of the measures to attenuate the high frequency (radio frequency) emissions from the CDM.

- Fitted to the a.c. supply connections to the CDM.
- Most effective when used at an EMC shielding boundary.
  - Cables and components (e.g. isolator) on the mains side of the filter must be screened from the rest of the DELTA circuit.

- Sized for the application.
  - Type and attenuation depend on the emission level required for application (see Section 3.3.1.4: Electrical Interference / Electromagnetic Compatibility (EMC)).
  - AEM style drives require more attenuation than diode front end (DFE) drives.
  - Current rating based on the power rating of the CDM for the main supply connections, and the power rating of auxiliary components for control supplies.

Note: Auxiliary supplies may have lower emissions limits (see Section 3.3.1.4: Electrical Interference / Electromagnetic Compatibility (EMC)).

- EMC filters may only be used if the supply neutral is connected to earth/ground at the source of the supply (also known as TN or TT network). They must not be used on networks with ungrounded neutral (also known as IT network).
- If EMC filters are to be used and there are also thyristor converters (e.g. d.c. drives) on the same supply, there will be restrictions on the allowed commutation notch depth.
- When used on AEM drives, must be rated for the voltage-to-ground.

3.8.4 Power Cabling & Terminals

Voltage Rating

The insulation between live conductors and between live conductors and ground (earth) must be suitable for the voltages applied. In some locations there will be additional voltages due to PWM switching edges. These edges may be amplified by ‘ringing’ caused by reflections or resonant circuits. Every layout will have different stray inductive/capacitive circuits so the actual value must be measured.

Cable insulation must be selected to include a margin for these repetitive voltages.

<u>Nominal (continuous) voltage ratings:</u>

AEM drives, d.c. link voltage is usually 1.6x a.c. r.m.s. voltage.

DFE drive d.c. link voltage is 1.35x a.c. r.m.s. voltage.

Current Rating Of Connections

Simple formulae are provided to allow the quick selection of power cable current rating (ampacity) between power modules. Leave a margin in the sizing based on these simple formulae or use a detailed circuit analysis for accurate size calculations:

For drives supply power to motors:

$$CDM_{Total\ Output\ Current} = \frac{P_{Motor}}{\sqrt{3} \times V_{a.c.\ rms} \times pf_{Motor} \times \eta_{Motor}}$$

$$CDM_{Total\ d.c.current} = \frac{P_{Motor}}{\sqrt{3} \times V_{d.c} \times pf_{Motor} \times \eta_{Motor} \times \ \eta_{output\ bridge} \times I_{ripple\ factor}}$$

Where:

$$P_{Motor} = Machine\ Power$$

$$pf_{Motor} = Machine\ power\ factor$$

$$\eta_{Motor} = Machine\ efficiency$$

$$V_{d.c.} = 1.6\ \times\ V_{a.c.\ rms}\ Typically\ for\ AEM\ drives$$

$$V_{d.c.} = 1.35\ \times\ V_{a.c.\ rms}\ \ for\ DFE\ drives$$

$$\eta_{output\ bridge} = Efficiency\ of\ output\ bridge$$

$$I_{ripple\ current} = additional\ factor\ for\ the\ ripple\ between\ input\ and\ output\ bridges$$

$$for\ AEM\ assume\ 1.05, and\ DFE\ 1.1$$

Also:

$$I_{a.c.current\ per\ DELTA\ transistor\ module} = \frac{1.04 \times I_{a.c.\ Total\ CDM}}{Number_{of\ Transistor\ modules}}$$ (i.e. 4% sharing allowance)

$$I_{d.c.current\ per\ DELTA\ transistor\ module} = \frac{1.04 \times I_{d.c.\ Total\ CDM}}{Number_{of\ Transistor\ modules}}$$ (i.e. 4% sharing allowance)

$$I_{d.c.current\ per\ DELTA\ rectifier\ module} = \frac{1.1 \times I_{d.c.\ Total\ CDM}}{Number_{of\ parallel\ modules}}$$ (i.e. 10% sharing allowance)

Note: The rectifier part number gives the d.c. current in Amps, i.e. MVRL2100 = 2100 A d.c. and is designed for cable connection only.

Temperature Rating

- There is limited space for power cabling to the a.c. connections on the DELTA power modules and so the connections are intended for use with high temperature cables.
- The a.c. and d.c. terminal insulation in the DELTA power module limit the maximum allowed conductor temperature of the interconnection cable. This is usually 125°C (257F), but refer to the individual component specifications for actual component values.
- Beware that non-DELTA parts may have lower temperature limits, for example cable supports, cable ties, terminals and adjacent insulation.
- To minimise inductance the cables are normally arranged in trefoil, so the cable rating / temperature rise requires the appropriate bunching factor.

Examples of high temperature 125°C (257F) or above cables are:

- Silicon rubber, e.g. or Nexans type SIWO-KUL (www.nexans.com) or
- Polyolefin, e.g. Huber and Suhner type Radox 125 (www.hubersuhner.com).

These cables are intended for inter-connection within the enclosure (not field wiring terminals).

3.8.5 Fuse Selection & Mounting

Fuses from other manufacturers may be used in place of those specified in Table 2–13 and Table 2–20, for use with the Rectifier and Transistor Modules if they give equivalent performance.

- Semiconductor fuses usually require a minimum sized busbar connection and have limits on local ambient temperature – refer to the manufacturer's data.

3.8.5.1 Fuse Micro-Switch Attachment

For fuse indication a micro-switch attachment should be fitted to each fuse. The micro-switch should be connected as shown in the circuit diagrams in Appendix B: Electrical Connection Diagrams.

3.8.6 Pre-Charge For AEM Systems

Drive systems that use the DELTA modules as both the front end AEM modules as well as the machine bridge controllers need to be pre-charged to establish the DC link operating voltage of the system. This is achieved by a pre-charge resistor and contactor in parallel with the main supply (network) contactor. The pre-charge sequence is initiated manually or automatically and is the controlled by the controller. Completion of the pre-charge event is indicated by the controller and normal operation can then continue.

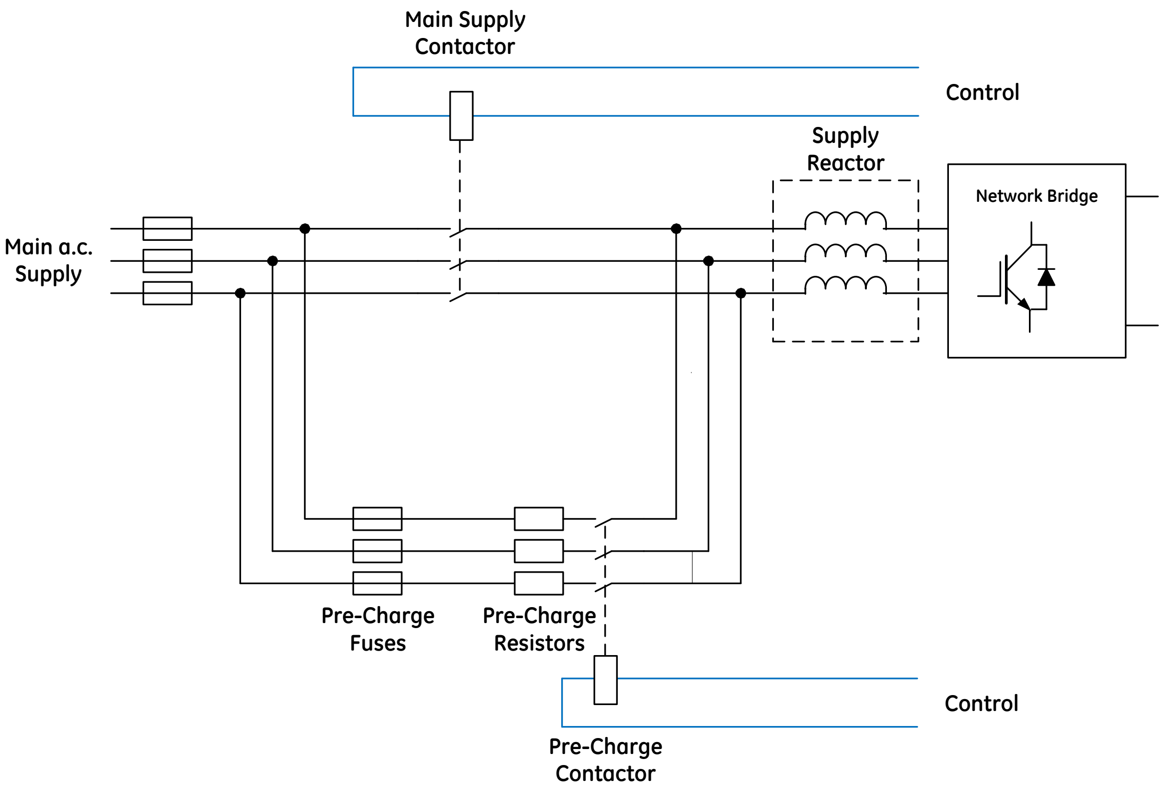


Figure 3–11. – AEM Pre-Charge Arrangement

3.8.6.1 Pre-Charge System Components

NOTE: All components are system dependant and must be specified and sourced per application.

- Pre-charge resistors (multiple components in series/parallel to provide the correct rating per phase) and mounting kits.
- Pre-charge contactor and suppression components.
- Pre-charge fuses and mounting kits.
- Power connections between supply, fuses, pre-charge resistors, pre-charge contactor and main supply reactor.
- Control electrical connections to the controller for the pre-charge contactor and main supply contactor.

3.8.6.2 Pre-Charge System Electrical Details

See Figure 3–11.

- Pre-charge current is typically 30 to 50% of drive rating. DELTA module capacitor bank details are given in the individual component specification.
- Pre-charging energy levels need to be considered due to the impulse nature of the pre-charging event.
- When sizing pre-charge components, consider all items to be pre-charged (DELTA modules, DB units, SMPS's).
- In multiple parallel network DELTA systems, pre-charging can be done through one DELTA module only.
- The control connections are as follows:
    - The "pre-charge complete" signal is generated by the controller and must be used to close the main supply contactor.
    - The "pre-charge acknowledge" signal from the main contactor back to the controller confirms correct operation and interlocks the sequence to prevent the drive from starting if not complete.
    - The pre-charge circuit must be opened at the end of the pre-charging period to prevent circulating currents.
    - Controller connections are detailed in Section 2: Specification.

3.8.7 Dynamic Braking (DB) Units

The DB Unit is used in conjunction with an externally mounted braking resistor, to dissipate kinetic energy stored in a motor and its load or to assist in limiting transient voltages. The kinetic energy is regenerated into the drive during deceleration or when the load is overhauling. The DB monitors the DC link voltage and switches the braking resistor into circuit when the voltage exceeds a pre-set level.

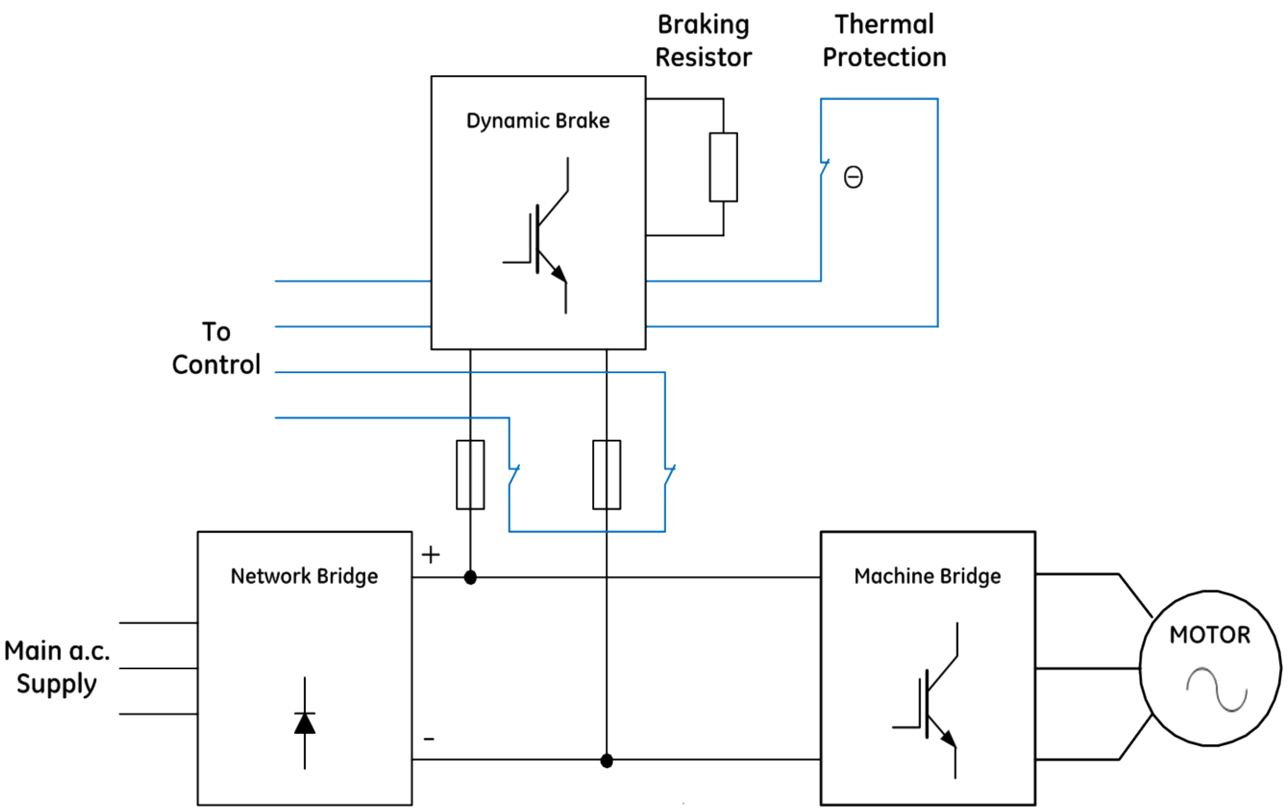


Figure 3–12. – DB System Arrangement

3.8.7.1 DB System Components

- DB Unit (e.g. GDB400).
- Braking Resistor, specified and sourced per application.
  - An integral thermal protection device must be used.

- Power connections between the CDM DC Link, DB Unit and brake resistor.
  - The unit is designed for cable connection only.
  - These cables must be rated for high voltage d.c. plus switching transients. See recommended cable types 3.8.4.

- Control connections to the controller (indicates DB status).
- d.c. link fuse protection (as defined by the application and unit specification).

3.8.7.2 DB System Location

The DB unit must be located close to the DC Link of the PDS to minimize the cable loop inductance.

The DB unit must be located within the same enclosure as the DELTA power modules.

When the DB resistor is located outside of the enclosure, the losses are dissipated to the external ambient without heating the enclosure.

The resistor's local enclosure must meet the Essential Requirements For The Enclosure as given in Section 3.5.1.1.

- For EMC compliance, the power cables must be screened, e.g. run inside metal conduit.
- Ventilation will be dependent upon resistor style and duty cycle but space must be left around the resistor for ventilation and also for segregation as this will be a hot component.
- Some duty cycles may produce high acoustic noise levels in the resistor.

3.9 COMPONENT SELECTION - MECHANICAL

3.9.1 Enclosure (/s)

3.9.1.1 Selection Of Enclosure/s

The power rating and complexity of the CDM will define how many separate enclosures (these must be bonded together as described in Section 3.3.2.1: Bonding) are required.

For a simple, low power system one enclosure may be used but care must be taken to ensure adequate separation of the LV control circuits to the hazardous voltage, high power circuits, see Section 3.5.4.

3.9.1.2 Performance

The enclosure must meet the Essential Requirements For The Enclosure as given in Section 3.5.1.1.

3.9.1.3 Enclosure Size

This will have been established from the initial mechanical layout.

3.9.1.4 Enclosure Type

Panels			
Material		Steel	To provide a conductive and magnetic screen in addition to safety segregation. This minimises electrical radiated emissions from the drive and helps protect the drive from radiating sources
Finish	External	Painted	Good environmental protection
	Internal	plated or galvanised (e.g. Zintec)	For good electrical bonding
Frame			
Material		Steel	Strength and cost
Finish		Plated or galvanised	This gives good low inductance connections for electrical bonding

Recommended

Rittal TS range:

- with galvanized frame and
- painted steel cladding
- without the rear mounting panel

or the EMV version for higher emission shielding.

3.9.1.5 Enclosure Further Requirements

Earthing / Bonding

The enclosure bonding must comply with instructions given in Section 3.5.3: Electrical Bonding.

Openings

Avoid all unnecessary apertures. All doors and covers to hazardous parts to be closed when the equipment is energized.

Cable Glanding

The cables entering the enclosure must be correctly bonded through the gland plates. See Section 3.5.3: Electrical Bonding.

3.9.2 DELTA Mounting Frames

DELTA power modules are only designed to fit into the DELTA guide plate and support frames. The assembly of these 'frames' is shown in Section 5: CDM Assembly.

These frames are designed to fit Rittal TS8 enclosures. See Section 3.9.1.4: Enclosure Type for recommended types.

- Ensure that the enclosure attachment point is sufficiently strong for the weight of components attached to the frame, for lifting and for the final installations environment (e.g. vibration).
- See Section 2: Specification for available frame sizes.
  - These are limited to a maximum of four DELTAs per frame due to the combined weight of these modules.
- It is recommended that a standard mounting frame is used regardless of the enclosure selection. If an alternative enclosure style is utilised, interface brackets will be required to allow the mounting frame to be used.
- If a standard mounting frame is not to be used, the CDM builder will need to design and manufacture their own, following the guidance below:
  - A maximum of four DELTA power modules per enclosure (due to the combined module weight over a wide span);
  - It must be possible to secure the DELTA power modules with their designed fixing points. DELTA power module dimensions are shown in Appendix A: Dimensioned Mechanical Drawings;
  - Access to all fixing points and coolant connections must not be affected;
  - Air flow through the d.c. link capacitors of DELTA transistor modules must not be impeded;
  - Clearance to the enclosure frame is required when fitting and removing modules;
  - The live right side of the module requires clearance to the enclosure's earthed metal during operation.

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4. PDS DESIGN

4.1 SUITABILITY OF MOTORS

Motors with Insulation Peak Voltage Withstand ratings of 1200 V (400 V motors), 1500 V (500 V motors) and 2250 V (690 V motors) can be operated with rectifier-fed drives without risk to the motor winding insulation, for cable lengths up to 500 m (1640 ft.). Such motors are available from reputable manufacturers, as standard motors up to 500 V and with an enhanced insulation system for voltages greater than 500 V up to 690 V. For lower quality motors a dv/dt filter will be required.

The DC link voltage in an AEM drive is higher than the DC link voltage in a diode rectifier-fed drive. For the default DC link voltage, motors with Insulation Peak Voltage Withstand ratings of 1420 V (400 V motors), 1560 V (480 V motors), 2000 V (600 V motors) and 2250 V (690 V motors) can be operated with AEM drives without risk to the motor winding insulation, for cable lengths up to 500 m (1640 ft.). Such motors are available from reputable manufacturers, as standard motors up to 415 V and with an enhanced insulation system for voltages greater than 415 V up to 690 V. For lower quality motors a dv/dt filter will be required.

NOTE: If a high control bandwidth (Vector control) is required from the MV3000 drive, dv/dt filters cannot be used. Cable the motor directly to the drive.

In applications where the rated voltage of the motor is lower than the supply voltage, the motor insulation must comply with the requirements for the supply voltage. For example a 600 V motor used on a drive fed from 690 V must comply with the insulation requirements for a 690V motor.

4.2 SUITABILITY OF MOTOR CABLES

To avoid EMC problems, the motor cable should be screened (e.g. NYCWY according to VDE 0276 or steel wire armoured) or fully enclosed in metallic trunking. The screen or metallic trunking must be continuous throughout its length and be connected directly to both the drive enclosure and the motor.

Where the current rating of the drive is beyond the capability of an overall screened or armoured 3-core cable, several 3-core cables should be connected in parallel, as shown in Figure 4–1. It is important that the phase currents are evenly distributed across the cables - it is not permissible to run the whole of each phase current down one cable. The screen or armour of each cable must be bonded to both the drive enclosure and the motor.

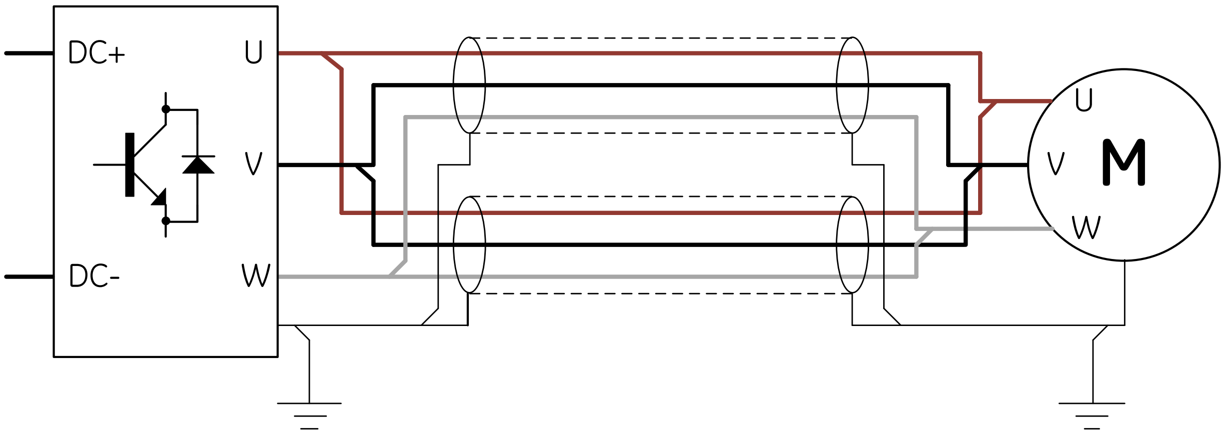

Figure 4–1. – Parallel Cables For High Current Ratings

If unscreened cables are run within metallic trunking, the following points need to be taken into account:

- The cables should be run in trefoils, each trefoil carrying one cable of each phase. This is to avoid unequal sharing of current between cables.
- Where the trunking is not large enough to take all the cables, each trunking should carry an equal number of trefoils.
- The metal trunking must be bonded to the drive enclosure and to the motor.

Outside the drive enclosure the motor cable must be segregated from other cables by at least 300 mm (12 in).

4.3 ENCODERS & ENCODER CABLES

4.3.1 Encoder Selection

Only encoders having RS422A output (A/B/Z) can be used (a marker pulse is only required when using the drive's position controller).

The MV3000 is equipped with two power supplies to power various encoders which may be used. There are two acceptable types of encoder:

- Encoders requiring +5 V supply and producing RS422A output.
  For these encoders use TB5/4 (+5 V) to supply them and in cases where long cable runs cause a supply volts drop to the encoder, parameter P13.06 will allow this supply voltage to be adjusted between +4.5 V to +6.5 V. Refer to the guided commissioning charts in the Commissioning section of the appropriate Getting Started Manual for details. If the sense wires are connected (FB+ and FB–) at the encoder end of the cable, the MV3000e will automatically adjust the encoder supply accordingly.

- Encoders requiring +24 V supply and producing RS422A output. For these encoders use TB5/6 (+24 V).

Encoders requiring +24 V supply and producing 24 V differential outputs are **NOT** compatible with the MV3000 controller, the pulse train must be RS422A.

4.3.2 Encoder Resolution

For accurate speed control, especially at low speeds, a resolution ("line count") of no less than 1024 pulses per revolution is suggested.

There are two limits on the maximum line count for the chosen encoder. The line count must comply with both of the following conditions:

- The line count must be less than or equal to 64 000 pulses per revolution (due to the drive software).

- The time delay between an edge on encoder channel A and an edge on channel B must be greater than 333 ns at the required top speed of the motor.

Due to imperfections in encoder manufacture, the edges are not equally spaced. Some encoder manufacturers quote the minimum edge separation in electrical degrees. This is 90° for a perfect encoder but can be as low as 40°.

For a given required top speed and encoder minimum edge separation, the line count must not exceed:

$$Max\_Line\_Count = \frac{500 \times 10^{3} \times (Min\_Edge\_Separation)}{Required\_Top\_Speed}$$

where :

Min_Edge_Separation is in electrical degrees

Required_Top_Speed is in rev/min.

If the encoder manufacturer quotes a “scribing error” in electrical degrees, then

Min_Edge_Separation = 90 - Scribing_Error.

If the encoder manufacturer quotes a symmetry of 180 ± x and a quadrature phase shift of 90 ± y, then

Min_Edge_Separation = 90 - x - y.

4.3.3 Encoder Mounting

For vector control mode, the mechanical coupling between motor and encoder is critical and any eccentricity in the mechanical coupling will impair performance. The best solution is a motor built with an integral shaft encoder, otherwise accurate alignment of encoder with motor shaft is very important.

An encoder may be used to perform position control. For position control in frequency control or encoderless vector control modes, an encoder or linear scale may be mounted on the controlled plant.

4.3.4 Encoder Cable Screening

The encoder wires, including the encoder power supply wires, must be contained in a screened cable and the screen must be connected to the M4 screw adjacent connector TB5 on the User I/O Termination Panel. The screen must be continuous throughout its length. In addition to the connection to the M4 screw on the User I/O Termination Panel, the screen should be connected by a 360° bond to the drive enclosure and to the encoder body.

4.4 MAINS SUPPLY CABLES

Where the mains supply cable to the drive is a screened or armoured cable, the screen must be bonded to the drive enclosure. The screen or armour should also be bonded to safety earth at the source of the supply.

Where the drive is fed from an isolating transformer, the supply cable to the drive must be screened or armoured or placed in a metallic trunking. The screen or armour or metallic trunking must be bonded to the drive enclosure and to safety earth at the supply transformer. This bonding is most effective when it is done via 360° cable glands.

4.5 SPECIAL REQUIREMENTS FOR "IT" NETWORKS

An IT network is a network in which the neutral of the supply is not earthed.

This leads to two requirements:

- protection against transients coupled from the primary of the supply transformer;
- earth fault monitoring.

4.5.1 Protection Against Transients

In IT networks, the power circuit is effectively floating. A capacitive potential divider can exist between the supply transformer primary, the motor and the system earth, with the power electronics of the DC link, being the centre node. If switching transients are capacitively coupled from the primary of the transformer, the DC link could move to a very high voltage with respect to earth. This could exceed the voltage rating of the insulation between the power circuit and the control electronics on the DELTA modules.

To prevent this, the supply transformer must contain an earthed screen.

4.5.2 Earth Fault Monitoring

Local safety regulations may dictate the form of earth fault monitoring. Where these regulations conflict with the information here, the safety regulations take precedence.

The enclosure designer should clarify whether earth fault monitoring is to be performed within the drive enclosure or whether it is being performed elsewhere in the supply system.

Proprietary insulation monitoring devices operate by using an internal voltage source to inject a signal with respect to earth and thereby to measure the insulation resistance of the system. Such insulation monitoring devices should comply with an appropriate safety standard, such as IEC 61557-8, Insulation monitoring devices for IT systems up to 1000V AC and 1500V DC. If such a device is used, this should be fitted between the supply transformer and the drive.

Alternatively, one point in the supply system may be connected to earth via a high resistance. A current sensor measuring any current to earth is then used to drive an earth fault alarm. If such a system is used, the following points should be observed:

- If the neutral of the supply system is available, the resistor should be connected between the supply neutral and earth. The voltage and power rating of the resistor must be able to withstand the full line-to-line voltage in case of an earth fault on the output to the motor.

- If the neutral of the supply system is not available, two resistors may be connected in series across the DC link. The midpoint is then connected to earth. This method is only possible when there is only one drive connected to the supply transformer. Each resistor must have a voltage and power rating sufficient to withstand the full DC link voltage in case of an earth fault on the DC link.

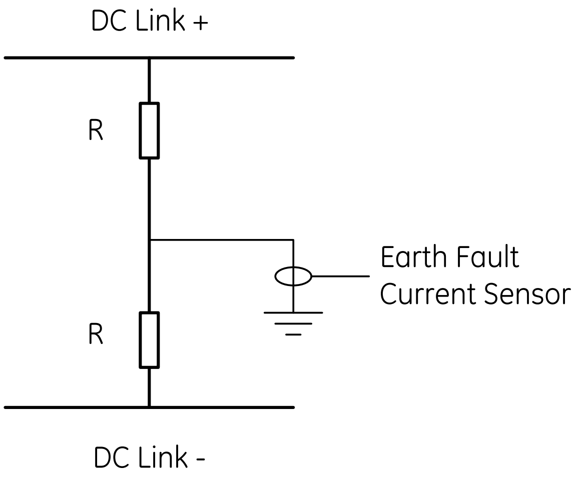

Figure 4–2. – DC Link Earth Referencing

- The resistance value should be chosen to suitably limit the current to earth during fault conditions. A value of 1 kΩ per resistor is commonly used.

- A current sensor placed around the wire between the resistor and earth will detect an earth fault anywhere in the system.
  The current sensor must be capable of detecting DC as well as AC.

4.6 PROTECTION OF CABLES ROUTED OUTSIDE THE ENCLOSURE

All cables which are routed outside the drive enclosure - e.g. plant wiring where there is a requirement for screening, segregation, terminations etc. - require protection which would normally be determined by the application but generally follow the rules already described in this section.

4.7 RECOMMENDATIONS FOR ROUTING PIPES INTO MULTI-ENCLOSURE SUITES

When routing piping into multi-enclosure suites there are additional recommendations which should be observed.

These are:

- Follow the diagonal flow principle for routing pipes to all the enclosures in a suite;
- If the diagonal flow principle cannot be used for any reason, it is important that other methods of achieving an equalisation of coolant flow through all the enclosures in the suite be considered;
- One other method of achieving an equalisation of coolant flow is to use balancing valves. However when they are used it is important to establish a method of validating that equal flow is being achieved in each enclosure in the suite.

4.8 APPLICATION SPECIFIC WARNINGS FOR HIGH TEMPERATURES ON A PIPING SYSTEM

Wherever piping equipment is in a location accessible by personnel, **WARNINGS for High Temperatures** must be placed on, or near to, all pipes and associated valves etc. carrying hot coolant.

5. CDM ASSEMBLY

WARNING

- **Connect this equipment to earth (ground) using the earth terminal provided.**
  The minimum size of the protective conductor must be in accordance with local safety regulations.
- **High Leakage Current**
  This equipment and the driven motor(s) must be earthed (grounded).
- **High Voltages**
  Replace all shrouds and close all doors before energising the equipment.
- **This equipment may be connected to more than one live circuit.**
  Disconnect all supplies before working on the equipment.
- **Wait at least 8 minutes after isolating supplies and check that the voltage between DC+ and DC- has reduced to a safe level before working on this equipment.**
- **Surfaces on the following items can reach high temperatures and remain hot for some time after power has been removed:**
  - Reactors and transformers
  - Cables
  - Coolant pipes and couplings
- **Ensure that access to rotating arts of fans is prevented.**
- **Air used to cool the product is unfiltered. Air ejected from the product may contain foreign particles. Air outlets should be arranged to deflect the air away from the eyes.**
- **Items marked with weights greater than 20kg (44 lb.) should only be moved with lifting apparatus.**

CAUTION

- **This equipment contains solid state devices which may be affected by electrostatic discharge.**
  Observe static handling precautions.
- **Ensure that all conductors connected to this product are mechanically restrained.**
- **Where nuts, bolts and washers are supplied fitted to the terminal busbar, remove these fasteners, place the user's crimp (or busbar) directly against the terminal busbar of the unit and refit the fasteners. This is to prevent large currents flowing through steel fasteners and causing overheating.**
- **When drilling a panel or door to fit components do not allow any swarf from the drilling operation to enter the enclosure – it may cause component malfunction.**

NOTES: **Some components of the DELTA range are supplied with shrouds to partially protect against accidental contact with live parts – from front access only.**
DELTA transistor modules are not supplied with shrouds for the DC terminals, or the live right side or rear surface.
For certain applications, the shrouding supplied with these products may not provide the required protection. Additional shrouding must be fitted in these instances.

5.1 INTRODUCTION

This section of the manual describes the generic assembly processes for installing DELTA components into the enclosure. Other application specific tasks (such as mounting circuit breakers, fuses, coolant manifolds or a drip tray) should be performed when appropriate, and have not been included in these assembly instructions. Reference should be made to the specific assembly instructions and drawings produced by the drive designer.

Recommended torque settings are given in Appendix C: Recommended Torque Settings.

Guidance for Electromagnetic Compatibility is in Section 3: Drive (CDM) Design.

5.1.1 Recommended Order of Assembly

It is recommended that the drive assembly order shown below is followed:

a) Fit floor mounted reactors (interbridge transformer / d.c. link reactor, line reactor);

b) Fit DELTA mounting rails and other internal metalwork;

c) Fit a.c. sharing reactors;

d) Install DELTA power modules, including coolant connections;

e) Install control components;

f) Connect high power cables or busbars;

g) Fit DELTA power module shrouds and earth bonding plates.

h) Fit SMPS modules;

i) Connect control cabling;

j) Fit overall enclosure shrouds.

NOTE: Some of the steps listed above may not be required, depending upon individual system configuration.

Before starting any assembly work, reference should be made to Sections 2, and 3 of this manual. Section 2: Specification gives details of individual components of the DELTA product range. Section 3: Drive (CDM) Design includes details about preparation and planning for assembly, and guidance for design of the cooling circuit.

NOTE: References in this section to 'left' and 'right' should be taken to mean the viewer's left and right when facing the front of a module.

5.2 RECEIPT & STORAGE OF EQUIPMENT

If the product is to be installed at a later date, or is being kept for spares:

- Retain the product within the packaging supplied – only remove when required;
- The modules are delicate and vulnerable to damage – handle and store carefully;
- Handling of the packed modules must be with appropriate pallet trucks or fork-lift trucks;
- Store in a dry area and protect from external water ingress;
- Maintain environmental levels within those defined in Table 2–3;
- If the packaging that the module is supplied in is considered inappropriate for the location where they are stored, provide additional protective packaging.

If the product is to be built immediately into equipment, before starting work the contents of the equipment supplied should be carefully unpacked and inspected. Check the complete consignment against the delivery note for any shortages or loss in transit.

Damaged or missing parts must be reported immediately to the supplier and the following details quoted:

- List of damaged or missing items with names and part numbers;
- Description of damage;
- Delivery/advice note numbers; dates; order numbers; item numbers.

If the equipment delivered to site is not to be installed immediately:

- Re-pack it in its original packaging material - if this is not possible it should be enclosed in polythene sheet to protect it from the ingress of dust;
- Store it in a clean dry atmosphere, preferably at room temperature - **DO NOT EXCEED** the storage temperature and humidity limits referred to in Table 2–3;
- Ensure that, if the equipment is stored for a long period of time, usually greater than two years, the equipment supplier is contacted for advice about reforming the d.c. link capacitors before the equipment is put into service;

- If the equipment is unpacked in a warm environment condensation may occur - if condensation is seen do not use the equipment until its temperature has stabilised to that of the working environment; See Section 7.5;
- Ensure that liquid cooled modules are stored dry (i.e. without coolant).

NOTE: Whenever possible retain and store the original packing materials for use if a product has to be returned for repair. See Section 13: Contact Details for Sales, Service & Support.

5.3 FITTING FLOOR MOUNTED REACTORS

Depending upon the system configuration, a number of wound components will require floor mounting.

Figure 5–1 shows a typical interbridge transformer. Other reactors (line, sharing and d.c. link) will be similarly constructed.

The reactor should be lifted into position, by its lifting eye bolts, with suitable lifting equipment. It should be secured through the fixing holes to the base of the enclosure.

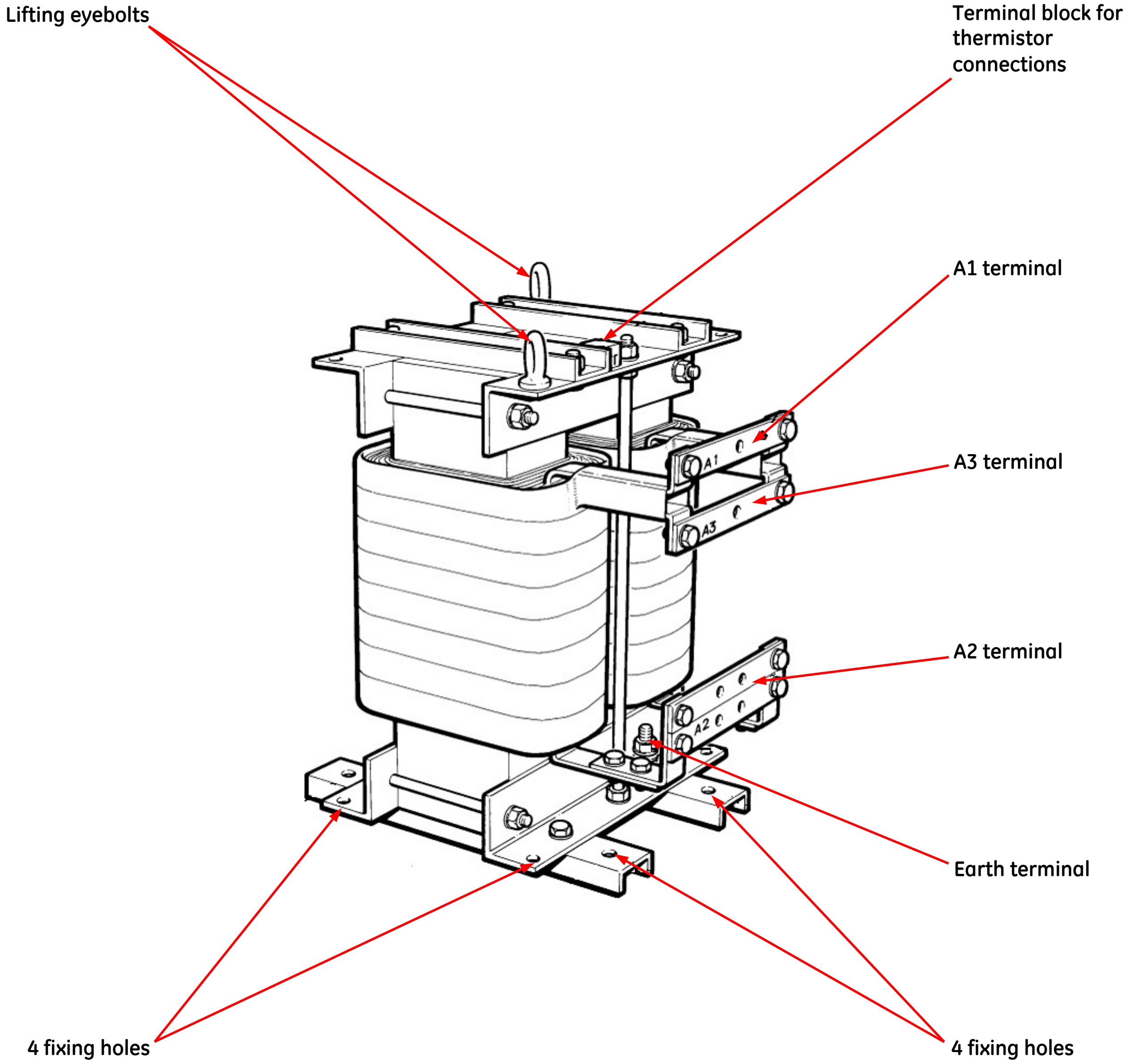

Figure 5–1. – Typical Interbridge Transformer

5.4 ASSEMBLING THE MOUNTING FRAME FOR DELTA POWER MODULES

5.4.1 General

Figure 5–2 shows the construction of the MVDL-TS-400x mounting frame in a Rittal TS8 enclosure. The diagram and following instructions can be used for all versions of the mounting frame. If an enclosure other than a Rittal TS8 is used, interface parts must be fitted to the enclosure prior to fitting the frame. Instructions for fitting interface parts should be provided by the enclosure designer.

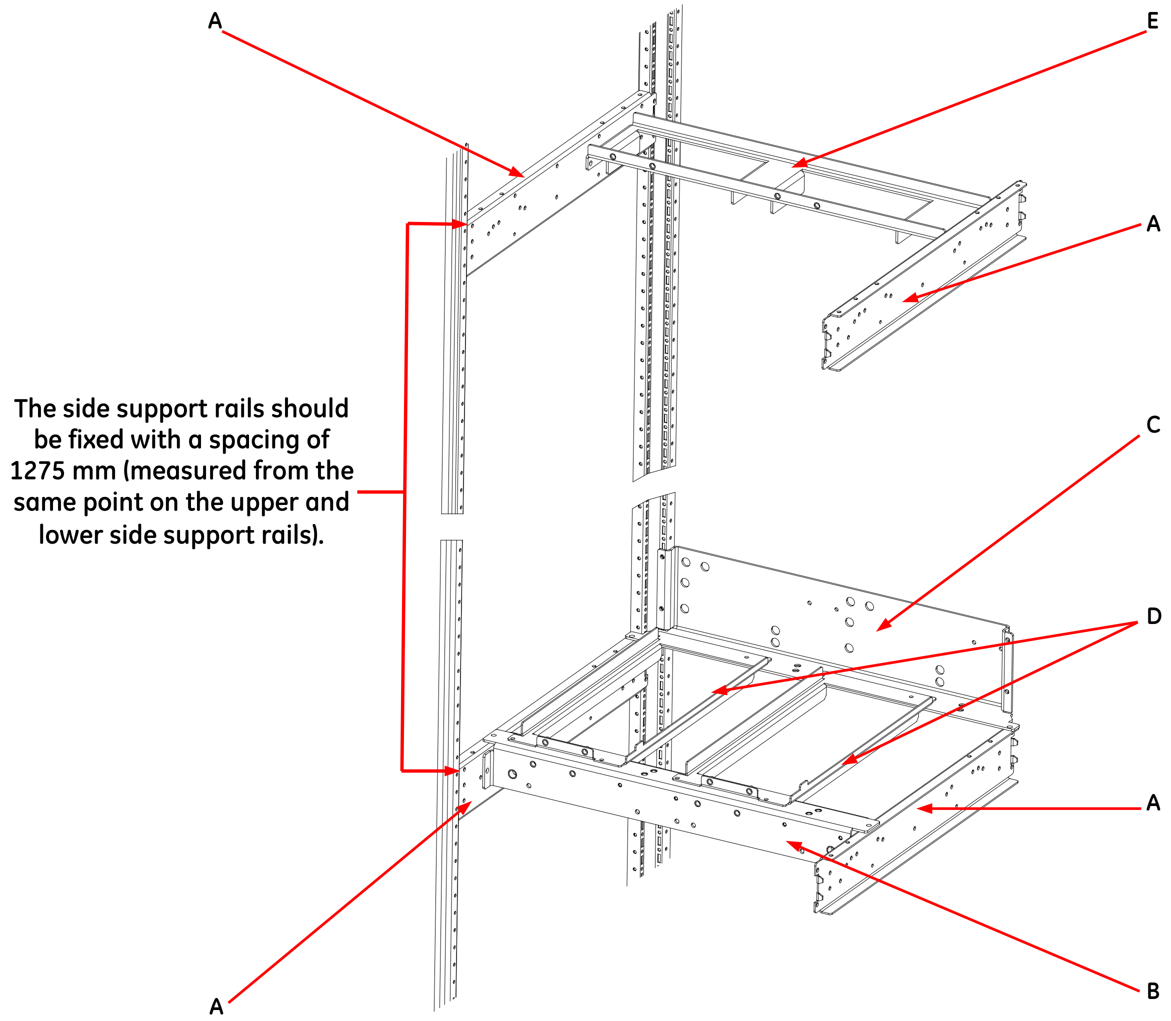

Figure 5–2. – Assembly Of MVDL-TS-400x

5.4.2 Side Support Rails

Each mounting frame kit contains four identical side support rails (either 600 mm [23.6 in] or 800 mm [31.5 in] long) that may be fitted to the left or right sides of the enclosure. The correct orientation of these supports can be identified by the holes in the upper flange - see Figure 5–2, item **A**.

NOTE: Front to back orientation is not important as all of the fixing holes have been mirrored about the centre line.

Each side support rail has two fixing holes at each end which accept the M5 hexagon head screws supplied in the kit. Use four M5 x 10 mm hexagon head earthed-nib screws to mount each of the four side supports as shown in Figure 5–2.

NOTE: For reasons of safety and correct routing of noise currents, there must be good low-inductance electrical continuity between the DELTA module mounting frame and the enclosure. For this reason, the mounting points for the side support rails must be of unpainted metal.

5.4.3 Lower Cross-members

5.4.3.1 Front

All six fixing holes for mounting the lower front cross member are pre-drilled to suit the M6 self-tapping screws supplied. The self-tapping screws may be driven in by hand using a pozi-drive screwdriver.

The exact position of the lower front cross-member (Item **B**) is shown in Figure 5–2.

Secure using six M6 x 12 mm hexagon head self-tapping screws between the two lower side-supports. Ensure that the threaded inserts are in the top and front faces.

5.4.3.2 Rear

Fit the lower rear cross-member (Item **C** in Figure 5–2). The cross-member is secured to the side rails with two M6 x 12 mm hexagon head self-tapping screws, and to the enclosure pillars with four M5 x 10 mm hexagon head screws.

5.4.4 Guide Plates

Two guide plates are shown in Figure 5–2 (Item **D**). A guide plate is required for each DELTA power module. Guide plates are secured to the lower cross-members with four M5 x 10 mm self-tapping screws.

5.4.5 Upper Cross-Member

Fit the upper cross-member (Item **E** in Figure 5–2). The cross-member is secured to the upper side rails with four M6 x 12 mm hexagon head self-tapping screws.

5.5 FITTING A.C. SHARING REACTORS

The a.c. sharing reactors are usually mounted above or below the DELTA power modules. The mounting frames for liquid cooled DELTA modules do not provide features for mounting the sharing reactors. Such mounting features have to be provided by the CDM designer. Refer to Section 2: Specification for technical details, including weight, and Appendix A: Dimensioned Mechanical Drawings for dimensional details.

5.6 FITTING DELTA POWER MODULES

CAUTION

- **The modules are delicate and vulnerable to damage – handle carefully.
Only lift or move them by use of the lifting point.
Lay them down on the plain left-hand face when not fitted in a frame.
Do not leave modules unsupported in the upright position.**

5.6.1 Guidance for Handling

The DELTA power modules require particular care and attention during handling to ensure that personnel are not injured, or the modules damaged. The lifting arrangement is the same for each type of module.

They should only be lifted with a crane rated for the module weights, as detailed in Section 2: Specification, and suitable for enclosure access. The modules should be handled without any pipes, cables or busbars attached. All preparatory work should be done in the enclosure prior to any module being lifted.

5.6.2 Transistor Module Identity

DELTA transistor modules in the drive are numbered from 1 to 6. This identity is determined by the connections that are made to the controller, see Appendix B: Electrical Connection Diagrams. It is recommended that DELTA transistor module number 1 is located either at the left-hand or right-hand end of the group of DELTA transistor modules in the cabinet. The remaining DELTA transistor modules should be connected sequentially.

5.6.3 DELTA Rectifier Module Position

If a DELTA rectifier module is fitted, it is recommended that it be located in the right hand side of the cabinet to give the best access for cabling.

5.6.4 DELTA Power Module Lifting & Fitting Procedure

a) Attach the lifting shackle to the module lifting hole (20 mm [3/4 in] diameter) at the top of the module - see Section 2 Figure 2–7 and Figure 2–9.

b) Lift the module to the appropriate height and move it into position to insert into the frame.
See Figure 5–3 and Figure 5–4.

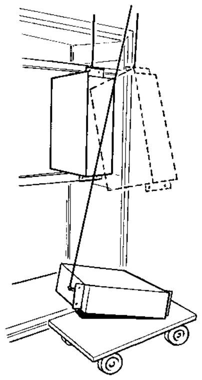

Figure 5–3. – Lifting A DELTA Power Module

c) Tilt the module as it is moved into its slot so that it clears the withdrawal 'stop screw' which is built into the bottom right-hand guide.
See Section 2 Figure 2–7, Figure 2–9 and Figure 5–4.

d) When the rear of the module is located between the guide rails, it can be slowly lowered and pushed into the frame until the stop screw is reached.

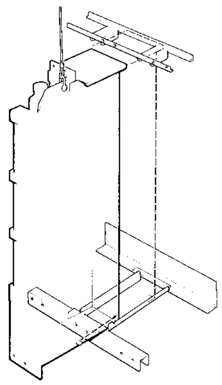

Figure 5–4. – Positioning A Power Module Between The Guide Rails

e) Remove the lifting shackle and push the module firmly into position, lifting over the stop screw. The upper and lower flanges of the power module will be in contact with the front face of the cross-members. The four fixing holes will align with the holes in the cross-members.

f) Use four M6 x 12 mm pozi-head screws with plain and spring washers, supplied as part of the mounting frame kit, to secure the power module in place, see Figure 5–5.

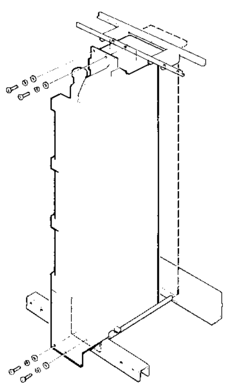

Figure 5–5. – Moving & Securing A Power Module In Position Beyond The Stop Screw

5.6.5 Cooling System Connections

Cooling system connections between the enclosure manifold and the DELTA power modules should be made with flexible hose, secured with suitable hose clamps.

All flexible hoses and couplings should have their protective end caps removed prior to the connection being made - the end caps should be stored safely for use whenever a power module is removed or refitted

The positioning and method of retaining the flexible hoses should not restrict access to other components in the CDM.

The bending radii limit of all hoses must be respected.

5.7 MV3000E CONTROLLER

Mount the controller with four M5 self-tapping screws to the fixing dimensions in Appendix A: Dimensioned Mechanical Drawings and torque setting as detailed in Appendix C: Recommended Torque Settings. The orientation of the controller will depend upon the application.

5.8 USER I/O TERMINATION PANEL

Mount the I/O panel with two M5 self-tapping screws to the fixing dimensions in Appendix A: Dimensioned Mechanical Drawings, and torque setting as detailed in Appendix C: Recommended Torque Settings. The orientation of the I/O panel will depend upon the application; however it must be mounted adjacent to the controller due to the length of the supplied ribbon cable.

5.9 MAINS VOLTAGE MONITOR

Mount the MVM unit with four M5 self-tapping screws to the fixing dimensions in Appendix A: Dimensioned Mechanical Drawings, and torque setting as detailed in Appendix C: Recommended Torque Settings. The orientation of the MVM unit will depend upon the application; however it must be mounted adjacent to the controller due to the length of the supplied ribbon cable.

5.10 DRIVE DATA MANAGER™ (KEYPAD)

The Keypad can be mounted in a separate location from the controller within the enclosure. It should be retained by the six M4 x 8 mm fixing screws and washers supplied.

Refer to the Instruction Sheets T1915 (Drive Data Manager™ Installation) and T1916 (Mounting Kit Instructions) for details of the keypad and mounting.

5.11 DELTA RECTIFIER MODULE POWER CONNECTIONS

5.11.1 General

- The a.c. and d.c. terminals on the modules are not suitable to support the weight of any attached cables. These cables must have additional mechanical support;
- The bending radii limits of all cables must be respected.

5.11.2 A.C. Terminals

All a.c. power terminals are located on the front of the module (see Figure 2–7), and are marked R1, S1, T1 and R2, S2, T2.

Each terminal provides two M10 studs which are suitable for ring-crimp connection. Refer to Appendix C: Recommended Torque Settings for torque settings.

5.11.3 D.C. Terminals

The d.c. terminals are located on the lower right hand side of the module (see Figure 2–7).

Each d.c. positive connection, marked RECT1 + and RECT2 +, have two M10 studs.
The d.c. negative connection, marked RECT1/2 -, has four M10 studs.

All terminals are suitable for ring-crimp connection. Refer to Appendix C: Recommended Torque Settings for torque settings.

5.11.4 Earth Connection

The earth terminal, see Figure 2–7, is a single M10 threaded insert, located on the lower front of the module and identified as shown in Figure 5–6.

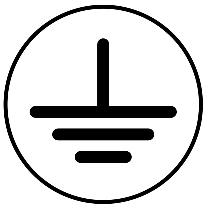

Figure 5–6. - Protective Earth (ground) Symbol

5.11.5 Fitting Shrouds

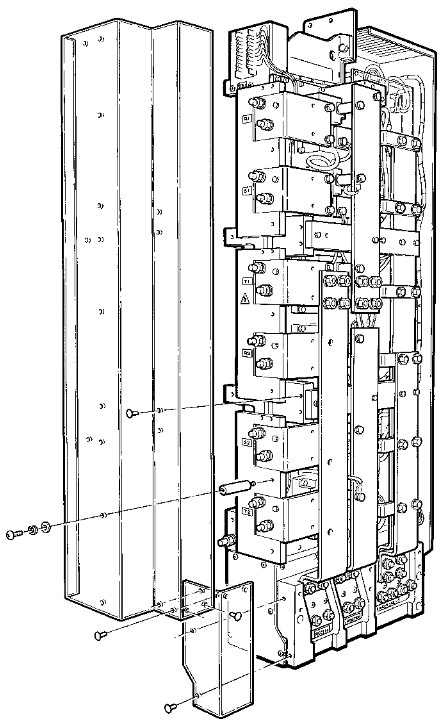

Figure 5–7. – Shroud Assembly

There are two terminal shrouds used on the DELTA rectifier module as shown in Figure 5–7. One shroud covers the a.c. phase terminals R1, S1 T1 and R2, S2, T2. It is secured with M5 pozi-head screws into spacers which in turn screw into the front of the module.

The second shroud covers the RECT1+ terminal (located at the lower front right corner of the module) and is secured to the module with 'snap' type rivets.

NOTE: **These shrouds are supplied loose and must be fitted after the connections have been made.**

5.12 DELTA TRANSISTOR MODULE POWER CONNECTIONS

5.12.1 General

- The a.c. and d.c. terminals on the modules are not suitable to support the weight of any attached cables. These cables must have additional mechanical support;
- The bending radii limits of all cables must be respected.

5.12.2 A.C. Connections

The a.c. power terminals are located on the front of the module (see Figure 2–7), and are marked A, B and C. To gain access, the two shrouds must be removed. The A and B phase shroud is secured with M5 'nyloc' nuts. The C phase shroud is secured with 'snap' type rivets.

Each terminal provides two (for MVDL800 modules) or three (for MVDL1000 modules) M10 studs which are suitable for ring-crimp connection. Refer to Appendix C: Recommended Torque Settings for torque settings.

5.12.3 D.C. Connections

The d.c. link terminals are located in the lower front of the module (see Figure 2–7), and are marked DC+ and DC-.

Each terminal provides two (for MVDL800 modules) or three (for MVDL1000 modules) M10 studs which are suitable for ring-crimp connection. Refer to Appendix C: Recommended Torque Settings for torque settings.

To avoid stressing the d.c. terminals when connecting these together with a single busbar, ensure that DELTA transistor modules are fully inserted and are correctly aligned.

5.12.4 Earth Connection

The earth terminal, see Figure 2–9, is a single M10 threaded insert, located on the lower front of the module and identified as shown in Figure 5–8.

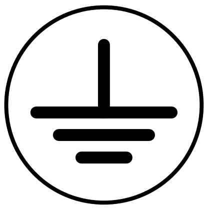

Figure 5–8. - Protective Earth (ground) symbol

5.12.5 Fitting Shrouds

The shroud for the A and B phase terminals is located on M5 studs and secured with 'Nyloc' nuts.

The shroud for the C phase power connection is secured with 'snap' type rivets as shown in Figure 2–9. Shrouds for the D.C. terminals must be provided by the enclosure manufacturer.

All shrouds must be fitted after the connections have been made.

5.13 FITTING EARTH BONDING PLATES

Each DELTA transistor module is supplied with a bonding plate. These plates must be fitted between adjacent DELTA transistor modules as shown in Figure 5–9. The bonding plates are secured to the A and B phase shroud with six M5 'Nyloc' nuts which are supplied with the DELTA transistor modules.

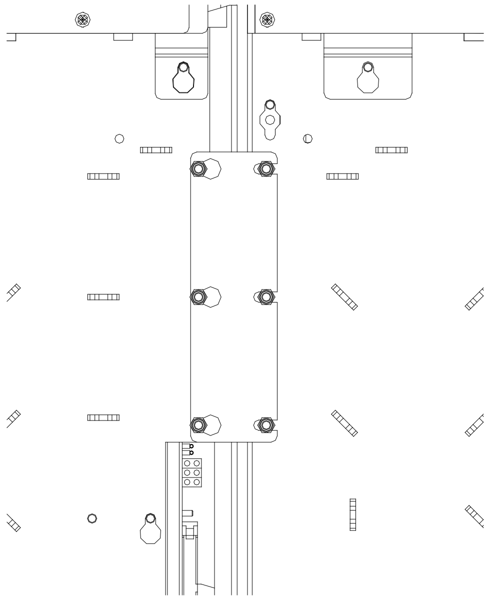

Figure 5–9. – DELTA transistor bonding plate fitment

A similar bonding plate system should be incorporated to link the DELTA transistor modules to the controller and enclosure frame. Since controller location may vary from installation to installation, this is the responsibility of the drive designer.

Where multiple sections of plate are used, they must be in direct metal-to-metal contact with each other, without intervening paint or wires.

5.14 CONNECTIONS TO THE A.C. SHARING REACTORS

Dependent upon the variant, connections to the a.c. terminals should be made with M10 or M12 bolts. The a.c terminals are identified as:

- U1/U2; V1/V2; W1/W2; or
- A1 A2; B1/B2; C1/C2

Dependent upon the variant the earth terminal or terminals are M10 or M12 studs. Refer to Appendix A: Dimensioned Mechanical Drawings and Appendix C: Recommended Torque Settings for further details.

For a given phase, the cable lengths from the DELTA transistor module to sharing reactor must be the same on each DELTA module.

5.15 CONNECTIONS TO FLOOR MOUNTED REACTORS

Connections to floor mounted reactors will vary dependent upon the application. Refer to the circuit diagrams provided by the drive designer, and Appendix C: Recommended Torque Settings.

The chassis of the reactor must be connected to earth

5.16 SWITCH MODE POWER SUPPLY

Each DELTA transistor module requires an SMPS module to be fitted.

NOTE: If an MVC3003-4020 or MVC3003-4030 SMPS unit is to be used, it MUST be fitted to DELTA 1. See Section 2: Specification for DELTA identity information. See T1973 for Over-voltage Trip link settings.

The SMPS unit is mounted on to three M5 studs as shown in Figure 5–10.

a) Loosen the 'Nyloc' nuts and locate the SMPS on to the studs.

b) Retighten the three M5 nuts.

NOTE: For MVC3003-4025 & MVC3003-4030, which have a flat mounting bracket, if bump stops are fitted to the transistor module back plate, these will need to be removed before fitting the SMPS unit.

The cable supplied as part of the SMPS, should be connected to TB1 on the DELTA transistor module. A 40 way ribbon cable, supplied as part of the DELTA transistor module, should be connected to PL22 (or PL2 on MVC3003-4020 and MVC3003-4030) on the SMPS.

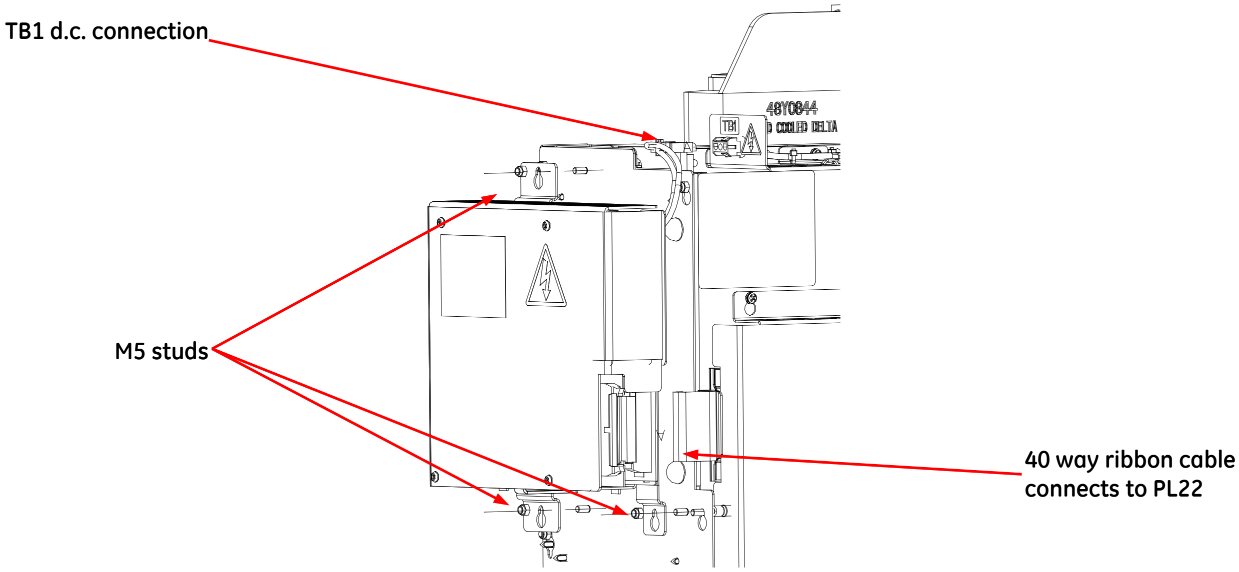

Figure 5–10. – Fitting The SMPS

5.17 CONTROL CONNECTIONS - RIBBON CABLES

5.17.1 Fitting Screened Ribbon Cables

The ribbon cables used in the DELTA drive are screened to prevent the electrical noise generated by the drive from interfering with control signals. It is therefore very important that these cables are fitted correctly.

The screen is exposed at each end of the ribbon cable, and this exposed area should be located in the two-piece clamps provided with the products (or available separately), and the clamps tightened.

NOTE: The correct clamp should be chosen for securing the 40way DELTA ribbon cables at the controller. Clamp sets are available to secure from one to six ribbon cables. Only ribbon cables supplied by GE Power Conversion must be used. This is to ensure that the screen is of a suitable construction and performance, enabling the clamps described in Section 2.13.2: Ribbon Cable Clamps to correctly secure the ribbon cables.

Ribbon cables should be routed flat to earthed steelwork where possible and secured at regular intervals with cable ties or similar mechanical restraints. Typical ribbon cable installations are shown in Figure 5–11 to Figure 5–14.

NOTE: Ribbon cables must not be run in front of the ribbon header of another DELTA module.

Figure 5–11. – Ribbon Cable Clamp At The DELTA Transistor Module

Figure 5–12. – Ribbon Cable Clamp At The DELTA Controller

Figure 5–13. – Typical Ribbon Cable Routing Across The DELTA Transistor Modules

Figure 5–14. – Typical Ribbon Cable Routing Between Enclosures

5.17.2 DELTA Transistor Modules

DELTA transistor modules are connected to the controller with a 40 way screened ribbon cable. PL1 of DELTA 1 should always be connected to PL2 on the controller. PL1 on the remaining DELTA transistor modules should be connected in ascending order as shown in Appendix B: Electrical Connection Diagrams.

5.17.3 User I/O Termination Panel

The user I/O termination panel is connected to PL20 of the MV3000e controller with a 50 way screened ribbon cable. The ribbon cable is supplied with the Termination Panel.

5.17.4 Mains Voltage Monitor

The MVM unit is connected to PL10 of the MV3000e controller with a 16 way screened ribbon cable. The ribbon cable is supplied with the MVM unit.

5.18 CONTROL CONNECTIONS – DISCRETE WIRING

5.18.1 General

- The terminals on the modules are not suitable to support the weight of any attached cables. These cables must have additional mechanical support;
- The bending radii limits of all cables must be respected.
- Refer to Section 3: Drive (CDM) Design for cable routing guidance.

5.18.2 Connecting Cable Screens To Earth

All cable screens must be connected to earthed metalwork. These connections must be via an uninsulated metal 'p-clip'.

5.18.3 Rectifier

The rectifier control terminals are located on the front face of the module and identified as TB1. The connections shown in Appendix B: Electrical Connection Diagrams should be made to PL12 on the controller. Maximum wire sizes are given in Section 2: Specification.

5.18.4 Controller

The Drive Data Manager ™ cable plugs directly into SK5. The cable connector screw locks should be tightened to secure the cable. Details for connecting the cable at the keypad are provided in T1916.

CAN communications are made available on TB7. For connectivity see Section 2: Specification and circuit diagrams provided by the CDM designer. For wire size information, see Section 2: Specification.

NOTE: **Optional communication modules such as a 2nd CAN port or Ethernet are available. Installation and operation instructions are provided with those modules and are therefore not covered by this manual.**

5.18.5 User I/O Panel

User connections to the I/O termination panel are dependent upon the particular application. Section 2: Specification provides details of the connector functions and wiring sizes. Reference should be made to the assembly documentation and circuit diagrams provided by the CDM designer.

All wiring must be mechanically supported.

NOTE: **TB4 and TB6 are both 9 way terminal blocks of the same connector pitch and so it is important that wiring for these blocks is connected to the correct terminal block. TB1 is also a 9 way terminal block but this has a different connector pitch to TB4 and TB6.**

5.18.6 MVM

Connections to the incoming a.c. supply are made to PL28, as shown in Figure 5–15. For further installation instructions, see T1930.

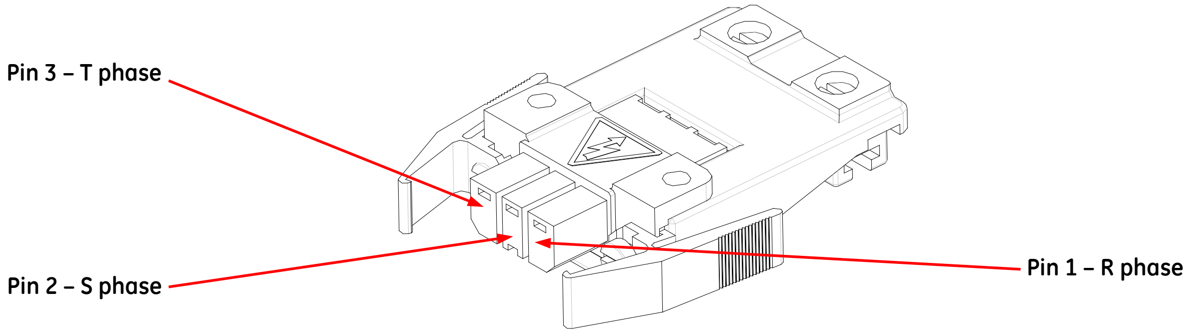

Figure 5–15. - PL28 a.c. connections

5.19 FITTING ENCLOSURE SHROUDS

Overall enclosure shrouds should be fitted after all assembly and wiring have been completed. These will be application specific, and must be fitted in accordance with the CDM designer's instructions.

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6. CDM COMMISSIONING GUIDANCE

WARNING

- **Do not use mobile phones or radio communication equipment within 2 metres (6 feet) of the enclosure.**
- **Connect this equipment to earth (ground) using the earth terminal provided.**
  The minimum size of the protective conductor must be in accordance with local safety regulations.
- **High Leakage Current**
  This equipment and the driven motor(s) must be earthed (grounded).
- **This equipment may be connected to more than one live circuit.**
  Disconnect all supplies before working on the equipment.
- **High Voltages**
  Replace all shrouds and close all doors before energising the equipment.
- **Wait at least 8 minutes after isolating supplies and check that the voltage between DC+ and DC- has reduced to a safe level before working on this equipment.**
- **Surfaces on the following items can reach high temperatures and remain hot for some time after power has been removed:**
  - reactors & transformers
  - cables
  - coolant pipes and couplings
- **The combined audible noise emitted by fans in an installation can be greater than 70 dB(A), dependent on the air flow path.**
  Measure the audible noise in the installation.
  When the audible noise level exceeds 70 dB(A), appropriate warning notices should be displayed.

CAUTION

- **This equipment contains solid state devices which may be affected by electrostatic discharge.**
  Observe static handling precautions.
- **Ensure that all conductors connected to this product are mechanically restrained.**
- **Where nuts, bolts and washers are supplied fitted to the terminal busbar, remove these fasteners, place the user's crimp (or busbar) directly against the terminal busbar of the unit and refit the fasteners. This is to prevent large currents flowing through steel fasteners and causing overheating.**

6.1 INTRODUCTION

The detailed commissioning procedure for a drive based on liquid cooled DELTA modules will vary for each application; such details are not included in this manual. However, reference should be made to the MV3000e Getting Started Manual T1676 (or T2002 for AEM drives) which does include general guidance for commissioning. The procedures in this manual are split into two discrete sections. This section describes the commissioning procedures for the Complete Drive Module that should be undertaken by the enclosure manufacturer.

Section 7: PDS Commissioning Guidance describes the procedures for integrating the CDM into the end user's application.

Each section gives guidance on visual inspection, coolant system pressure tests and electrical safety tests.

When the equipment has been designed and built for a particular application by an enclosure manufacturer then it is important, for the safety of personnel and equipment, that all commissioning instructions prepared by the manufacturer include the following details:

- Warnings and cautions as necessary;
- Visual / mechanical checks;
- Electrical safety checks;
- Cooling system checks - internal and external to the enclosure;
- Functional tests.

6.2 VISUAL INSPECTION

The pre-commissioning visual checks now outlined apply to DELTA equipment housed in an enclosure and also, where appropriate, to DELTA modules supplied loose. The checks outlined include those for the cooling system within the enclosure. Check that:

- If multiple modules are required, ensure they are of the same type and voltage grade;
- Check that the Timed Overvoltage links (if fitted) on the DELTA 1 SMPS module are correct;
- The modules have been correctly assembled in the appropriate mounting frames in accordance with the instructions in Section 5; CDM Assembly.
- There is adequate clearance around the control components within the enclosure for ventilation;
- There is adequate clearance around the enclosure for ventilation, and that the ventilation louvres are not covered or blocked;
- All piping from a liquid cooled module to the enclosure mounted manifold is installed in accordance with the guidance in Section 3: Drive (CDM) Design and Section 5; CDM Assembly;

NOTE: Check that the material compatibility rules have been followed in the cooling system.

6.3 ELECTRICAL SAFETY TESTS

6.3.1 Introduction

When the visual inspection has been completed it is recommended that earth continuity and insulation tests be carried out, prior to the equipment being commissioned. This is to check that cables have not been damaged during installation and that the equipment is correctly bonded for earthing purposes. These tests will vary in detail for each application, and therefore only general guidance is included.

6.3.2 Earth Continuity

All external metal parts (such as doors, side and rear panels, roof plate) and internal panels, support rails and other metal hardware must be tested to ensure that they are effectively connected to the main incoming enclosure earth connection. The test is performed by injecting a current of at least 25A between the earth connection and each panel in turn.

The measured resistance **MUST** be less than 0.1Ω.

6.3.3 Voltage Groups For Insulation Tests

For the insulation tests, drive systems can be considered to consist of several different voltage groups, see the typical system example in Figure 6–1 and Table 6–1.

6.3.4 Insulation Resistance Test

The insulation resistance should be measured and recorded before and after the High Voltage Insulation test. The connections of each voltage group will be bonded together, and then connected to earth. Each group is tested individually by removing its bond to earth (the other circuits remain connected to earth). After each group is tested, the earth bond must be reconnected.

NOTE: Lightning surge arrestors should be disconnected for the tests.

Test voltage = 1000 V
The resistance value is expected to be $>500M\Omega$.

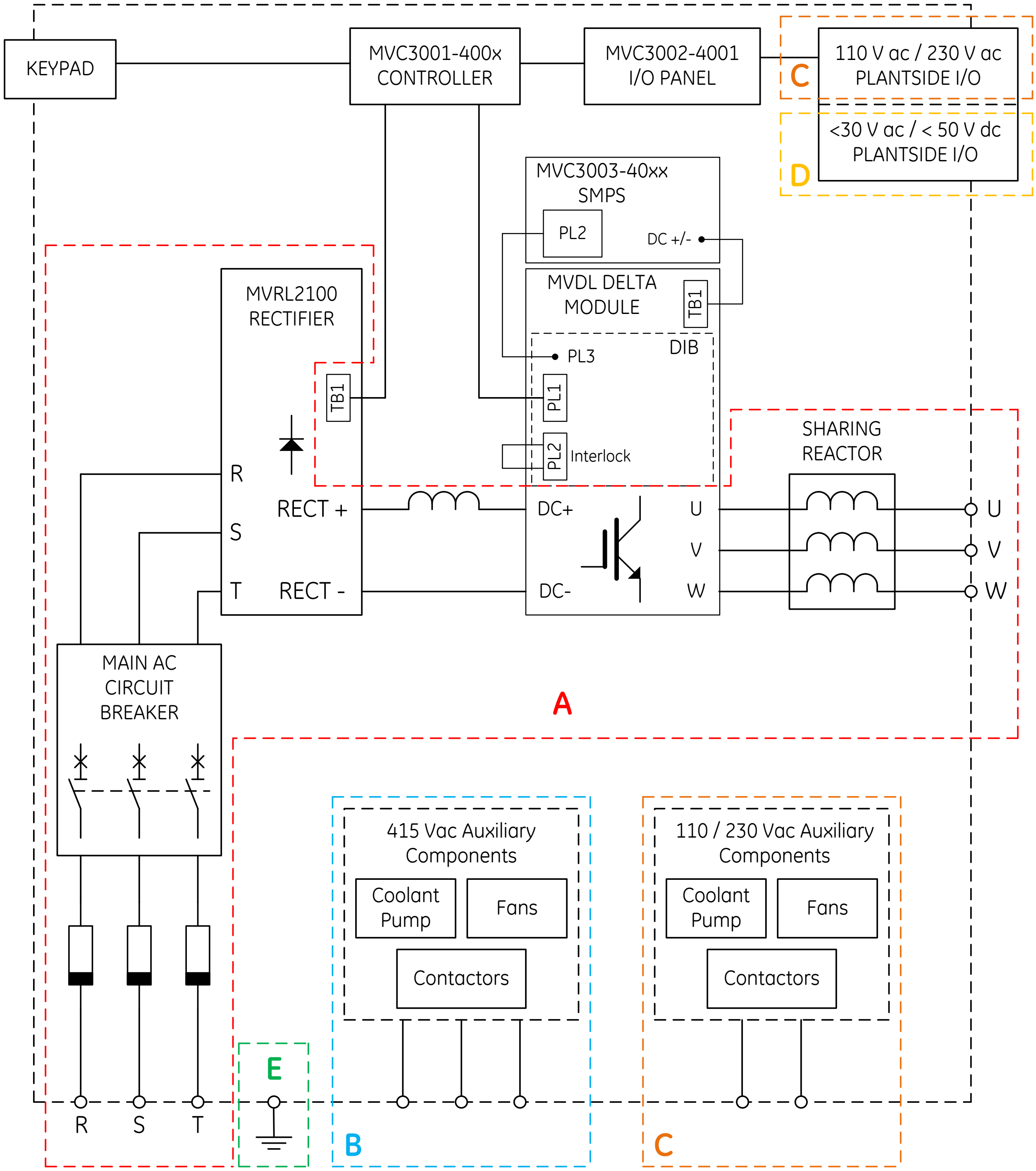

Figure 6–1. – Voltage Grouping For Insulation Tests

Group	Nominal Circuit Operating Voltage	Detail
A	690 V a.c.	The main power circuit – includes main fuses, main isolator, DELTA module power connections, input, d.c. link and output reactors
B	400 – 480 V a.c.	Auxiliary circuits. These may include coolant circuit pumps, fans and contactors
C	110 / 230 V a.c.	Auxiliary circuits. These may include coolant circuit pumps, fans, contactors and plant I/O
D	<30 V a.c. / < 50 V d.c.	Extra Low Voltage (ELV), such as plant I/O circuits
E	Earth	Main enclosure earth point, enclosure structure, other earthed metalwork etc.

Table 6–1. – Voltage Grouping For Insulation Tests

6.3.5 High Voltage Insulation Test

The connections of each voltage group will be bonded together, and then connected to earth. Each group is tested individually – see Table 6–2 - by removing its bond to earth (the other circuits remain connected to earth).After each group is tested, the earth bond must be reconnected.

NOTE 1: Use test voltages and periods that are required by the standards the drive system must adhere to. The test voltages and periods quoted in Table 6–2 are MAXIMUM values and must not be exceeded.

NOTE 2: All high voltage insulation tests must be conducted using a test set that indicates the current, and whose output is limited with a trip circuit to reduce the consequential damage should an insulation failure occur.

NOTE 3: Lightning surge arrestors should be disconnected for the tests.

Test Group	Procedure	Maximum Test Voltage	Maximum Duration
A **≥690 V a.c.**	• Connect groups B, C and D to group E (earth); • Close or short circuit the main breaker; • Remove control connections to the DELTA transistor and rectifier modules; • Disconnect the SMPS units; • Disconnect the MVM module (if fitted); • Disconnect the earth connection to the DVDT filter (if fitted); • Connect the insulation test set output to group A; • Connect the insulation test set output to group E;	3.1 kV dc	60 s
B **400 – 480 V a.c.**	• Connect groups A, C and D to group E (earth); • Close or short circuit any breakers necessary to make these connections; • Connect the insulation test set output to group B; • Connect the insulation test set output to group E;	2.8 kV dc	60 s
C **110 / 230 V a.c.**	• Connect groups A, B and D to group E (earth); • Close or short circuit any breakers necessary to make these connections; • Remove any transformer Centre Tap Earth connections; • Connect the insulation test set output to group C; • Connect the insulation test set output to group E;	2.5 kV dc	60 s
D **<30 V a.c. / < 50 V d.c.**	• Connect groups A, B and C to group E (earth) • Connect the insulation test set output to group D; • Connect the insulation test set output to group E;	140 V d.c.	60 s

Table 6–2. – Insulation Test Guidance

6.4 COOLING SYSTEM TESTS

6.4.1 Initial Checks Prior To Filling The Cooling System

To ensure cooling efficiency for the power devices in the DELTA modules carry out the following checks before loading the coolant into the cooling system.

Check that:

- All cooling system connections are correctly made and the external cooling system has been appropriately designed (see Section 3: Drive (CDM) Design, and Section 5: CDM Assembly);
- The FLOW and RETURN pipes are in the correct positions at the modules;
- All flexible pipes are securely fastened within the enclosure;
- All materials used in the external cooling system are compatible with the materials in the module cooling path (see Section 3: Drive (CDM) Design);
- The coolant to be used is of a recommended type or a compatible alternative;
- The coolant mixture and concentration meet required temperature range.

6.4.2 Pressure Test

A pressure test must be performed to ensure that the cooling system is free from leaks:

Pressurise the liquid cooling system with air to 4 bar pressure.

- Check there is no noticeable change in pressure ("On Gauge") over a four hour period using a calibrated pressure gauge.
- **NOTE:** Maximum change is 0.1bar;
- Test all coolant connections at the manifold, DELTA modules and heat-plate /exchanger connections after a four hours for leaks;
- Record the date, time and pressure readings.

NOTE: **If a drive fails the pressure test, the fault MUST be rectified and the unit retested for another four hour period.**

6.5 FILLING THE COOLING SYSTEM

CAUTION
• **Do not fill the cooling system at low temperature.**

The procedure for filling the cooling system will depend on the specific application. The requirements will vary for each application but will normally include the following stages:

- Ensure that the drain and bleed valves are closed;
- Fill the cooling system either via the header tank or through a suitable filling location if the cooling system is sealed;
- Vent any residual air by opening each bleed valve in turn. Take care during this process that coolant leaking from the bleed valves does not spill onto the equipment;
- After venting any air from the system, top up with additional coolant if necessary;
- Perform a visual check for leaks.

6.6 FUNCTIONAL TESTS

The following information is generic explanation of commissioning for many variants of the MV3000e DELTA drives. The commissioning procedure should be in accordance with instructions in the MV3000e Getting Started Manual T1676 (or T2002 for AEM drives) and, when applicable, additional instructions prepared by the enclosure manufacturer.

6.6.1 Software

Drive software will already have been installed in the controller at its manufacture. This will need to be checked to ensure it is the latest version. If not, the latest version must be installed.

The drive controller will need to be loaded with the relevant application code. A PC with Drive Coach™ software will be required for this.

For information on how to perform software updates / installation, see T1676 (or T2002), T1679 and the specific application notes prepared for the drive.

6.6.2 Fans

Ensure that all fans operate as they should, this could include:

- Enclosure fans;
- Capacitor fans;
- Heat exchanger fans;
- Controller fan.

6.6.3 Communication Links

Ensure that the communication links to the drive are operational. These should be initialised by following the guidance provided by the relevant Instruction Sheet. The communication links could include CANopen, Ethernet and Serial Links.

6.6.4 Plant I/O

Check all feedback signals into the I/O circuits are functioning. This could include cooling system feedbacks, and “User Daisy Chain” healthy signals. The operation of these circuits will be detailed in the circuit diagrams and the Test Specification produced by the enclosure manufacturer.

6.6.5 Power Circuit

The method of testing the power circuit will depend upon the facilities available at the enclosure manufacturer, and the requirements of the final customer. Ideally, the drive should be run at its rated current and voltage for an extended period to prove that all system functions are operating correctly.

7. PDS COMMISSIONING GUIDANCE

WARNING

- **Do not use mobile phones or radio communication equipment within 2 metres (6 feet) of the enclosure.**
- **Connect this equipment to earth (ground) using the earth terminal provided.
  The minimum size of the protective conductor must be in accordance with local safety regulations.**
- **High Leakage Current
  This equipment and the driven motor(s) must be earthed (grounded).**
- **This equipment may be connected to more than one live circuit.
  Disconnect all supplies before working on the equipment.**
- **High Voltages
  Replace all shrouds and close all doors before energising the equipment.**
- **Wait at least 8 minutes after isolating supplies and check that the voltage between DC+ and DC- has reduced to a safe level before working on this equipment.**
- **Surfaces on the following items can reach high temperatures and remain hot for some time after power has been removed:
  - reactors & transformers
  - cables
  - coolant pipes and couplings**
- **The combined audible noise emitted by fans in an installation can be greater than 70 dB(A), dependent on the air flow path.
  Measure the audible noise in the installation.
  When the audible noise level exceeds 70 dB(A), appropriate warning notices should be displayed.**

CAUTION

- **This equipment contains solid state devices which may be affected by electrostatic discharge.
  Observe static handling precautions.**
- **Ensure that all conductors connected to this product are mechanically restrained.**
- **Where nuts, bolts and washers are supplied fitted to the terminal busbar, remove these fasteners, place the user's crimp (or busbar) directly against the terminal busbar of the unit and refit the fasteners. This is to prevent large currents flowing through steel fasteners and causing overheating.**

7.1 INTRODUCTION

The detailed commissioning procedure for a drive based on liquid cooled DELTA modules will vary for each application; such details are not included in this manual. However, reference should be made to the MV3000e Getting Started Manual T1676 (or T2002 for AEM drives) which does include general guidance for commissioning. The procedures in this manual are split into two discrete sections. Section 6: CDM Commissioning Guidance describes the commissioning procedures for the Complete Drive Module that should be undertaken by the enclosure manufacturer.

This section describes the commissioning procedures for integrating the Complete Drive Module into the Power Drive System on the end user's site.

Each section gives guidance on visual inspection, coolant system pressure tests and electrical safety tests.

When the equipment has been designed and built for a particular application by an enclosure manufacturer then it is important, for the safety of personnel and equipment, that all commissioning instructions prepared by the manufacturer include the following details:

- Warnings and cautions as necessary;
- Visual / mechanical checks;
- Dry out / warm-up procedure;
- Electrical safety checks;
- Cooling system checks - internal and external to the enclosure;
- Functional tests.

7.2 VISUAL INSPECTION

7.2.1 Delivery Checks

It is possible that the enclosure could have sustained damaged during transport and installation. Inspect the enclosures for any damage that may have been caused.

This could include:

- Broken or cracked shrouds;
- Wiring insulation damage;
- Panel damage including paint chips or dents;
- Loose or broken connections;
- Debris or foreign objects in the enclosures.

7.2.2 Enclosure Installation

Once the enclosures have been installed into their final location, the following checks should be made:

- Ensure that the enclosure is connected to the local earth circuit;
- Ensure that all wiring to the system is in accordance with the installation drawings. This could include supply, communications and I/O connections;
- Ensure that the enclosure is supported using the correct mounting points;
- Check that, all gland plates are present and secured in place with appropriate glands fitted;
- Check that connections to the external cooling system are secure and the correct orientation.

7.3 DRY-OUT / WARM-UP PROCEDURE

Before applying power to the converter for the first time, or after an extended period of no power applied to the converter, it is necessary to go through a heat/dry cycle.

This is dependent on many factors, including the following:

- Where the converter was manufactured;
- When the converter was manufactured;
- The converter's final installation location;
- The environmental conditions at the time of final installation and commissioning.

The dry-out process must be implemented by one or more of the following:

- All doors and panels closed;
- Warming up the cooling system;
- Operating the internal heater systems (e.g. anti-condensation heaters);
- Applying an external heat source;
- Operation of a three-way valve (see Section 3.7.7.4) to prevent external cold coolant from circulating through the system.

The duration of the dry-out period is dependent on the initial condition of the equipment and the following time durations are recommended:

Initial condition of equipment	Recommended dry-out period
Commissioning of equipment in humid conditions	48 hours
Commissioning of equipment in dry conditions	24 hours
Re-starting of equipment following a period of isolation in excess of 48 hours	24 hours

7.4 SYSTEM CONFIGURATION WHEN NON-OPERATIONAL

The installation, configuration and modes of operation of this equipment may require internal heating during periods when the main drive is not powered to prevent condensation forming.

The implementation of this type of heating is dependent on the following:

- External environmental conditions;
- Required internal environmental limits;
- External power sources;
- Safety implications of powered heater elements.

7.5 COOLING SYSTEM COMMISSIONING

Following installation the external cooling system performance should be verified. This test procedure should include:

- Ensure that the inlet and outlet connections are the correct orientation;
- Fill the system with coolant that meets the requirements given in Section 3: Drive (CDM) Design. The exact procedure will depend on the customer's external cooling system design;
- Inspect the system for leaks;
- Run the cooling system and check all monitoring functions are operating correctly.

7.6 FUNCTIONAL TESTS

7.6.1 Software

Drive software will already be installed in the controller. This will need to be checked to ensure it is the latest version. If not, the latest version must be installed.

The drive controller will need to be loaded with the relevant application code. A PC with Drive Coach ™ software will be required for this.

For information on how to perform software updates / installation, see T1676 (or T2002 for AEM drives), T1679 and the specific application notes prepared for the system.

7.6.2 Fans

Ensure that all fans operate as they should, this could include:

- Enclosure fans;
- Capacitor fans;
- Heat exchanger fans;
- Controller fan.

7.6.3 Communication Links

Ensure that the communication links to the drive are operational. These should be initialised by following the guidance provided by the relevant Instruction Sheet. The communication links could include CANopen, Ethernet and Serial Links.

7.6.4 Plant I/O

Check all feedback signals into the I/O circuits are functioning. This could include cooling system feedbacks, and "User Daisy Chain" healthy signals. The operation of these circuits will be detailed in the circuit diagrams and the Test Specification produced by the enclosure manufacturer.

7.6.5 Power Circuit

The commissioning procedure for the power circuit should be determined by the final customer. Reference should be made to the Getting Started Manual T1676 (or T2002 for AEM drives) and the enclosure manufacturer installation instructions.

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8. MAINTENANCE

WARNING

- **Do not use mobile phones or radio communication equipment within 2 metres (6 feet) of the equipment.**
- **The coolant used in this equipment may be hazardous to health if not stored, handled and disposed of in accordance with the manufacturer's instructions.**

CAUTION

- **To help prevent corrosion, any metallic items attached to the coolant duct or the aluminium heatsink MUST BE ALUMINIUM OR STAINLESS STEEL – note particularly when fitting screws.**

8.1 INTRODUCTION

This section describes maintenance for the DELTA modules and the controller in a liquid cooled DELTA System.

No component maintenance is described for the module or the controller. If either product requires component maintenance a request for assistance should be made to a GE Power Conversion via the appropriate national address at the back of this manual.

Some users may have the facilities, skilled personnel and the appropriate lifting equipment to enable a replacement DELTA module to be fitted should this become necessary. This section of the manual therefore includes sufficient detail to enable such users to remove and refit a module.

Due to the technology used in the DELTA modules there is a requirement for periodic maintenance to be carried out and this is also detailed in this section of the manual.

Throughout this section of the manual reference to a DELTA module should be read as applying to either a rectifier or transistor module unless a type of module is specifically stated.

8.1.1 Restarting The System

Following any maintenance procedure, the system should be restarted following the instructions provided in Section 6: CDM Commissioning Guidance.

8.2 SPECIAL TOOLS, EQUIPMENT & MATERIALS

In addition to commonly available hand tools such as spanners, and screwdrivers, certain specific tools are required to perform maintenance tasks on a DELTA drive system:

- Torque screwdriver or torque wrench suitable for M10 fixings;
- Small container for up to 20 ml (7 fl oz) of coolant;
- Large container (e.g. a bucket) for at least 1.75 litres (0.38 UK gallon or 0.46 US gallon) of coolant;
- Container suitable for storage of coolant;
- Spare hose coupling (Staubli RMI16 style), GE Power Conversion Part Number MVS3010-4001, attached to a suitable length (e.g. 1 metre or 3 ft.) of hose (for draining a module into a large container);
- Suitable 'soak-up' material (e.g. cloths, rags, absorbent paper) for the surplus or spilt coolant;
- Two pairs of gloves - one pair for handling the module and the coolant hoses (when uncoupling) and a waterproof pair for protection when handling the coolant;
- Crane suitably rated for lifting the DELTA modules (see Section 2: Specification for module weights and Section 5: CDM Assembly for procedure).

8.3 PREVENTATIVE MAINTENANCE

There are several preventive maintenance routines which should be performed to ensure optimum operating efficiency of the system is maintained. GE Power Conversion recommends that these are performed bi-annually, but individual applications may require a different maintenance schedule.

NOTE: All supplies must be isolated before preventative maintenance tasks are performed.

8.3.1 Bi-Annual Maintenance Routine

The following checks should be carried out every six months:

a) Ensure that all ventilation louvres to the enclosure are unobstructed;

b) Examine the a.c. phase and d.c. link terminals for any signs of overheating;

c) Check that all electrical connections are secure. Torque settings are given in Appendix C: Recommended Torque Settings;

d) Remove any accumulated dust from the system, using a vacuum cleaner with a non-conducting nozzle.

8.3.2 Periodic Checks Of The Cooling System

At a period determined by the application and environmental conditions under which the equipment is operating carry out the following checks:

a) Check all pipes and connections in the cooling system for signs of coolant loss;

b) If there has been any loss of coolant, repair the leak and top up the system with a coolant of the same type and concentration. It is recommended that a supply of coolant is retained for this purpose when the original mixture of coolant is prepared (see Section 3: Drive (CDM) Design);

c) Carry out a periodic check of coolant concentration and compare this with the originally specified concentration. Any variation should be corrected.

8.3.3 Strainer Cleaning

If a strainer is fitted in the cooling system it should be regularly cleaned. The most convenient time to clean it is when the cooling system is out of service for renewal of the coolant as described in Section 8.4.

However, should problems occur during normal operation because of the strainer becoming blocked, then it should be cleaned more frequently and the cleaning period adjusted accordingly.

Records should be retained of all the cleaning dates.

8.4 RENEWAL OF COOLANT

GE Power Conversion recommends that the coolant should be renewed each year by following the procedure detailed below:

NOTE: All supplies must be isolated before coolant renewal is performed.

a) Drain the coolant from the cooling system and dispose of it in accordance with the coolant manufacturer's instructions;

b) If a strainer is fitted in the cooling system it should be removed, cleaned, inspected and refitted or replaced;

c) Flush the cooling system through with de-mineralised water;

d) Renew the coolant immediately after flushing the system. (see Section 3: Drive (CDM) Design for additional information on coolant selection);

e) Record the following details (see typical record sheet in Section 8.11.4: Coolant Renewal Record);

- Coolant type;
- Water type;
- Concentration;
- Volume of coolant in the system;
- Details of sample analysis

8.5 REMOVAL OF MODULES FOR SERVICE OR REPAIR

WARNING

- **High Voltages**
  Replace all shrouds and close all doors before energising the equipment.
- **This equipment may be connected to more than one live circuit.**
  Disconnect all supplies before working on the equipment.
- **Wait at least 8 minutes after isolating supplies and check that the voltage between DC+ and DC- has reduced to a safe level before working on this equipment.**
- **Surfaces on the following items can reach high temperatures and remain hot for some time after power has been removed:**
  - Reactors and transformers
  - Cables
  - Coolant pipes and couplings
- **Items marked with weights greater than 20kg (44 lb.) should only be moved with lifting apparatus.**

CAUTION

- **This equipment contains solid state devices which may be affected by electrostatic discharge.**
  Observe static handling precautions.
- **Ensure that all conductors connected to this product are mechanically restrained.**
- **Where nuts, bolts and washers are supplied fitted to the terminal busbar, remove these fasteners, place the user's crimp (or busbar) directly against the terminal busbar of the unit and refit the fasteners. This is to prevent large currents flowing through steel fasteners and causing overheating.**

8.5.1 Preliminary Checks

Before commencing any maintenance or servicing tasks on a DELTA system check that:

- The warnings and cautions given above have been understood and followed;
- If a DELTA module is to be replaced, ensure that:
  - The coolant system has been isolated;
  - A suitably rated crane is available;
  - Instructions for the safe handling, use, storage and disposal of coolant, supplied by the manufacturer, have been read and understood.

8.5.2 Removal Of The Controller

Removal of the controller does not require any special equipment. The controller should be removed from the enclosure by following the steps below. Refer to Section 5: CDM Assembly, for further information:

a) Remove the ribbon cable clamps (secured with M5 nuts) as required. Carefully cut and remove any cable ties securing the wiring. Disconnect the ribbon cables, first noting their routing and positions;

b) Disconnect all remaining wiring from the controller by unplugging the connectors. It is not required to remove individual wires from the terminals. Ensure that wiring is labelled to allow correct connections to be made to the replacement controller;

c) Loosen (removal is not necessary) the four M5 fixing screws and remove the controller by lifting it free of the screws.

8.5.2.1 Removal Of Optional Modules

If the controller has an optional communications module fitted, it should be removed at this stage. Refer to the relevant instruction sheet for details.

8.5.3 Removal Of The I/O Termination Panel

Removal of the I/O termination panel does not require any special equipment. The I/O panel should be removed from the enclosure by following the steps below. Refer to Section 5: CDM Assembly, for further information:

a) Disconnect all wiring from the panel by unplugging the ribbon cable and terminal blocks. It is not required to remove individual wires from the terminals. Ensure that each terminal block is labelled to allow correct connections are made to the replacement unit;

b) Loosen (removal is not necessary) the two M5 fixing screws and remove the I/O panel by lifting it free of the screws;

c) Note the position of the DIP switches on the I/O panel so that the replacement can be correctly configured.

8.5.4 Removal Of The MVM Module

Removal of the MVM module does not require any special equipment. The MVM module should be removed from the enclosure by following the steps below. Refer to Section 5: CDM Assembly, for further information:

a) Carefully cut and remove any cable ties that secure the ribbon to the MVM module.

b) Disconnect the three pin connector and the ribbon cable;

c) Loosen (removal is not necessary) the four M5 fixing screws and remove the MVM module by lifting it free of the screws.

8.5.5 Removal Of An SMPS Module

Removal of an SMPS module does not require any special equipment. An SMPS module should be removed from the enclosure by following the steps below. Refer to Section 5: CDM Assembly, for further information:

a) Disconnect the two pin connector and the ribbon cable;

b) Loosen the three M5 nuts that secure the SMPS to the DELTA module;

c) Remove the SMPS module by lifting clear of the fixing screws.

d) If the SMPS is a -4020 or -4030 variant (identified on the rating label on the rear of the module), note the position of the DIP switches so that the replacement can be correctly configured

8.5.6 Removal Of A DELTA Rectifier Module

CAUTION
• **The modules are delicate and vulnerable to damage – handle carefully. Only lift or move them by use of the lifting point. Lay them down on the plain left-hand face when not fitted in a frame. Do not leave modules unsupported in the upright position.**

A DELTA rectifier module should be removed from the enclosure by following the steps below. Refer to Section 5: CDM Assembly, for further information:

8.5.6.1 Removal Of Electrical Connections

a) Remove the terminal shrouds;

b) Disconnect the control connections by unplugging the connector;

c) Disconnect the a.c. phase cables or busbars, first noting their positions;

d) Disconnect the d.c. cables or busbars;

e) Disconnect the earth cable (if fitted).

8.5.6.2 Removal Of Coolant Connections – Staubli Style Couplings

a) Remove the shroud covering the coolant connections;

b) Disconnect the FLOW cooling system hose from the module by releasing the spring loaded coupling. Pour the remaining coolant, approximately 20 ml (7 fl oz), out of the coupling into a container. Take care not to spill any coolant in the enclosure;

c) Repeat above procedure for the RETURN coupling;

8.5.6.3 Removal Of Coolant Connections – Hosetail Couplings

a) Remove the shroud covering the coolant connections;

b) Drain the coolant system;

c) Disconnect the FLOW cooling system hose by loosening the hose-clip. Care must be taken with coolant that may remain in the hose;

d) Repeat the above procedure for the RETURN connection.

8.5.6.4 Removal Of The Module

a) Remove four M6 fixing screws (two from the top of the module and two from the bottom);

b) Slide the module forwards until the stop pin is reached;

c) Connect a suitable crane shackle to the lifting hole in the top of the module;

d) Take up the weight of the module, lift it over the stop pin and withdraw from the enclosure;

e) **Staubli equipped variants only -** With the module hanging on the crane and steadied in its vertical position, drain the coolant out of the module into a suitable large container (e.g. a bucket). Drain by attaching the spare hose to the spring loaded FLOW coupling on the module. Repeat for the RETURN coupling to ensure both sides of the module are drained;

f) Move the module into a safe position with its left hand side (when viewed from the front) laid on a flat surface.

8.5.7 Removal Of DELTA Transistor Module

CAUTION

- **The modules are delicate and vulnerable to damage – handle carefully.
Only lift or move them by use of the lifting point.
Lay them down on the plain left-hand face when not fitted in a frame.
Do not leave modules unsupported in the upright position.**

A DELTA transistor module should be removed from the enclosure by following the steps below. Refer to Section 5: CDM Assembly, for further information:

8.5.7.1 Removal Of Electrical Connections

a) Remove the SMPS module by following the instructions in Section 8.5.5: Removal Of An SMPS Module;

b) Disconnect the control ribbon cable by unplugging the connector;

c) Carefully cut and remove any cable ties securing the control ribbon cable to the SMPS plate. It may be necessary to release control ribbon cables to other DELTA modules if they run across the module to be removed;

d) Remove the SMPS mounting plate by loosening the M5 fixings and lifting clear;

e) Remove the terminal shrouds;

f) Disconnect the a.c. phase cables or busbars, first noting their positions;

g) Disconnect the d.c. cables or busbars;

8.5.7.2 Removal Of Coolant Connections – Staubli Style Couplings

a) Remove the shroud covering the coolant connections;

b) Disconnect the FLOW cooling system hose from the module by releasing the spring loaded coupling. Pour the remaining coolant, approximately 20 ml (7 fl oz) , out of the coupling into a container. Take care not to spill any coolant in the enclosure;

c) Repeat above procedure for the RETURN coupling;

8.5.7.3 Removal of Coolant Connections – Hosetail Couplings

a) Remove the shroud covering the coolant connections;

b) Drain the coolant system;

c) Disconnect the FLOW cooling system hose by loosening the hose-clip. Care must be taken with coolant that may remain in the hose;

d) Repeat the above procedure for the RETURN connection.

8.5.7.4 Removal Of The Module

a) Remove four M6 fixing screws (two from the top of the module and two from the bottom);

b) Slide the module forwards until the stop pin is reached;

c) Connect a suitable crane shackle to the lifting hole in the top of the module;

d) Take up the weight of the module, lift it over the stop pin and withdraw from the enclosure;

e) **Staubli equipped variants only -** With the module hanging on the crane and steadied in its vertical position, drain the coolant out of the module into a suitable large container (e.g. a bucket). Drain by attaching the spare hose to the spring loaded FLOW coupling on the module. Repeat for the RETURN coupling to ensure both sides of the module are drained;

f) Move the module into a safe position with its left hand side (when viewed from the front) laid on a flat surface.

8.6 REPLACEMENT OF MODULES FOLLOWING SERVICE OR REPAIR

WARNING

- **All items exposing high voltage must be placed in a suitable enclosure with restricted access.**
- **High Leakage Current**
  This equipment and the driven motor(s) must be earthed (grounded).

Refer to Section 5: CDM Assembly, for fitting instructions of replacement modules.

8.6.1 Replacement Of Control Components

Ensure that the following are observed when replacing control components:

- Ensure that the part number of the replacement item matches exactly with the original module;
- Refit any optional communications module to the replacement controller before installing it in the enclosure;
- Set DIP switches on replacement I/O panel and SMPS (if fitted) to match the original unit configuration.

NOTE: **Fitting a replacement module with a different part number to the original item, or failure to set the DIP switches correctly may result in maloperation of the system.**

8.6.2 Replacement Of DELTA Transistor & Rectifier Modules

Ensure that the following are observed when replacing control components:

- Ensure that the part number of the replacement item matches exactly with the original module;
- Refer to Appendix C: Recommended Torque Settings for the correct torque settings of the electrical connections;

8.6.3 Re-Commissioning The System

The equipment should be re-commissioned in accordance with the instructions for the particular application. See Section 6: CDM Commissioning Guidance for further details.

Depending on the replacement module source and the replacement duration, it may be necessary to dry out the equipment before powering it up.

The dry-out process must implement the following (as appropriate):

- All doors and panels closed;
- Warming up the coolant system;
- Operating the internal heater systems (e.g. anti-condensation heaters);
- Applying an external heater source;
- Operation of a three-way valve to prevent external cold coolant from circulating through the system.

The duration of the dry-out period will be dependent upon the initial condition of the equipment and the following time durations are recommended:

Initial condition of equipment	Recommended dry-out period
Installing new replacement module (sealed prior to installation).	4 hours
Installing replacement module that is either not new or not inside sealed packaging.	24 hours

8.7 MODULE PACKAGING & TRANSPORTATION

CAUTION

- **Do not transport a DELTA module at any time with the coolant inside it – there is a risk of damage due to differential expansion.**
- **Do not flush the module after it has been drained – there is a risk of damage due to corrosion from the use of ordinary water.**

Appropriate tools, equipment and materials are required for the handling and packaging of a DELTA module, MV3000e Controller, SMPS, I/O panel or MVM unit for transportation.

- Where possible return a module in its original packaging material, or in the replacement module packaging;
- If new packaging is used, label the box with all the warnings for transit including weight, orientation, protect against water, stacking limitations and temperature limitations.

8.7.1 DELTA Module

A suitable crane for moving the DELTA module will be required. The packaging process is detailed below:

a) Ensure that all coolant is drained from the module.

b) Wrap the module in a protective layer of paper packing/wrapping.

c) Seal the module and desiccant in an anti-static bag.

d) Evacuate the air from the bag prior to final sealing.

e) Seal and label the packing crate.

8.7.1.1 Packing Materials For A DELTA Module

- a waterproof anti-static bag size 1500 mm long x 730 mm wide x 840 mm high (60 in x 29 in x 33 in);
- 300 g (≈ 11 oz) of desiccant for moisture protection inside the bag;
- a supply of paper packing/wrapping or polystyrene suitable for the protection of a module within the packing case during transit;
- a tri-wall packing case, with wooden pallet, of internal dimensions 1370 mm wide x 600 mm deep x 350 mm high (54 in x 23.5 in x 14 in) which is capable of withstanding the conditions of transportation.

8.7.1.2 Control Components

The packaging process is detailed below:

a) Seal the module and desiccant in an anti-static bag.

b) Evacuate the air from the bag prior to final sealing.

c) Seal and label the packing box.

8.7.1.3 Packing Materials For A Control Component

- a waterproof anti-static bag of a size suitable for the module;
- 10 g (0.5 oz) of desiccant for moisture protection inside the bag;
- suitable polystyrene materials for retaining the unit in position in a packing box;
- a suitable packing box which is capable of withstanding the conditions of transportation.

8.8 SYSTEM DIAGNOSTICS

8.8.1 Controller Diagnostics

The MV3000e Controller provides diagnostic information which can be accessed by use of the optional Drive Data Manager™ (Keypad). The drive conditions for which diagnostic information is available are:

- drive status;
- warning of a problem;
- fault condition;
- trips.

The controller includes a group of LEDs (Light Emitting Diodes) shown in Figure 8–1 to provide an indication of the four statuses listed above. All of the diagnostic information, and some of the helpful hints for fault diagnosis, are detailed in the MV3000e Getting Started Manuals T1676 or T2002 (for AEM systems).

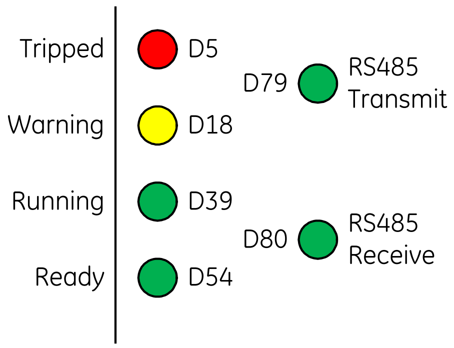


Figure 8–1. – MV3000e Controller LED Functions

8.8.2 DELTA Transistor Module Diagnostics

The PCB on the DELTA transistor module includes a group of six LEDs that display the operational status of the module. The LED functions are shown in Figure 8–2.

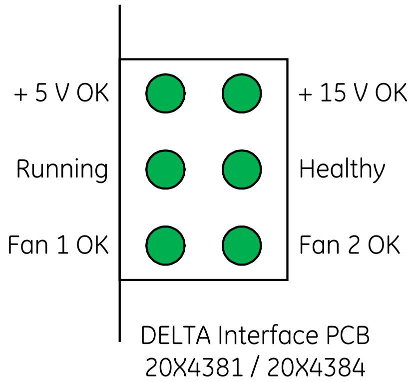


Figure 8–2. – DELTA Transistor Module LED Functions

8.9 SPARES & SERVICING

8.9.1 Spares

There are no recommended spares for the DELTA modules or the control components except for the pre-charge protection fuses for the rectifier module (see Section 8.9.3: Pre-Charge Fuses).

If either a DELTA module or a control component is suspected of being faulty it should be returned to GE Power Conversion for servicing.

8.9.2 Servicing

Before removing a module for return to GE Power Conversion for servicing the user should ensure that the facilities, skilled personnel and the appropriate lifting equipment are available to replace the module. Detailed instructions are included earlier in Section 1: Introduction.

When any equipment is being returned for servicing it is important that all the details available about the conditions under which the equipment failed are conveyed, preferably in writing, with the returned equipment.

When referring to GE Power Conversion about any modules the serial number for the suspect item must always be quoted. Any references to replacement ribbon cables should quote the part number from the original ribbon/connector.

8.9.3 Pre-Charge Fuses

The recommended pre-charge protection fuse for the MVRL2100-4601/2 rectifier module is:

Bussmann type	KTK-8. Rated at 8 A, 600 V a.c. Cartridge size 10 x 38 mm GE Power Conversion reference S82028/310.

NOTE: Replacing these fuses with another rating or type will invalidate safety approvals.

Three pre-charge fuses are located on the upper printed circuit board which is located at the rear of the rectifier module.

8.10 CAPACITOR REFORMING

If this equipment is kept in store for long periods of time, usually greater than two years, it may be necessary to reform capacitors before putting the equipment of which they are a part into service. This requirement applies to the d.c. link capacitors on the DELTA transistor module. Consult GE Power Conversion or one of its agents for details.

8.11 HANDLING, STORAGE & DISPOSAL OF COOLANT

CAUTION

- **Undiluted antifreeze freezes at a higher temperature than diluted antifreeze.
Freezing impairs its cooling and corrosion inhibiting properties.
Follow the manufacturer's storage instructions.**

8.11.1 Handling Of Coolant

The coolant is subject to particular conditions during handling and these instructions are normally included with the coolant. Refer to the manufacturer's instructions and Material Safety Data Sheet for advice about a particular coolant. It is recommended that the instructions be retained with this manual.

8.11.2 Storage Of Coolant.

The coolant should be stored in suitable containers in an indoor location. The freezing point of the undiluted ethylene glycol is -12°C (10.4 °F).

8.11.3 Disposal Of Coolant

The coolant, and its container, should be disposed of in accordance with the manufacturer's instructions for compliance with local and national Health and Safety and Environmental legislation. Such disposal will normally be done by approved waste contractors.

8.11.4 Coolant Renewal Record

COOLANT RENEWAL RECORDS

DATE RENEWED	COOLANT TYPE	WATER TYPE*	CONCENTRATION (%)	VOLUME OF MIXTURE IN LITRES	FLUSHING AGENT	SAMPLE ANALYSIS		REMARKS
						Volume	Date sent for test	

NOTE: * The water may be de-mineralised, de-ionised or distilled, and this should be recorded.

NOTE: This page may be photocopied.

9. DISPOSAL

This equipment or any part of the equipment should be disposed of in accordance with the laws of the country of use.

Modern high technology materials have been used in the manufacture of the equipment to ensure optimum performance. Care has been taken with the selection of these materials to minimise risks to health and safety. However, some materials require special consideration during disposal.

In common with all products of this type, the high voltage electrolytic capacitors contain an electrolyte, which must be disposed of as hazardous waste. The electrolytes are solutions of organic and/or boric acid. The major solvents in the capacitors are butyrolactone and ethylene glycol. The electrolyte is non-carcinogenic, but may cause irritation to the skin if contact is prolonged.

Liquid coolant is subject to special considerations during handling, storage and disposal. Refer to the manufacturer's instructions.

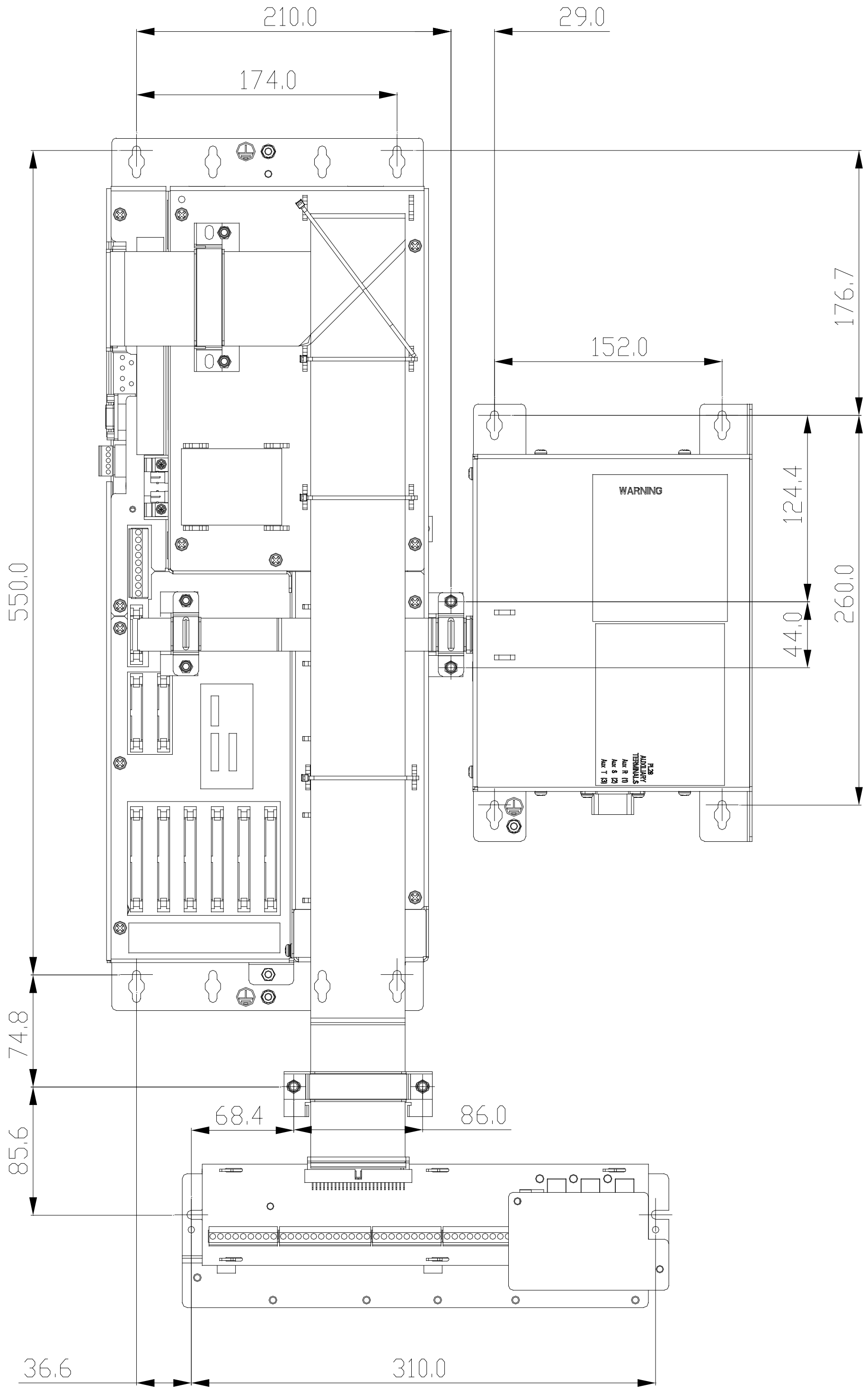
10. APPENDIX A: DIMENSIONED MECHANICAL DRAWINGS

10.1 SCOPE

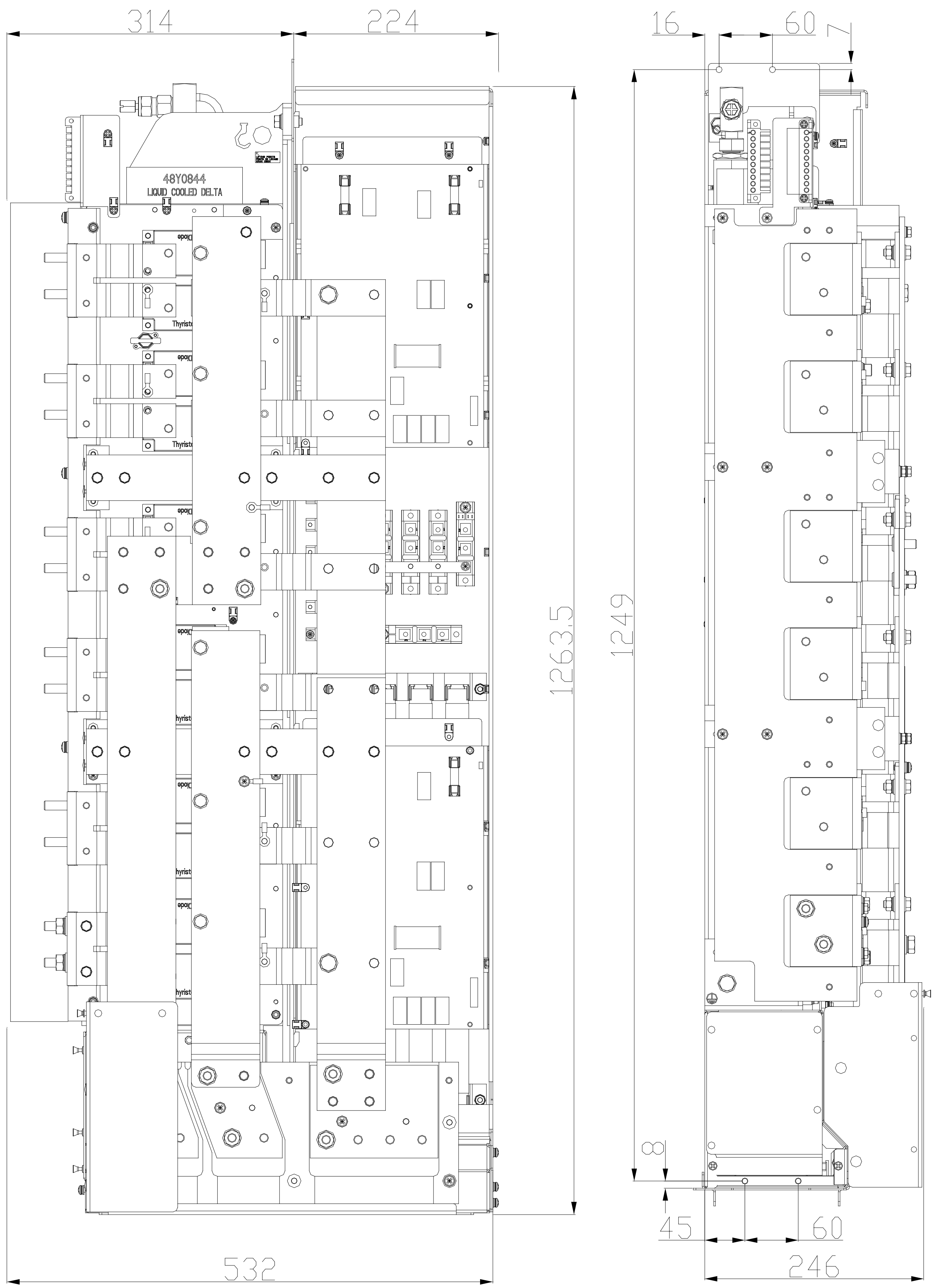
This section gives dimensioned drawings of some DELTA components, to allow the design and fabrication of application specific mounting arrangements.

The mechanical and electrical installation of the DELTA modules and the related control components are shown in Section 5: CDM Assembly of this manual.

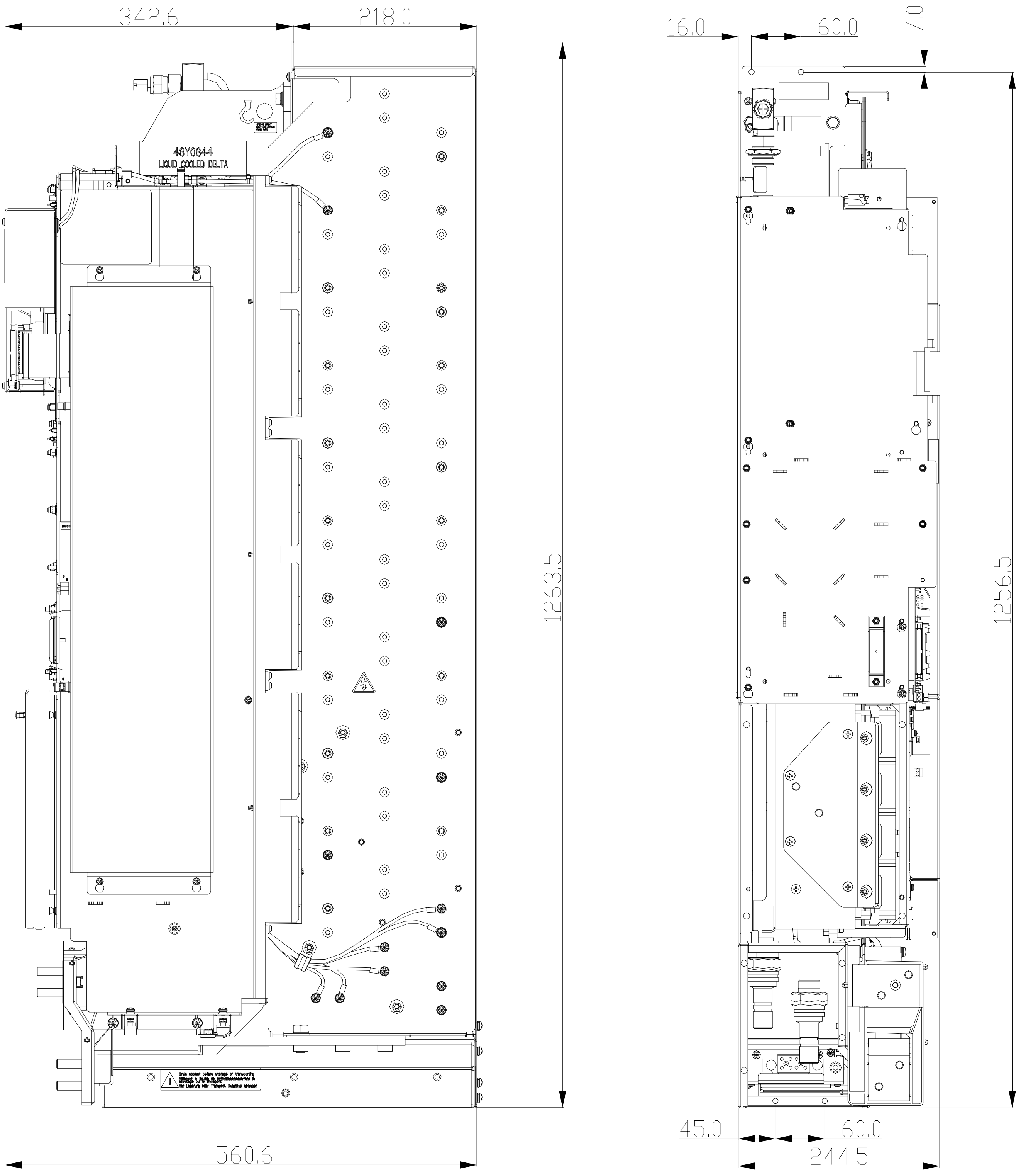
10.2 CONTROL ARRANGEMENT



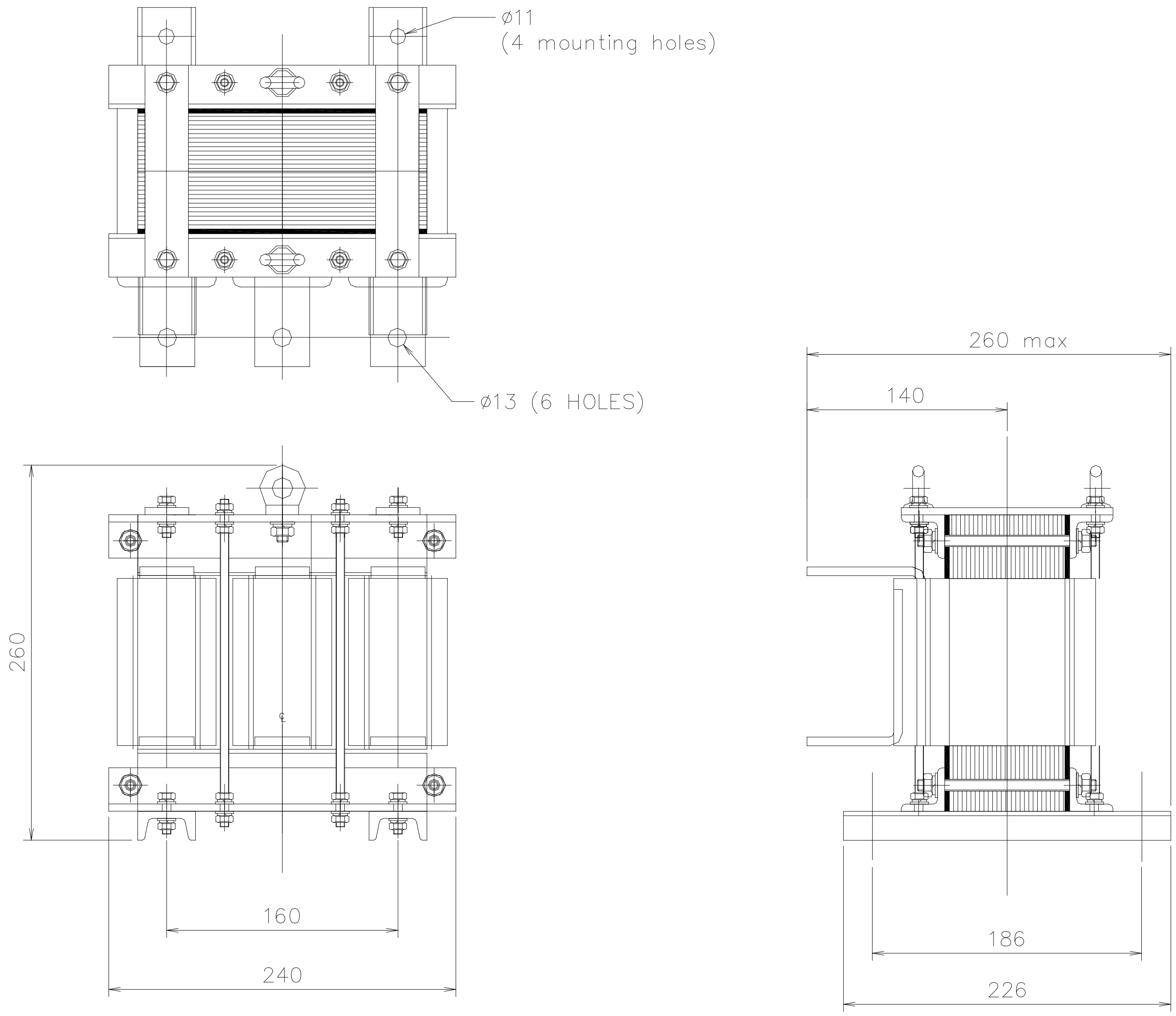
10.3 RECTIFIER MODULE



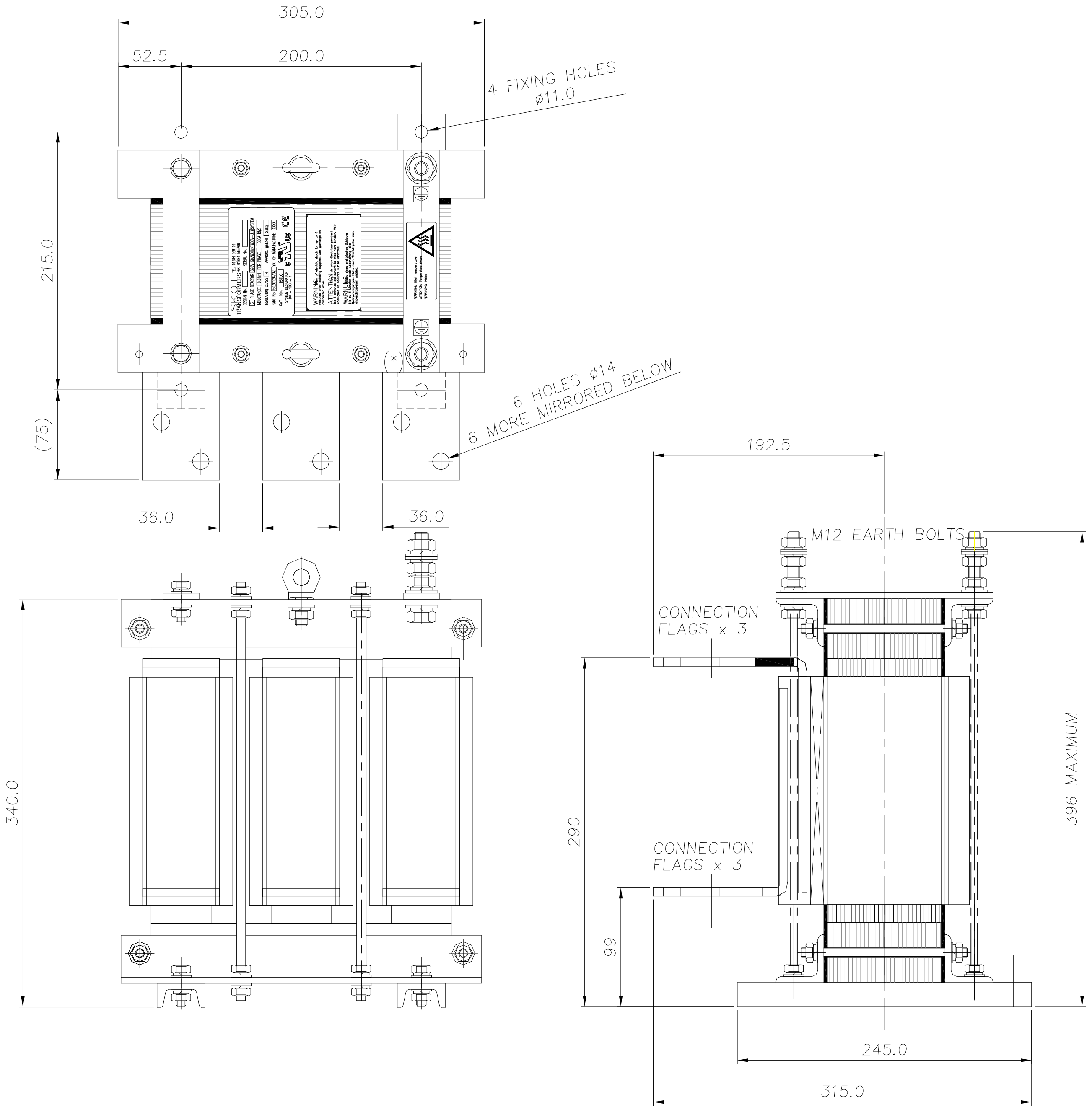
10.4 TRANSISTOR MODULE



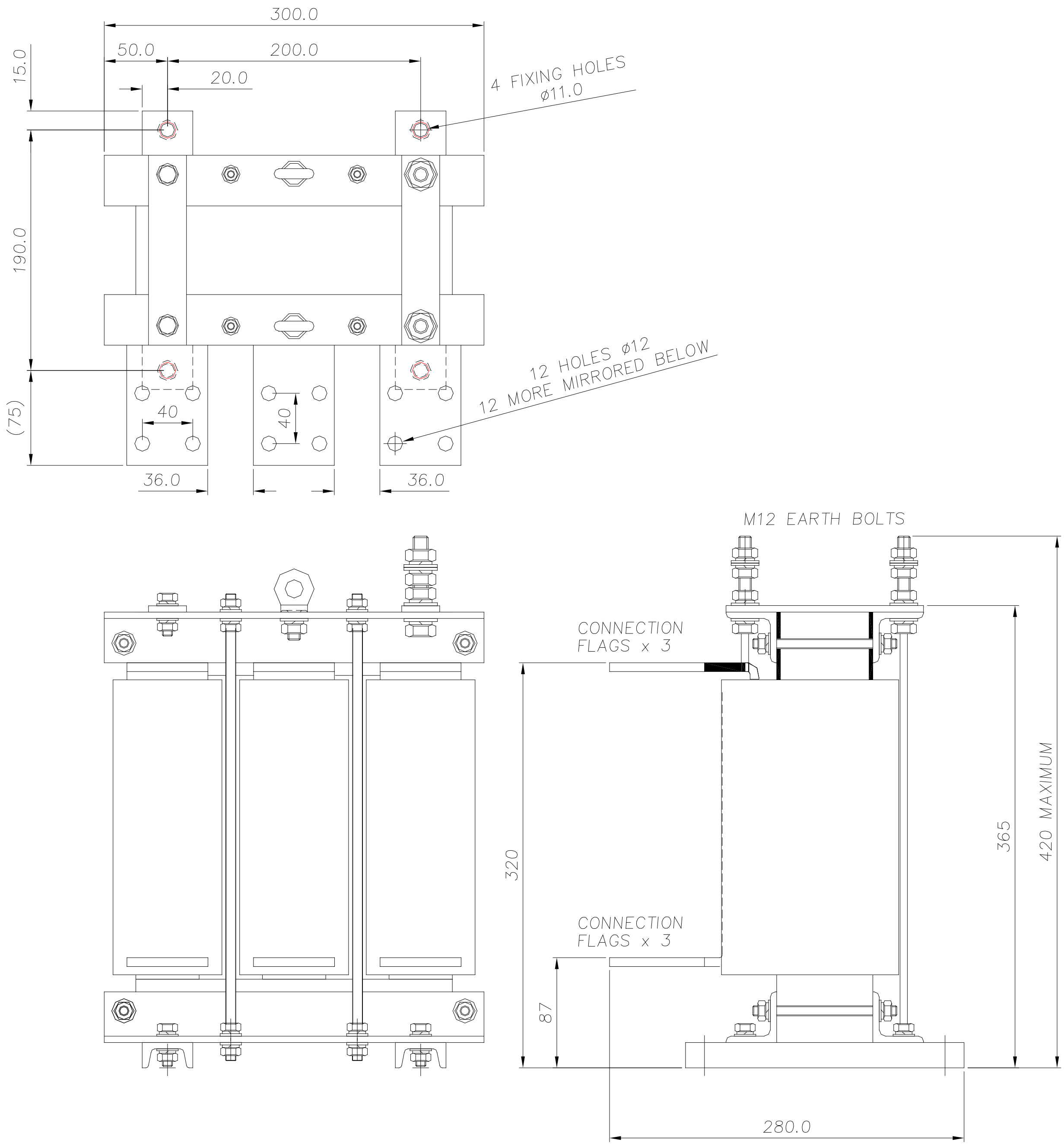
10.5 SHARING REACTOR 50Z0126/01



10.6 SHARING REACTOR 50Z0126/02



10.7 SHARING REACTOR 50Z0126/03



11. APPENDIX B: ELECTRICAL CONNECTION DIAGRAMS

11.1 SCOPE

This appendix shows the standard connections for: a.c. input DELTA modular drive systems. The diagrams can be used for drive systems constructed from a single module, to multiple modules connected in parallel.

Figure 11–1 shows the control connections required for two rectifier modules. If a single rectifier module is required, explicit connection changes are detailed in the figure.

Figure 11–2, Figure 11–7 and Figure 11–8 show the full complement of two rectifier or six transistor modules and the required connections. These diagrams can still be used for smaller systems by omitting the modules that are not required.

The mechanical and electrical installation of the DELTA modules and the related control components are shown in Section 5: CDM Assembly of this manual.

11.2 RECTIFIER BRIDGE – CONTROL CONNECTIONS

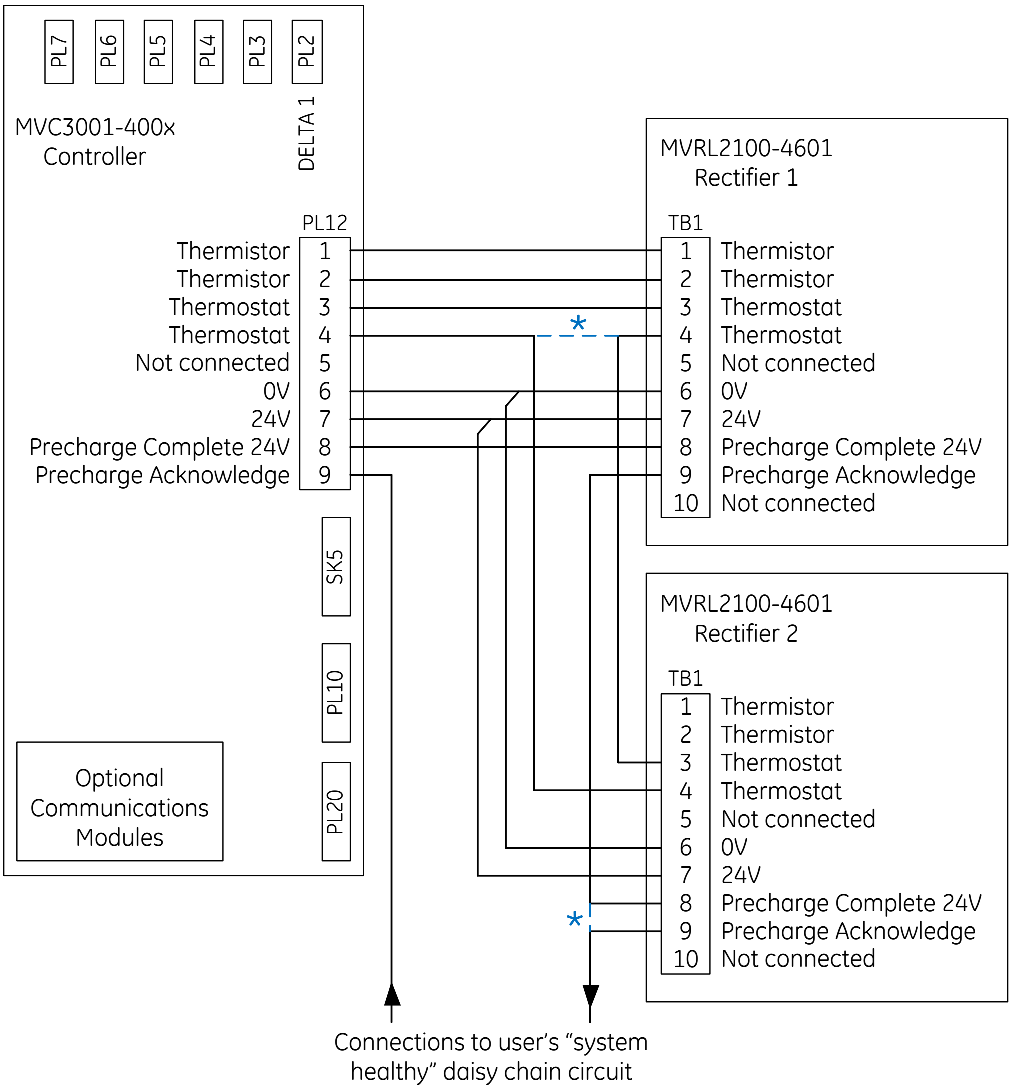


Figure 11–1. – Control Connections To Rectifier Modules

* If a single rectifier module is fitted, connect:

- TB1 pin 4 directly to PL12 pin 4 on the controller;
- TB1 pin 9 directly to the user's "system healthy" daisy chain circuit.

11.3 AEM / MACHINE BRIDGE - CONTROL CONNECTIONS

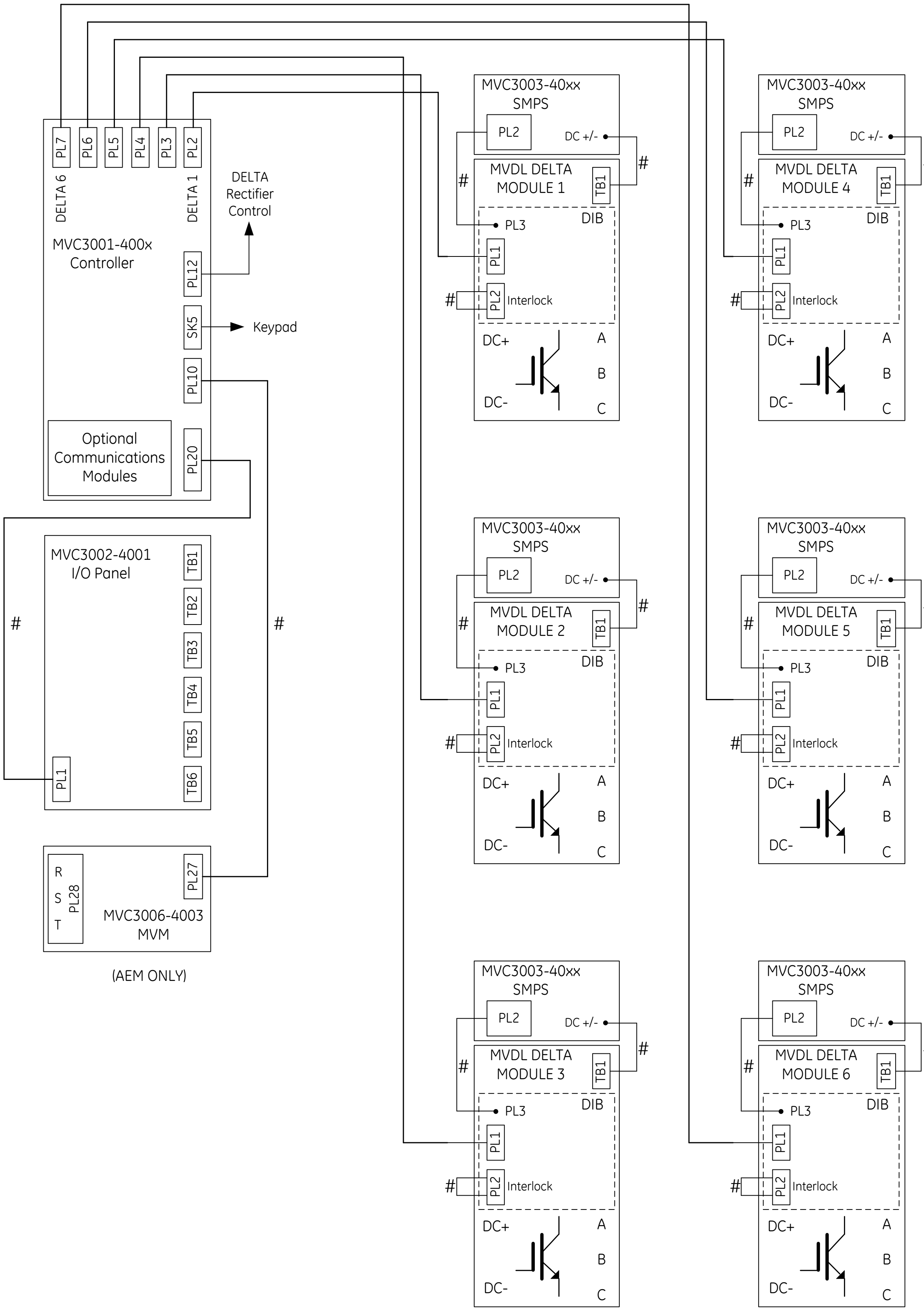


Figure 11–2. – Control Connections To Transistor Modules

NOTES: DELTA 1 must always be connected to PL2 on the controller. Any remaining DELTA control connections are allocated sequentially.

# Denotes cables supplied as part of the associated assembly.

11.4 RECTIFIER NETWORK BRIDGE – POWER CONNECTIONS

11.4.1 6 Pulse Supply, Single Rectifier Module

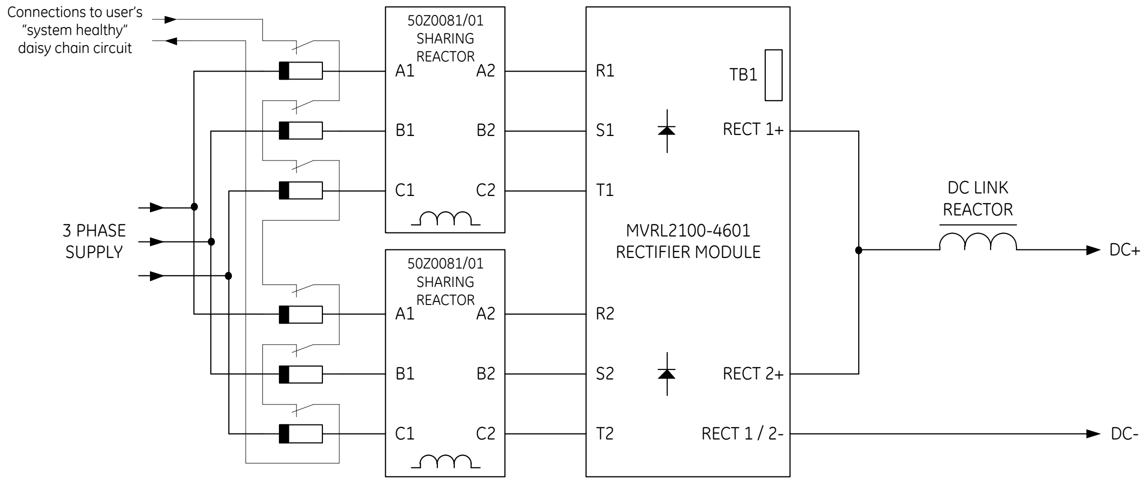


Figure 11–3. - Power Connections, 6 Pulse Supply, Single Rectifier Module

11.4.2 6 Pulse Supply, Dual Rectifier Modules

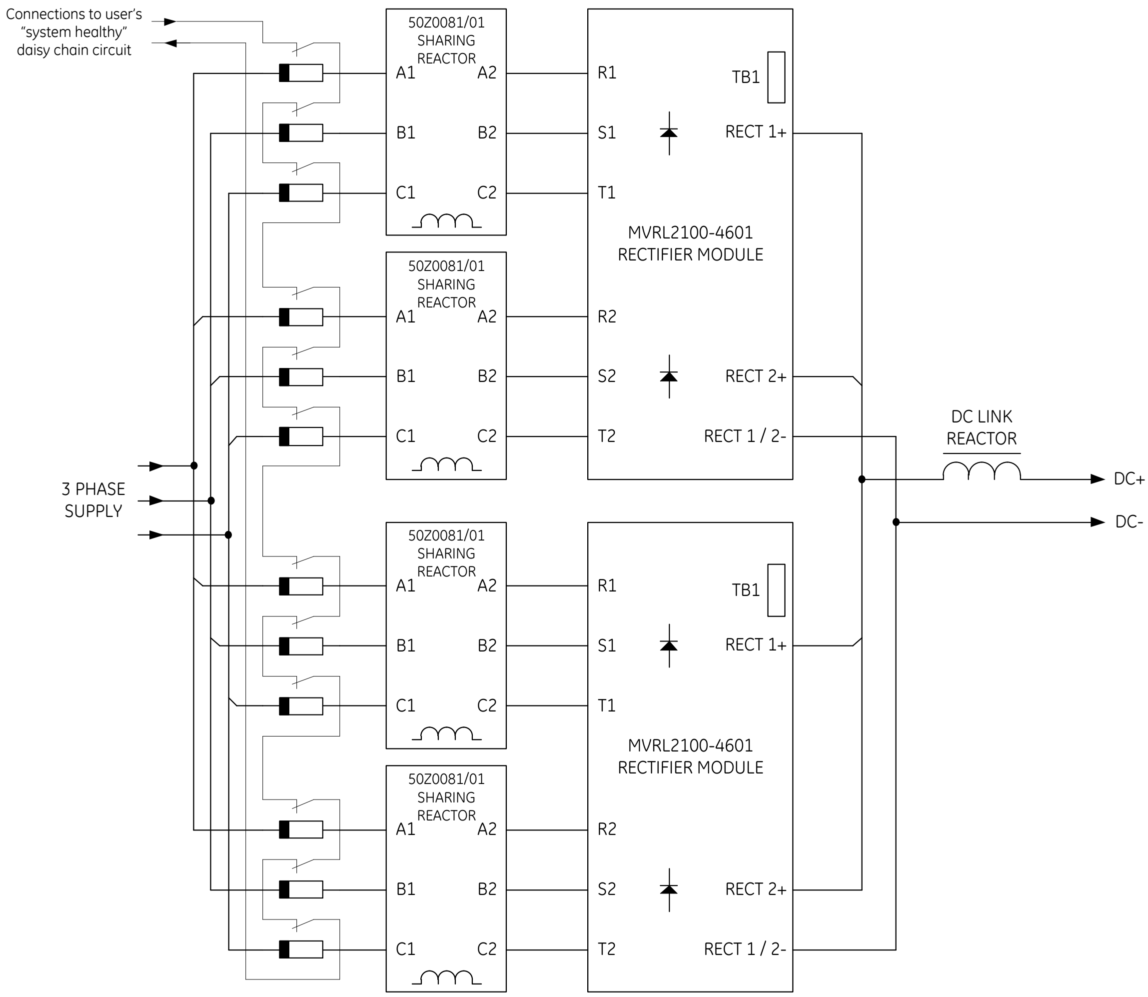


Figure 11–4. - Power Connections, 6 Pulse Supply, Dual Rectifier Modules

11.4.3 12 Pulse Supply, Single Rectifier Module

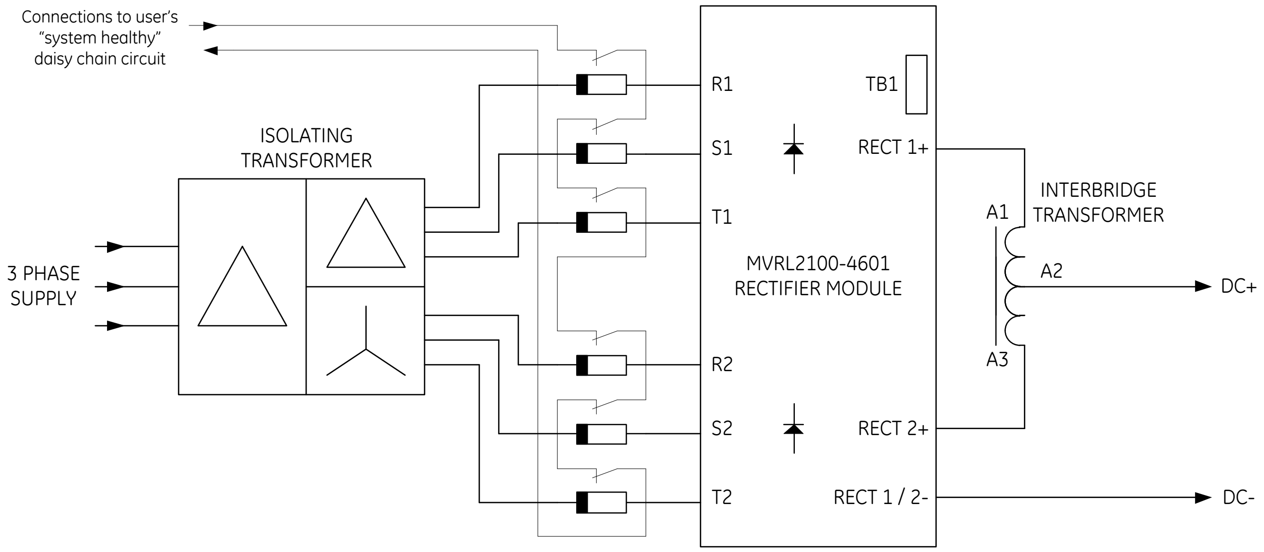


Figure 11–5. – Power Connections, 12 Pulse, Single Rectifier Module

11.4.4 12 Pulse Supply, Dual Rectifier Modules

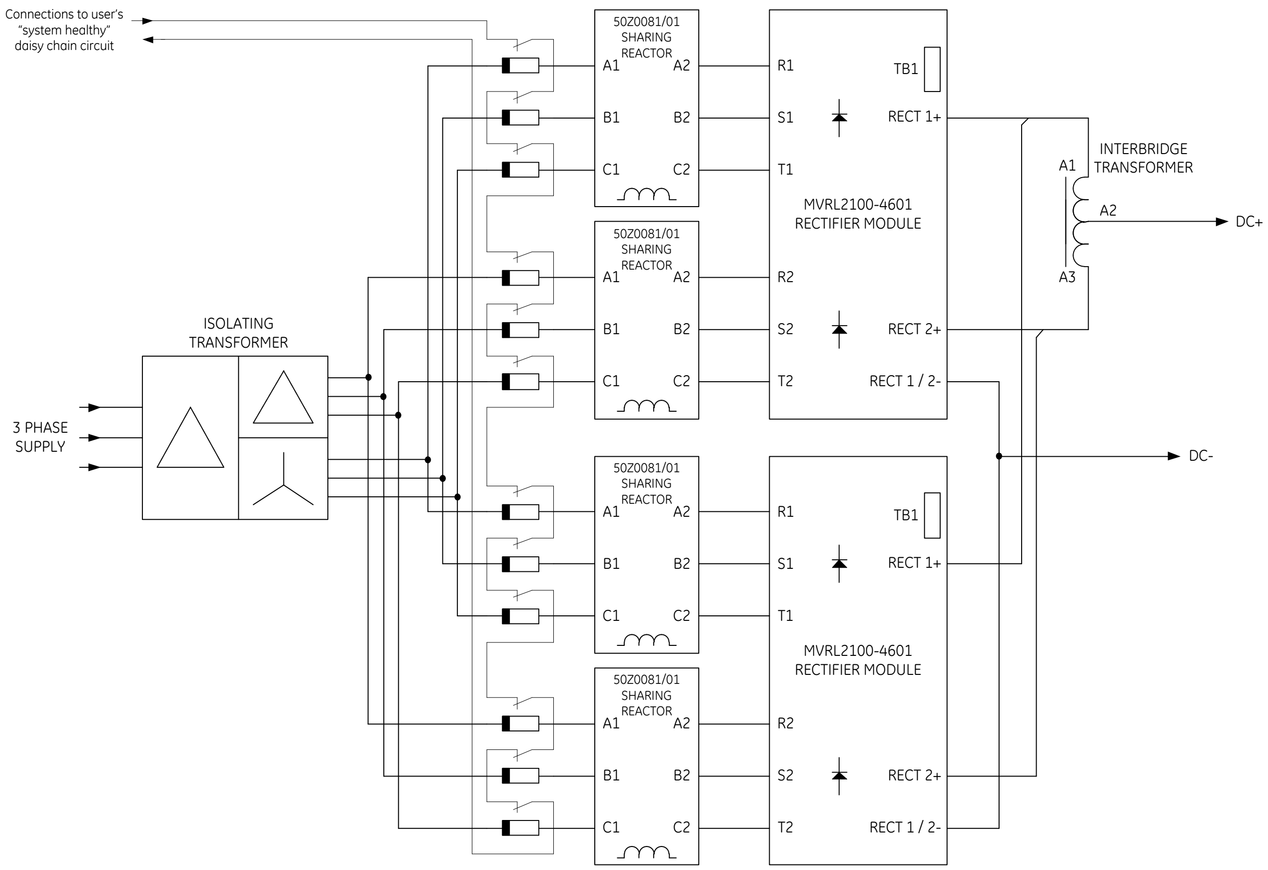


Figure 11–6. – Power Connections, 12 Pulse Supply, Dual Rectifier Modules

11.5 AEM NETWORK BRIDGE – POWER CONNECTIONS

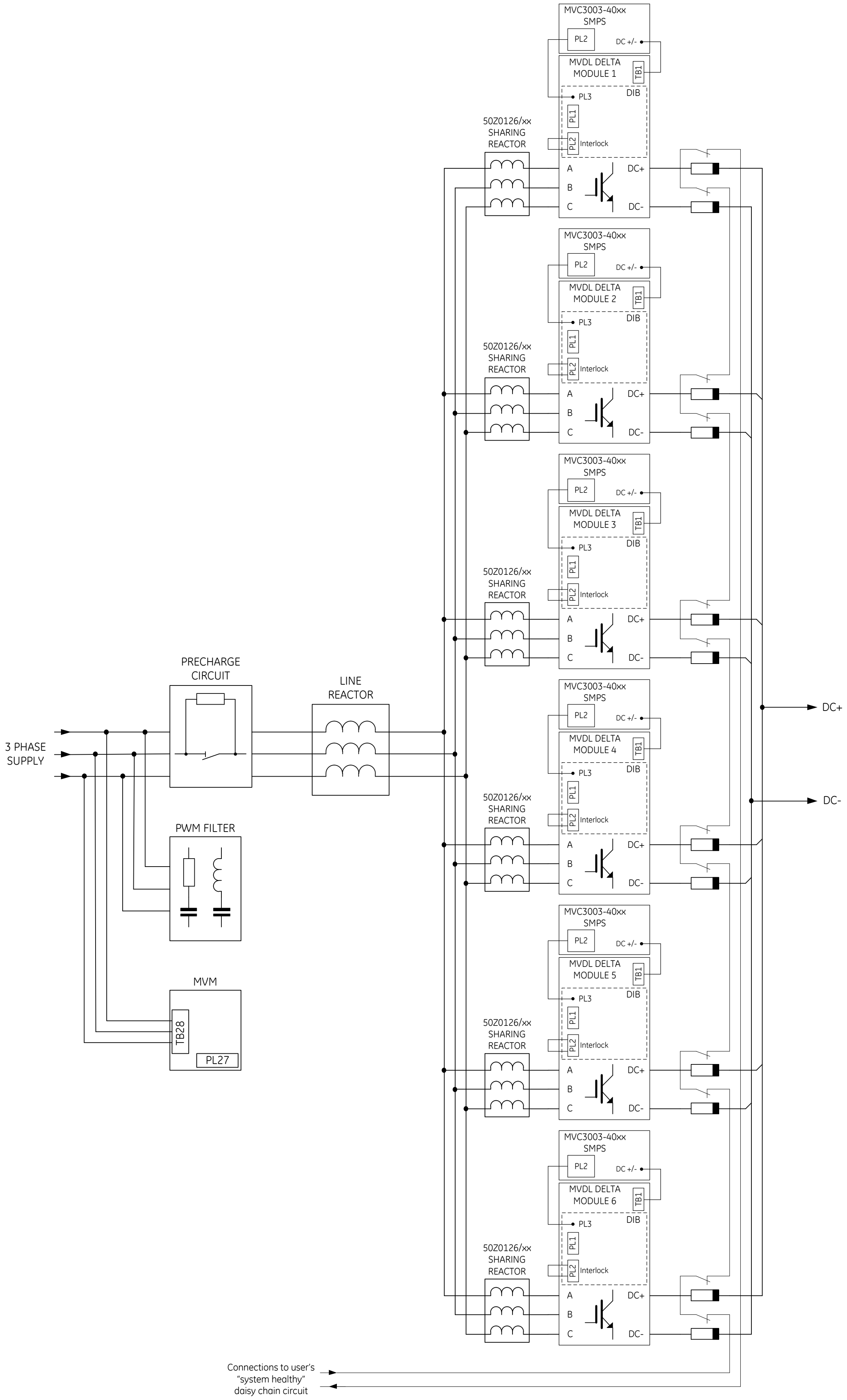


Figure 11–7. – Power Connections, AEM Network Bridge

11.6 MACHINE BRIDGE – POWER CONNECTIONS

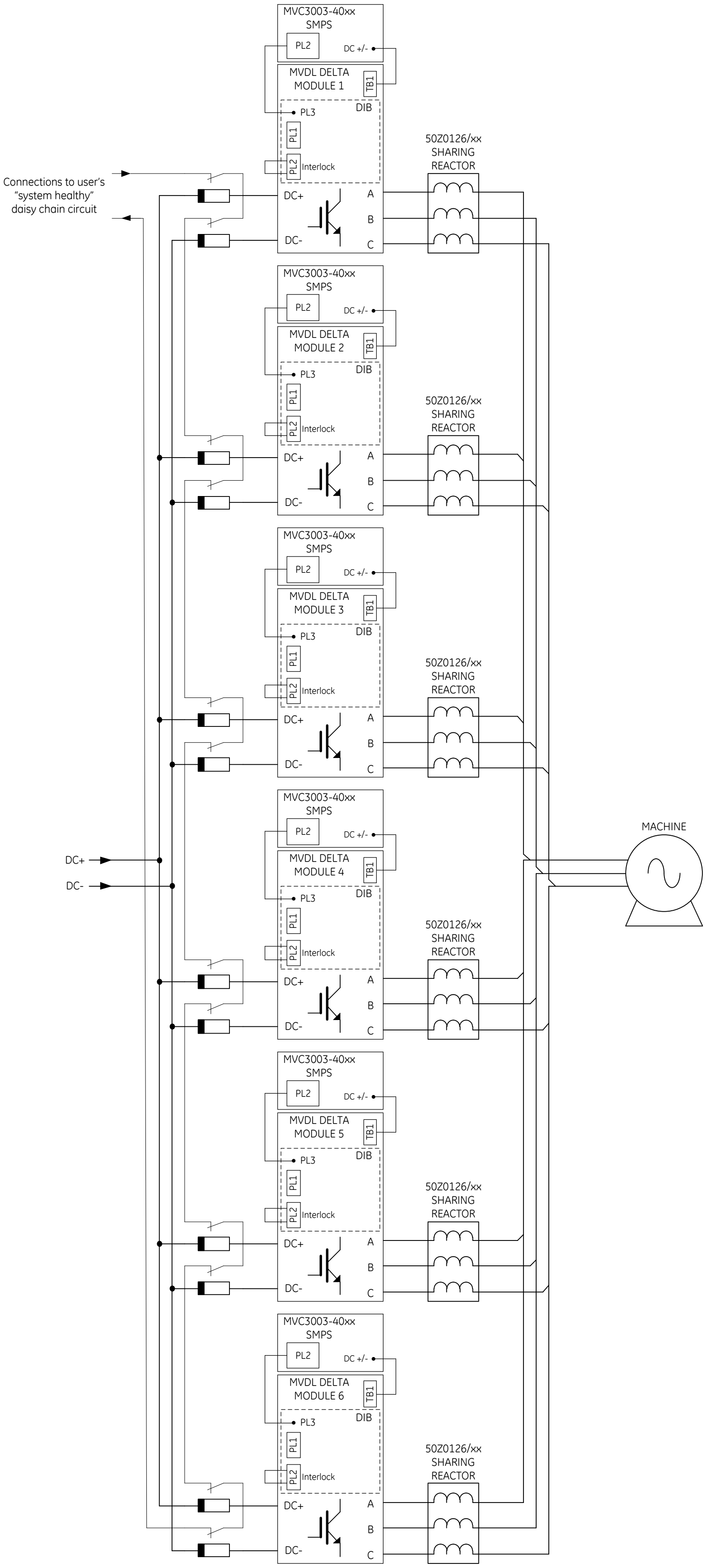


Figure 11–8. – Power Connections, Machine Bridge

12. APPENDIX C: RECOMMENDED TORQUE SETTINGS

12.1 SCOPE

This document details the recommended tightening torque settings for electrical and mechanical connections to DELTA modules.

The recommended torque settings are applicable to high-tensile steel (Grade 8.8) fasteners fitted with a single turn spring washer under the nut, and with the threads being zinc plated, passivated and unlubricated, over the normal operating temperature of these components.

Specifically excluded are:

- fasteners with any other material (e.g. brass);
- fasteners with any other finish (e.g. raw steel, cadmium plated, lubrication of any sort);
- slotted holes in either steel or copper.

12.2 TORQUE SETTINGS FOR ELECTRICAL CONNECTIONS

The figures included in Table 12–1 are for electrical connections of copper conductor crimps to device terminals and to all copperwork except busbars, for which figures are included in Table 12–2.

Fastener Size Carbon Steel (8.8)	Torque Setting		
	Nm	lbf. in	lbf. ft.
M5	3.5 - 5.5	30 - 48	2.5 - 4
M6	7 - 10	60 - 90	5 - 7.5
M8	10.5 - 16	96 - 144	8 - 12
M10	27 - 40	240 - 360	20 - 30
M12	40 - 60	360 - 576	30 - 48
M16	90 - 135	780 - 1200	65 - 100

Table 12–1. – Torque Settings for Electrical Connections

12.3 TORQUE SETTINGS FOR BUSBAR JOINTS

The figures in Table 12–2 are for all busbar joints on copperwork.

Fastener Size Carbon Steel (8.8)	Torque Setting		
	Nm	lbf. in	lbf. ft.
M8	20	180	15
M10	40	360	30
M12	64	576	48

Table 12–2. – Torque Settings for Busbar Joints

12.4 TORQUE SETTINGS FOR MECHANICAL CONNECTIONS

The figures in Table 12–3 are for the assembly and mounting of steel parts where specific electrical connection, other than continuity, is not involved.

Fastener Size Carbon Steel (8.8)	Torque Setting		
	Nm	lbf. in	lbf. ft.
M5	4 - 6	36 - 54	3.0 - 4.5
M6	7 - 10	60 - 90	5 - 7.5
M8	16 - 25	144 - 216	12 - 18
M10	34 - 47	300 - 420	25 - 35
M12	54 - 82	480 - 720	40 - 60
M16	135 - 200	1200 - 1800	100 - 150

Table 12–3. – Torque Settings for Mechanical Connections

13. CONTACT DETAILS FOR SALES, SERVICE & SUPPORT

www.ge.com

Please refer to your local technical support centre if you have any queries about this product.

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