Operation, Maintenance & Commissioning Manual

NYV3 5kVA Inverter Systems

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Revision History of the 5kVA Inverter Systems

Manual Revision 3 Released 28/07/2021

- Software Revision 3 for VSI
- Draft version released 1/12/21
- Updated the schematic 21/12/2021

Manual Revision 3.01 Released 04/01/2022

- Updated definition of serial port keyboard definitions
- Updated schematic drawings pages 1 - 3
- Updated the settings parameters values

Manual Revision 3.02 Released

- Added definition of Operating Modes to Section 7
- Added Operating Modes and Synchronisation options to Section 9.7.18

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CAUTION
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1.0 Safety Precautions

1.1 Warning

This equipment contains hazardous voltages. Loss of life, severe personal injury or property damage may result if the instructions contained in this manual are not followed.

Only qualified personnel should work on this equipment, and only after becoming familiar with all of the safety notices, handling, installation and operating procedures contained in this manual.

The safe and successful operation of this equipment is dependent upon proper handling, installation, operation and maintenance.

1.2 Definitions

For the purpose of this manual and product labels the following definitions apply.

1.2.1 *Qualified person*

A qualified person is someone who is familiar with the installation, construction, operation and maintenance of this equipment and all of the associated hazards. In addition, the person must have the following qualifications:

- Is trained and authorized to energise, de-energise, ground and tag circuits and equipment in accordance with established safety practices.
- Is trained in the proper care and use of protective equipment in accordance with established safety practices.
- Is trained in rendering first aid.

1.2.2 *Danger*

Danger indicates that loss of life, severe personal injury or substantial property damage <u>WILL</u> result if proper precautions are not taken.

1.2.3 *Warning*

Warning indicates that loss of life, severe personal injury or substantial property damage <u>CAN</u> result if proper precautions are not taken.

1.2.4 *Inverter System*

Inverter System indicates a grid connected 3 Phase Inverter system.

1.2.5 *Module*

Module indicates the Enclosures within the Inverter System.

1.2.6 *Inverter Module*

Inverter Module indicates the non-isolated DC-AC VSI Enclosure within the Inverter System.

2.0 General Description

The Inverter Module is a Grid-Connected Active Rectifier/VSI that interfaces to a 400VAC line-line, 50Hz, 3 phase grid. It operates with a nominal 600-700V DC bus. The Inverter Module uses IGBT technology for the main switching power stage and is non-isolated. A dedicated MCU controller monitors operation and it can communicate with a Modbus System Controller. Additionally, a USB interface is also provided for direct serial port access to the Module.

An external SCADA system can issue control signals to the inverter via a MODBUS (RS485) interface to control the power flow through the inverter.

The Inverter Module is mounted within a 19” 3U high, 600mm deep enclosure, with all of the power and control connections made at the rear of the unit. LED status and the USB interface are accessible/visible from the front panel.

3.0 Technical Features

- IGBT based three-phase active rectifier/VSI Module
- AC Current Regulation (including 3rd, 5th, 7th, 11th and 13th harmonics)
- DC Bus Voltage Control
- AC Over Current protection
- Heatsink Active Temperature Monitoring and Protection
- Output short-circuit Protection
- DC Under & Over Voltage Protection
- DC voltage monitoring (external + internal)
- Complete power stage disconnect (AC and DC contactors)
- High efficiency operation
- Fan Forced Cooling
- Modular design for easy maintenance
- RS485 MODBUS interface
- Auto-restart on fault elimination [I]

I Behaviour is dependent on the type and frequency of fault

4.0 Technical Specifications

4.1 Inverter Module

4.1.1 *Microgrid AC Side*

Rated Grid Voltage	: 400V AC 3 phase, 3 wire 50Hz
Minimum Grid Voltage	: 400V AC – 15% (340V AC)
Maximum Grid Voltage	: 400V AC + 15% (460V AC)

4.1.2 *HV DC Side*

Rated DC Voltage	: 550V – 750V DC – grid connected
Minimum DC Voltage	: 150V DC[I]
Maximum DC Voltage	: 750V DC

4.2 General Data

Efficiency	: More than 93%
Operating Temp. Range	: -5°C to 55°C
Cooling Medium	: Forced air cooling
Construction	: 19” Rack 3U Modular
Dimension (mm)	:
All Cubicles Overall	: 483(W) x 650(D) x 133(H)
Weight	: 14.6kg
Protection	: IP 20
Communications	: MODBUS (rear panel)
	: USB Serial (front panel)

I DC Bus Voltage < 550VDC when not operating in grid connected mode

5.0 Construction

5.1 Design

The 5kVA Inverter Systems have the following major functional elements:

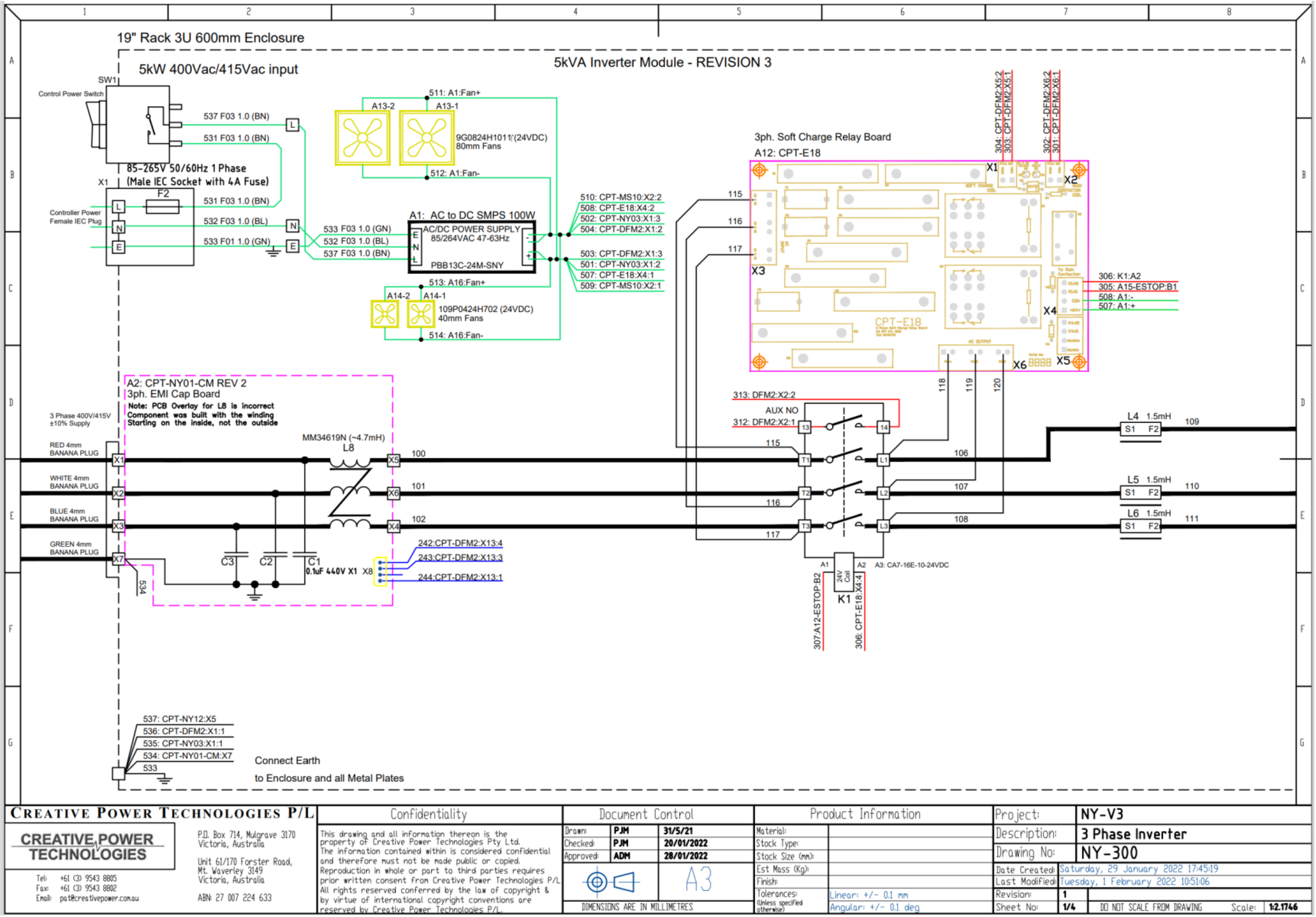
5.1.1 *Inverter Module*

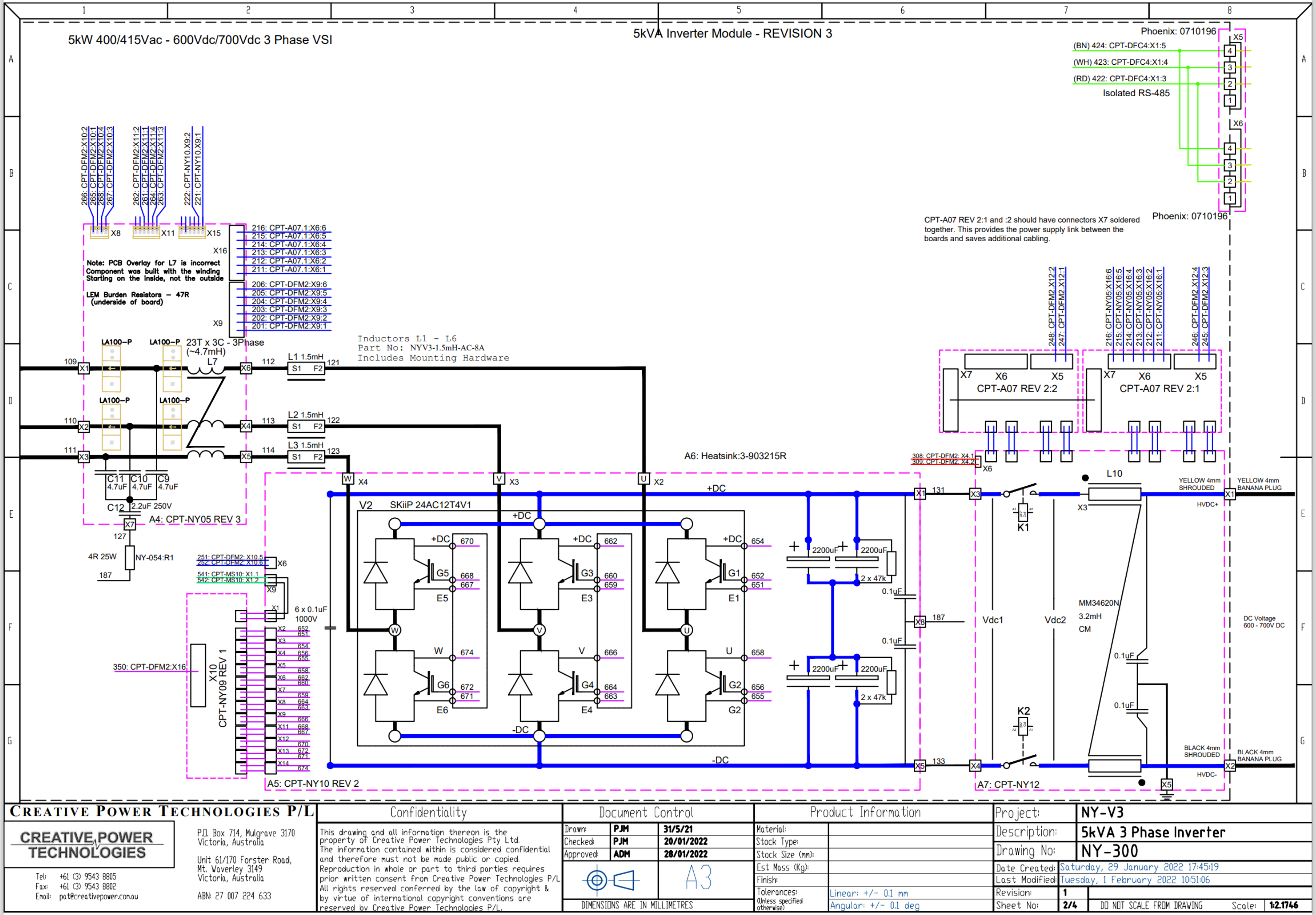
- Grid Soft Charge Contactor (Full Isolation at start-up)
- AC Inductors (2 sets of 3 phase)
- AC Filter Capacitors (PCB mounted)
- Three-Phase IGBT based PWM Active Rectifier / VSI Module
- Bulk DC Link Capacitors (High Voltage Bus)
- MCU based Controller Boards (including Isolated Communications)
- LEM Current Feedback
- Protection & Sensing Elements

All of the above components are permanently installed in a specially designed 19" cubicle. The power device is mounted on an earthed heatsink and the heatsink is forced air cooled via two 80mm fans. There are two 40mm circulating fans to ensure movement of air around the enclosure, particularly with inductor cooling in mind.

Note that the enclosure is not designed to be self-supporting in a 19" rack. It must be mounted sitting on a 19" shelf. The modules can run on a bench, but note that the front panel does protrude below the rest of the enclosure, as per a standard 19" configuration.

5.2 Schematic




5kW 400/415Vac - 600Vdc/700Vdc 3 Phase VSI
5kVA Inverter Module - REVISION 3
Phoenix: 0710196
(BN) 424: CPT-DFC4:X1:5
(WH) 423: CPT-DFC4:X1:4
(RD) 422: CPT-DFC4:X1:3
Isolated RS-485
CPT-A07 REV 2:1 and :2 should have connectors X7 soldered together. This provides the power supply link between the boards and saves additional cabling.
Note: PCB Overlay for L7 is incorrect Component was built with the winding Starting on the inside, not the outside
LEM Burden Resistors – 47R (underside of board)
216: CPT-A07.1:X6:6
215: CPT-A07.1:X6:5
214: CPT-A07.1:X6:4
213: CPT-A07.1:X6:3
212: CPT-A07.1:X6:2
211: CPT-A07.1:X6:1
206: CPT-DFM2:X9:6
205: CPT-DFM2:X9:5
204: CPT-DFM2:X9:4
203: CPT-DFM2:X9:3
202: CPT-DFM2:X9:2
201: CPT-DFM2:X9:1
LA100-P
23T x 3C - 3Phase (~4.7mH)
L7
L1 1.5mH
L2 1.5mH
L3 1.5mH
Inductors L1 - L6
Part No: NYV3-1.5mH-AC-8A
Includes Mounting Hardware
CPT-A07 REV 2:2
CPT-A07 REV 2:1
A6: Heatsink:3-903215R
C11 4.7uF
C10 4.7uF
C9 4.7uF
C12 2.2uF 250V
A4: CPT-NY05 REV 3
4R 25W
NY-054:R1
V2 SKiiP 24AC12T4V1
+DC
-DC
2200uF
2 x 47k
0.1uF
6 x 0.1uF 1000V
350: CPT-DFM2:X16
X10 CPT-NY09 REV 1
A5: CPT-NY10 REV 2
L10
MM34620N 3.2mH CM
Vdc1
Vdc2
K1
K2
YELLOW 4mm SHROUDED
YELLOW 4mm BANANA PLUG
HVDC+
DC Voltage 600 - 700V DC
BLACK 4mm SHROUDED
BLACK 4mm BANANA PLUG
HVDC-
A7: CPT-NY12
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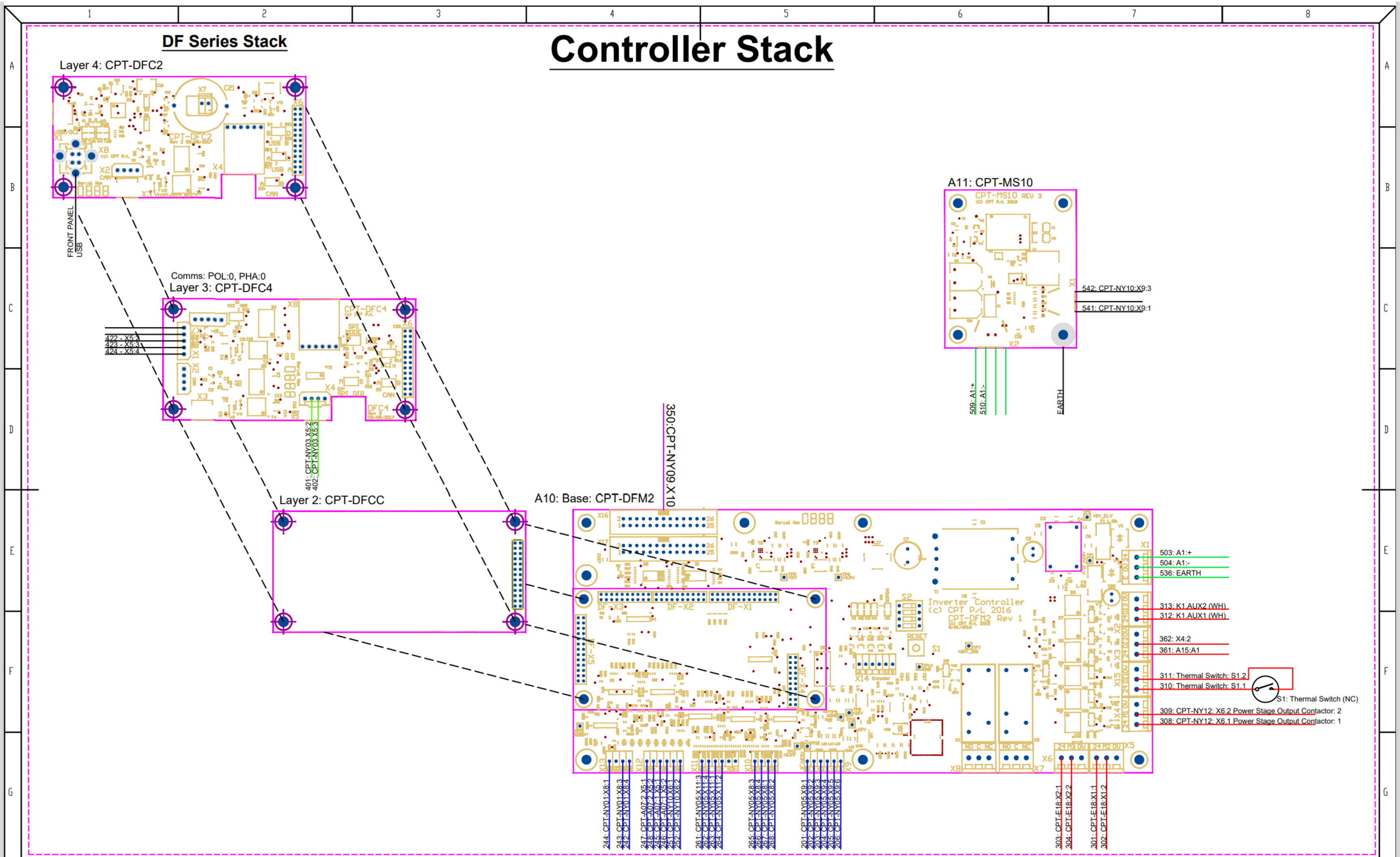
Checked: PJM 20/01/2022
Approved: ADM 28/01/2022
A3
DIMENSIONS ARE IN MILLIMETRES
Product Information
Material:
Stock Type:
Stock Size (mm):
Est Mass (Kg):
Finish:
Tolerances: Linear: +/- 0.1 mm
Angular: +/- 0.1 deg
Project: NY-V3
Description: 5kVA 3 Phase Inverter
Drawing No: NY-300
Date Created: Saturday, 29 January 2022 17:45:19
Last Modified: Tuesday, 1 February 2022 10:51:06
Revision: 1
Sheet No: 2/4
DO NOT SCALE FROM DRAWING
Scale: 1:2.1746



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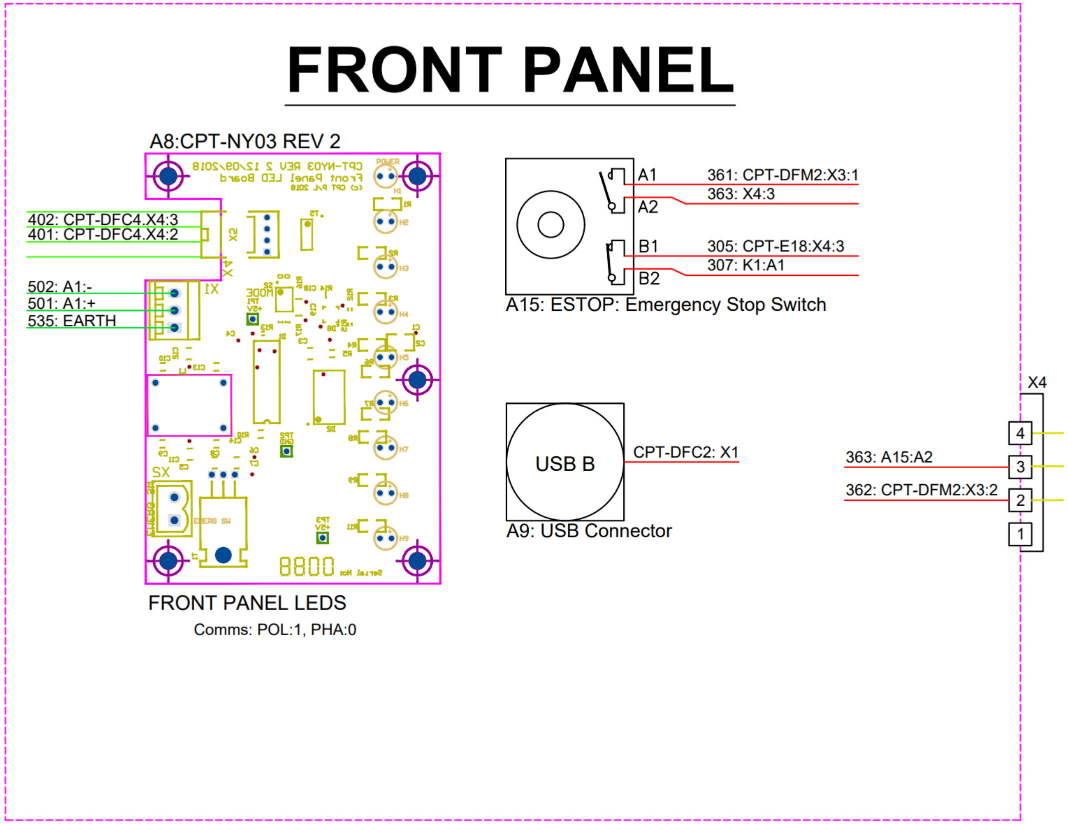
	Unit 61/170 Forster Road, Mt. Waverley 3149 Victoria, Australia		Checked:	PJM	20/01/2022	Stock Type:		Drawing No:	NY-300
Tel: +61 (3) 9543 8805	ABN: 27 007 224 633		Approved:	ADM	28/01/2022	Stock Size (mm):		Date Created:	Saturday, 29 January 2022 17:45:19
Fax: +61 (3) 9543 8802					A3	Est Mass (Kg):		Last Modified:	Tuesday, 1 February 2022 10:51:06
Email: pat@creativepower.com.au						Finish:		Revision:	1
			DIMENSIONS ARE IN MILLIMETRES			Tolerances: (Unless specified otherwise)	Linear: +/- 0.1 mm Angular: +/- 0.1 deg	Sheet No:	3/4 DO NOT SCALE FROM DRAWING Scale: 1:2.1746

FRONT PANEL



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Approved:	PJM	28/01/2022

A3

DIMENSIONS ARE IN MILLIMETRES

Product Information

Material:	
Stock Type:	
Stock Size (mm):	
Est Mass (Kg):	
Finish:	
Tolerances: (Unless specified otherwise)	Linear: +/- 0.1 mm
	Angular: +/- 0.1 deg

Project:	NY-V3
Description:	5kVA 3 Phase Inverter
Drawing No:	NY-300
Date Created:	Saturday, 29 January 2022 17:45:19
Last Modified:	Tuesday, 1 February 2022 10:51:06
Revision:	1
Sheet No:	4/4

DO NOT SCALE FROM DRAWING Scale: 1:2.1746

5.3 Major Component Details

Circuit Boards / Components			
Assembly No.	***Qty***	***Part Number***	***Description***
A1	1	PBB13C-24M-SNY	85-265VAC / 24VDC 100W SMPS
A2	1	CPT-NY01-CM REV 2	3 phase EMI board
A3	1	CA7-16E-10-24VDC	3ϕ AC Contactor, 24V DC electronic coil
A4	1	CPT-NY05 REV 3	3ϕ LEMs, Cap Filter Board
A5	1	CPT-NY10 REV 1	3ϕ VSI Power Stage (SKiiP Module) Includes: CPT-NY09 Gate Driver Board Semikron SKiiP 24AC12T4V1
A6	1	3-903215R	Heatsink – Cool Innoventions
A7	1	CPT-NY12 REV 1	DC EMI Filter + Contactors Board Includes: 2 off CPT-A07 REV 2
A8	1	CPT-NY03 REV 2	Front Panel LED Board
A9	1	09454521901	USB Connector – Hartung Socket Type A 2.0
A10	1	CPT-DFM2 Stack	CPT MCU Controller cards Includes: CPT-DFM2, CPT-DFCC, CPT-DFJ, CPT-DFC4
A11	1	CPT-MS10 REV 3	24V to Isolated 15V power supply
A12	1	CPT-E18 REV 2	3 Phase Soft Charge Board
A13	2	9G0824H1011	80mm Fan (24VDC)
A14	2	109P0424H702	40mm Fan (24VDC)
A15	1	SP0786	ESTOP: Emergency Stop (2 x NC contacts)
L1-L6	6	NYV3-1.5mH-AC-8A	1.5mH, 8A Inductor
R1	1	RH504R000FS03	4R 50W
SW1	1	GRS-2012-2009	ON/OFF Switch
V2	1	Semikron SKiiP 24AC12T4V1	1200V, 50A 3ϕ IGBT Module

Metal Sheets / Enclosures / Panels		
Assembly No.	***Qty***	***Description***
NY-302	1	Mounting Plate for E18/Power Supply
NY-310	1	19” 3U High – Front Panel for NYV3
NY-311	1	19” 3U High – Back Panel for NYV3
NY-312	1	19” 3U High – Left Panel 600mm depth for NYV3
NY-313	1	19” 3U High – Right Panel 600mm depth for NYV3
NY-314	1	19” 3U High – Bottom Panel 600mm depth for NYV3
NY-315	1 – Type A 1 – Type B	Z-shaped bracket for NY10 #1
NY-316	1 – Type A 1 – Type B	Z-shaped bracket for NY10 #2
NY-318	1	Z-shaped bracket for NY10 #3
NY-321	1	Thin L-shaped cover for the heatsink
NY-322	1	19” 3U High – Top Panel 600mm depth for NYV3
NY-323	1	Inductors Mounting Plate

5.3.1 *Inverter Module Connectors*

Circuit Boards			
Assembly No.	***Qty***	***Part Number***	***Description***
X1	1	IEC Male	Controller Power (85-265VAC 50/60Hz) Fuse Protected Safety Earth
X2	1	4mm Shrouded Sockets (Red, White, Blue, Green)	400V/415V 3ϕ Grid Connect Red, White, Blue – Phase Voltages Green - Earth (EMI path)
X3	1	4mm Shrouded Sockets (Yellow, Black)	HVDC Yellow– DC+ Black – DC-
X4	1	Phoenix 0710196 04 DFK-MSTB2,5/4-GF-5,08	ESTOP – External Emergency Stop connector. Normally Closed. Opens on Fault. In series with A15, the front panel Emergency stop button **Supplied with SHORTING LINK INSTALLED FOR CORRECT OPERATION – customer may add external NC contact as part of their system**
X5	1	Phoenix 0710196 04 DFK-MSTB2,5/4-GF-5,08	Main RS485 MODBUS Interconnect Port In parallel with X6
X6	1	Phoenix 0710196 04 DFK-MSTB2,5/4-GF-5,08	Spare RS485 MODBUS Port In parallel with X5
X7	1	09454521901	USB Connector – Hartung Socket Type A 2.0

X4 shorting link is a Phoenix MSTB2,5/4-ST-5,08 connector with pins 2-3 shorted.

6.0 Commissioning Instructions

6.1 Handling and storage

- Lift the module only with equipment that is appropriately rated and operated by trained personnel. The modules **MUST** be kept flat (horizontal) during transport.
- Improper lifting or handling can cause serious injury.
- Avoid severe jolts e.g., when setting the modules down.
- The consignment must not be stored outdoors or stacked.

6.2 Installation

6.2.1 *Rack Mounting*

- The Inverter Module can be installed within a 19” rack structure.
- It must be installed onto an existing 19” rack shelf as it cannot support its own weight in that installation.
- Ensure that any bolts are firmly and evenly tightened.
- Ensure that the module has adequate free space
  - For the fan openings on the left and right sides and the air vent on the right side.
  - For the cable entry at the Module rear for easy cabling.
  - In front of the cubicle to provide unimpeded access to the emergency stop button, Status LEDs and, if used, the USB interface.

6.2.2 *Expected External Hardware*

The following items are expected to be provided as a matter of course by the operator of the 5kVA Inverter Systems:

- A three-phase isolation switch between the Inverter Module Microgrid/Grid interface terminals and the Microgrid/Grid itself.
- A fused cable with an isolation switch between the DC terminals and any DC source, where the fuse and isolation switch are as close to the source as possible.
- All external cabling. Power cabling is to a 4mm banana plug termination.

WARNING!

Although the 5kVA Inverter Systems have internal isolation contactors on both the AC and DC interfaces, it is imperative that additional external isolation and fault protection devices are provided by the operator. This is to ensure that in the event of an emergency, the power systems can be completely isolated and prevent hazardous conditions from arising or potentially fatal accidents from occurring.

6.2.3 *Cabling*

WARNING!
Hazard of Electrical Shock! Capacitors retain charge after power is removed. Wait until the voltages across the Main DC bus is less than 10 VDC before servicing the Inverter or DC-DC Converter Modules (approximately 10 minutes)

- Before attempting any connection/ cabling work, CHECK and ENSURE that the system is electrically isolated (i.e., all the external MCBs and the inverter itself are disabled or in the OFF position) and all the cables are 'dead'.
- The System is safety earthed via the IEC cable. Please ensure that a 3 pin IEC cable is used with an explicit EARTH.

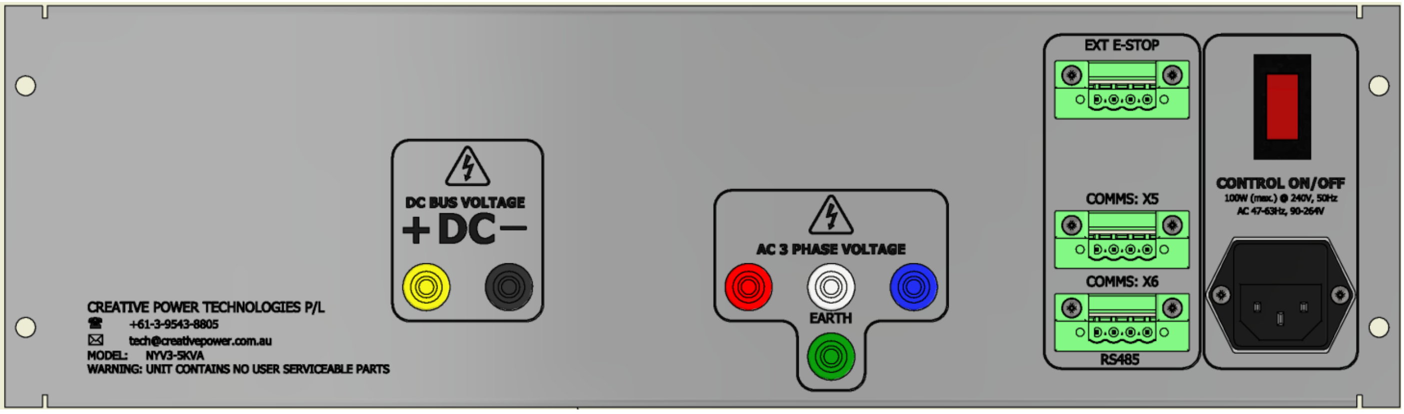

Figure 6-1: 5kVA Inverter Back Panel

6.2.3.1 For Power Cables

- First, ensure that the ON/OFF switch on the right rear of the Module is turned off, as per the diagram below.

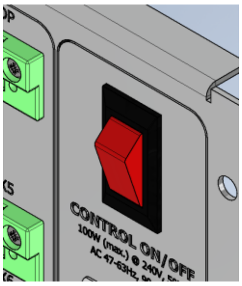

Figure 6-2: 5kVA Inverter Control Power Switch OFF position

- Connect the IEC Female plug cable to the Male IEC socket (**X1** - Inverter).
- Connect the DC Bus Cables (4mm Banana Plug terminations) to the Yellow (DC+) and Black (DC-) 4mm Shrouded Terminals on the rear of the Module.
- Connect the 3 phase AC supply (4mm Banana Plug terminations) to the Red (*A/u* Phase), White (*B/v* Phase) and Blue (*C/w* Phase) 4mm Shrouded Terminals on the rear of the Inverter Module.
- The Power earth should be connected to the Green 4mm Shrouded Terminal.
- Use appropriately sized & type of cable terminations for each of the cables.

- Ensure that all connections are tight (so that sparking due to loose connections and hence damage to the equipment is avoided).
- While routing the cables, avoid any sharp bends or sharp edges.

6.2.3.2 For Control Cables

- Connect RS485 Communications to **X5** on the Module's rear. Either **X5** or **X6** can be used as they are paralleled to enable daisy chaining.
    - The connector required is a Phoenix MSTB 2,5/4-ST-5,08
        - Signals are:

          Pin 2: RS485_A
          Pin 3: RS485_B
          Pin 4: RS485_GND

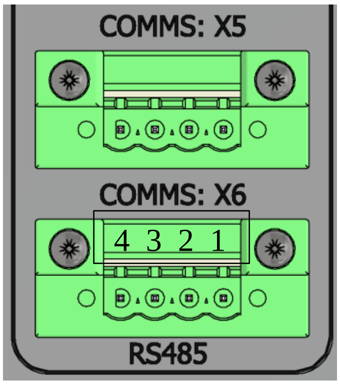

Figure 6-3: RS485 Connectors, X5 and X6

- Connect the USB Serial Communications connector to the **USB A** connector on the Module's front. (if required)
    - Each module has been provided with a USB A to USB A 1 metre cable.
- **X4** External ESTOP Connector.
    - External ESTOP is NOT used
        - Ensure that the supplied shorting connector is installed.
    - External ESTOP is used (External System Trigger)
        - Ensure a Normally Closed clean contact is used and connected across pins 2 and 3 of **X4** as per schematics page 4 and below.
    - The connector required is a Phoenix MSTB 2,5/4-ST-5,08 (1757035)

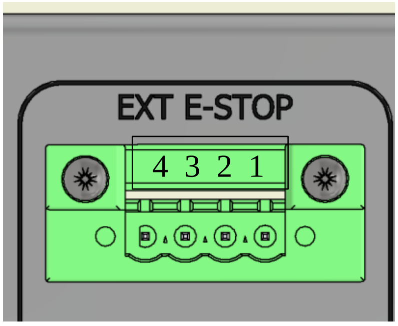

Figure 6-4: External E-STOP connection

6.2.4 *Power-up Procedure*

WARNING!

Hazard of Electrical Shock! Capacitors retain charge after power is removed. Wait until the voltages across the Main DC bus is less than 10 VDC before servicing the Inverter or DC-DC Converter Modules (approximately 10 minutes)

- Ensure that external protection circuitry as described in Section 6.2.2 is present.
- Check and ensure that the DC breakers (external DC isolating switches) are in the OFF position.
- Apply mains (220/240V) power to the Module via the IEC socket and switch the Rocker switch on the right rear of the unit to ON.
- Actuate the external 3 phase MCB Inverter Module to connect the external 3 phase supply to the Inverter internals.
- Ensure that cooling fans have immediately begun operating.
- Ensure that "Controller On" LED is illuminated on the energized Module.
- If using the RS 485 interface: Query the `STATUS` (0002) and `VERSION` (0011) Modbus registers via the RS485 interface and ensure a valid value is returned.
    - If the `ADDRESS` Modbus register has not yet been configured, write the necessary values to this register. Note that a single module should be energized to enable setting of this register. By default all modules start with the same address. Record and store the module address in a safe location as losing this will affect Modbus access.

  Note: Detailed instructions on how to access and write Modbus registers are included in Section 9.4.
- Write to the Settings group Modbus registers via the RS485 interface to configure the units for the appropriate operation, and to reflect the current hardware configuration. Read these values back to ensure they have been written correctly. Changes to most of these registers are automatically written to flash memory.

Note: At any time, pressing the Emergency Stop button will immediately deactivate the switching of a unit. However, due to the way the system operates, it is recommended that it is only used in unexpected or hazardous circumstances. Sending a STOP command to the Command Group Modbus register is the appropriate and preferred method and will terminate the switching process gracefully.

7.0 Technical Description

The 5kVA Inverter Systems are compatible with both stand-alone and Microgrid system operation. By default the system is configured for Constant DC Bus Voltage with Grid/Microgrid connected.

The system has 4 available operating modes, which are: Open Loop Modulation (OL), Current Regulated – Passive Load (CL), Current Regulated into a Grid/Microgrid (CG) and Constant DC Bus Voltage with Grid/Microgrid connected (VG).

The system operating mode should be selected before attempting to start operation. The mode to select is determined upon the external source/load combinations for the overall system.

7.1 Operating Modes

7.1.1 *Open Loop Modulation (OL)*

In ***Open Loop Modulation*** Mode the system expects to operate from a DC Supply into a passive/standalone AC load. In this mode the output voltage can be controlled through the serial port with keyboard entries used to set the frequency and modulation depth.

This mode is NOT compatible with grid connected operation. There must be no AC voltage present before the inverter can start in this mode.

The external DC supply voltage must be within 50V of the internal bus voltage before the DC contactor will close. In normal operation for Open Loop Modulation the DC supply voltage starts at zero and is increased as needed. Some fault types may result in the DC contactor opening, leaving a charged internal DC bus. In this case the operator needs to either wait for the internal bus to discharge, or adjust the external DC supply voltage to match the internal bus voltage.

7.1.2 *Current Regulated – Passive Load (CL)*

In ***Current Regulated – Passive Load*** Mode the system expects to operate from a DC Supply into a passive/standalone AC load. In this mode the load current is specified either by keyboard entry or MODBUS command, and then maintained. This mode assumes that there is a suitable DC Bus Voltage available from the DC supply.

This mode is NOT compatible with grid connected operation. There must be no AC voltage present before the inverter can start in this mode.

The external DC supply voltage must be within 50V of the internal bus voltage before the DC contactor will close. In normal operation for this mode, the DC supply voltage starts at zero and is increased as needed. Some fault types may result in the DC contactor opening, leaving a charged internal DC bus. In this case the operator needs to either wait for the internal bus to discharge, or adjust the external DC supply voltage to match the internal bus voltage.

7.1.3 *Current Regulated into a Grid/Microgrid (CG)*

In ***Current Regulated into a Grid/Microgrid*** Mode the system is connected to a microgrid or grid and also connected to a DC source (bidirectional power flow to/from the DC source is supported). In this mode, the inverter real current and reactive power are controlled by the inverter, whilst the DC bus voltage must be regulated by the connected external DC supply.

The external DC supply voltage must be within 50V of the internal bus voltage before the DC contactor will close. In normal operation for this mode, the DC supply voltage starts at zero and is increased to greater than the peak of the AC grid voltage before starting. Some fault types may result in the DC contactor opening, leaving a charged internal DC bus. In this case the operator needs to either wait for the internal bus to discharge, or adjust the external DC supply voltage to match the internal bus voltage.

The DC supply voltage must be greater than the peak of the grid AC voltage before the inverter will start.

7.1.4 *Constant DC Bus Voltage with Grid/Microgrid connected (VG)*

The ***Constant DC Bus Voltage with Grid/Microgrid*** (VG) Mode is the **DEFAULT** mode for this inverter system. The system is connected to a microgrid or grid and an active DC current source (such as a fuel cell or PV array). This mode means that the inverter will control the DC bus voltage and maintain it at the set value (**SET_VDC**). The real current flow in or out of the inverter AC is then determined by what power is required to maintain the bus voltage. In addition, the reactive power flow can be set for the inverter through specification of the VAr Register (**SET_QOUT**). The overall inverter cannot produce more than 5kVA.

In operation the real AC current flow is generally determined by the behaviour of the equipment connected to the Inverter’s DC terminals. For example, a system supplying power to the DC Bus such as a Fuel Cell DC/DC Converter will generate real AC power flow into the grid to maintain the DC bus voltage. Similarly, a passive load connected to the DC bus will generate real AC power flow from the grid to maintain the DC bus voltage.

NOTE: for a passive DC bus load, the passive load must be connected to the DC bus **after** the inverter is in operation, to avoid loading the DC bus during start-up. It is the responsibility of the external load equipment to make this connection safely once the inverter is in operation.

The external DC supply voltage must be less than 50V before the DC contactor will close. The inverter soft charges the DC bus from the grid before closing the main contactor. There can be no DC load on the bus during the soft charge time. If a DC load is present then the bus will not charge sufficiently and a fault will be declared.

Some fault types may result in the DC contactor opening, leaving a charged internal DC bus. In this case the operator needs to wait for the internal DC bus to discharge before restarting.

7.2 Inverter Module

The Inverter Module is a 3-phase inverter capable of bi-directional power flow. The module synchronizes to a nominal 400V AC three-phase Microgrid supply and operates with a nominal DC bus voltage of 650V DC. The Inverter module operates over an AC voltage range of 360V AC – 440V AC in grid connected modes.

An IGBT based PWM (Pulse Width Modulated) power stage, switching at 20kHz is used for the main power flow within the Module. The Inverter Module is capable of transferring power to and from the AC voltage supply.

The Inverter Module consists of bulk capacitor storage, a 3ϕ-IGBT module, filter capacitors, ac inductors, ac filter capacitors, voltage and current sensors and a MCU controller. The IGBT module is configured as a 3ϕ bridge, controlled by the CPT-DFCC MCU. The phase legs feed into an LCL filter that produces a smooth sinusoidal 3ϕ AC. The HV DC bus can be connected to a separate DC Source/Load, which can be uni-directional or bi-directional.

The power stage heatsink is fan-forced cooled with thermal protection provided within the IGBT Module with the system actively monitoring the IGBT junction temperature. Additionally, enclosure fans provide cooling across the ac inductors. When operating at full power, warm air is expected to be present at the air outlet on the right side of the inverter.

7.3 MCU Controller

The MCU Controller within the Module manages the overall module operation. It generates all switching pulses required to drive the associated IGBTs, monitors all voltage and current measurements relevant to the power module and communicates its status via the Modbus interface. The status of the Inverter is continually monitored by the MCU Controller and this information is continuously made available for interrogation by an External MODBUS Communications Module connected to (**X5** or **X6**).

If a fault is detected by the MCU Controller, the IGBT switching pulses are blocked and fault details are reported to the External Communications Module.

7.3.1 *Gate Drivers*

The power stage board has a solder-in 3ϕ gate driver module. It utilises Texas Instruments gate driver ICs to convert MCU Controller logic level signals to isolated gate drive outputs that directly switch the IGBT module. The Texas Instruments ISO5852SDW gate driver modules have built-in capacitive isolation between the power and control circuitry so they can directly interface with an IGBT module. When a fault is detected by the gate driver, it issues a fault signal, blocks all gate driver pulses to protect the IGBTs and sends a fault signal to the MCU Controller. Similarly, when the MCU Controller detects a fault it triggers a shutdown of all gate driver signals to ensure overall Module protection. There is a separate RESET* signal that is cycled to clear a gate fault condition.

A permanent gate fault condition will not clear in this case. For proper operation of the gate modules both the Ready and Reset inputs must be logic level high. This process is handled automatically within the inverter software and is only mentioned here as a notice for the user.

7.3.2 *SMPS (Switched Mode Power Supply)*

The Switched Mode Power Supply operates from an 85-265V AC 50/60Hz input and generates the internal 24V DC / 100W that is reticulated throughout the Module.

This inverter system works with separate control and power connections. All control power is supplied via the SMPS. The SMPS is powered via the IEC socket rear of the module and is energised via the power switch located above the socket.

7.4 LEM Sensing

The ac current is measured through the on-card LEM Sensing modules which send a scaled current to the MCU controller. The LEM modules are located on the CPT-NY05 circuit board that also contains the LCL filter capacitors and a common mode filter.

7.5 Soft Charge Relay Boards

The Soft Charge relay board within the Inverter System is for the AC input. The board receives control signals from the MCU controller that drive the soft charge contactor (on-card) and the main power contactor.

The AC Microgrid soft charge relay board enables controlled charging of the DC bus through the on-card soft charge resistor and relay, and aids with synchronization to the Microgrid by controlling the main contactor. The board contains fuses to protect against a system fault during soft charging.

7.6 Protection

The Module has internal protection against abnormal operation. If a fault condition is detected, the module outputs are immediately tripped and isolated, and an appropriate LED fault indication is illuminated. The Fault is also indicated via the External Communications Module. More detailed information relating to the fault can be accessed by interrogation of the Modbus Fault Registers.

When a fault is cleared, the system will automatically restart, with a time delay that depends on the type of fault that has occurred. Repeated occurrences of the same fault within a prescribed time period will cause a permanent fault lockout that can only be reset by power cycling the system.

7.6.1 *Input AC Under / Over Voltage*

The Inverter Module’s MCU Controller continuously monitors the Microgrid AC voltage. The voltage measurement point is located before the soft-charge relay and main contactor, to also enable detection of a soft-charge relay or contactor failure.

When the measured AC Microgrid voltage is outside the acceptable operating range (below 360V AC or above 440V AC (400V ± 10%)), the MCU Controller initiates a self-protection system shutdown. The Inverter Module front panel fault LED illuminates for over voltage conditions, and the fault occurrence is logged to the Modbus register.

When the AC Microgrid voltage returns within the acceptable operating range the system resumes normal operation. Interrogation of the Fault Registers will indicate the cause of the fault shutdown.

7.6.2 *DC Bus Voltage not present with AC Voltage and Closed Contactors*

The inverter continually monitors the DC bus voltage to ensure that it is at a sensible value with respect to the AC input voltage. This test is active when the input AC voltage exceeds the imbalance limit specified by the `VAC_IMB_LIM` register. The measured DC voltage must be outside the permissible percentage difference, $\left(\frac{\texttt{VDC\_IMB\_DIFF}}{10}\right)$%, for at least $\left(\frac{\texttt{VDC\_IMB\_CNT}}{10}\right)$ seconds for a fault to be declared. For example, this fault occurs if the inverter believes the main contactor is closed but the voltage measurements do not match that condition.

If the voltage imbalance is detected the fault LED will be set and the system shutdown. The fault occurrence is logged into the internal fault record. Interrogation of the Fault Registers will indicate the cause of the fault shutdown.

7.6.3 *LEM Failure*

As part of the start-up procedure the Inverter measures the no-load output of the LEM modules to calibrate them. If the LEM outputs are not within bounds a LEM Failure fault is triggered.

During normal inverter operation if the LEM output exceeds limits an overcurrent trip would be triggered that disables the inverter output. If the LEM were to continue reading an out-of-range value then a LEM failure may also be triggered.

A fault LED pattern is displayed on the Inverter, and the fault occurrence logged into the internal fault record. Interrogation of the Fault Registers will indicate the cause of the fault shutdown.

7.6.4 *Soft Charging Failure*

The System initialisation process requires the internal DC bus capacitors to have been charged above a pre-set voltage before the main contactors close to initiate synchronization and normal operation. The MCU controllers monitor the internal voltages and if they fail to reach the threshold within 30 seconds of the soft charge relay closing a CHARGE FAULT is initiated to protect the system from a possible DC bus short. The front panel fault LED illuminates, and the fault occurrence is logged into the Modbus register. Interrogation of the Fault Registers will indicate the cause of the fault shutdown.

In Open Loop Modulation mode and Current Regulation – Passive Load mode, the soft charge process and protection is bypassed.

7.6.5 *Output AC Over Current*

The AC current overload limits can be specified through Modbus and consist of four software selectable trip levels and one hardware limit. The Inverter output overload characteristics are based on a piece-wise stepped model as shown in Figure 7-1. For example, the inverter will trip if the output is sustained above 105% of rated output current for 30 seconds. The instantaneous overcurrent can be set via `IAC_INST_OC`.

The three piece-wise trip levels are defined as Levels 3, 2, 1 and 0 with sensitivity set at 2, 5, 10 and 30 seconds respectively. They are configured by default to approximate an I^2t curve, as can be seen in Figure 7-1. These overload settings can be configured via the Modbus Interface using registers `IAC_OL_LEVEL0`, `IAC_OL_LEVEL1`, `IAC_OL_LEVEL2` and `IAC_OL_LEVEL3`. The default register settings are shown in Table 7-1.

AC Trip Current Level		*AC Trip Current Time*	
Register	***Default % of Nominal Current***	***Register***	***Default Time to Trip (seconds)***
`IAC_OL_LEVEL0`	105.0	`ACI0_OL_TIME`	30
`IAC_OL_LEVEL1`	107.5	`ACI1_OL_TIME`	10
`IAC_OL_LEVEL2`	110.0	`ACI2_OL_TIME`	5
`IAC_OL_LEVEL3`	120.0	`ACI3_OL_TIME`	2

Table 7-1: Default Overload Current Settings

It is recommended that if any changes are made to the above settings, the fault magnitude sequence structure shown in Figure 7-1 is maintained.

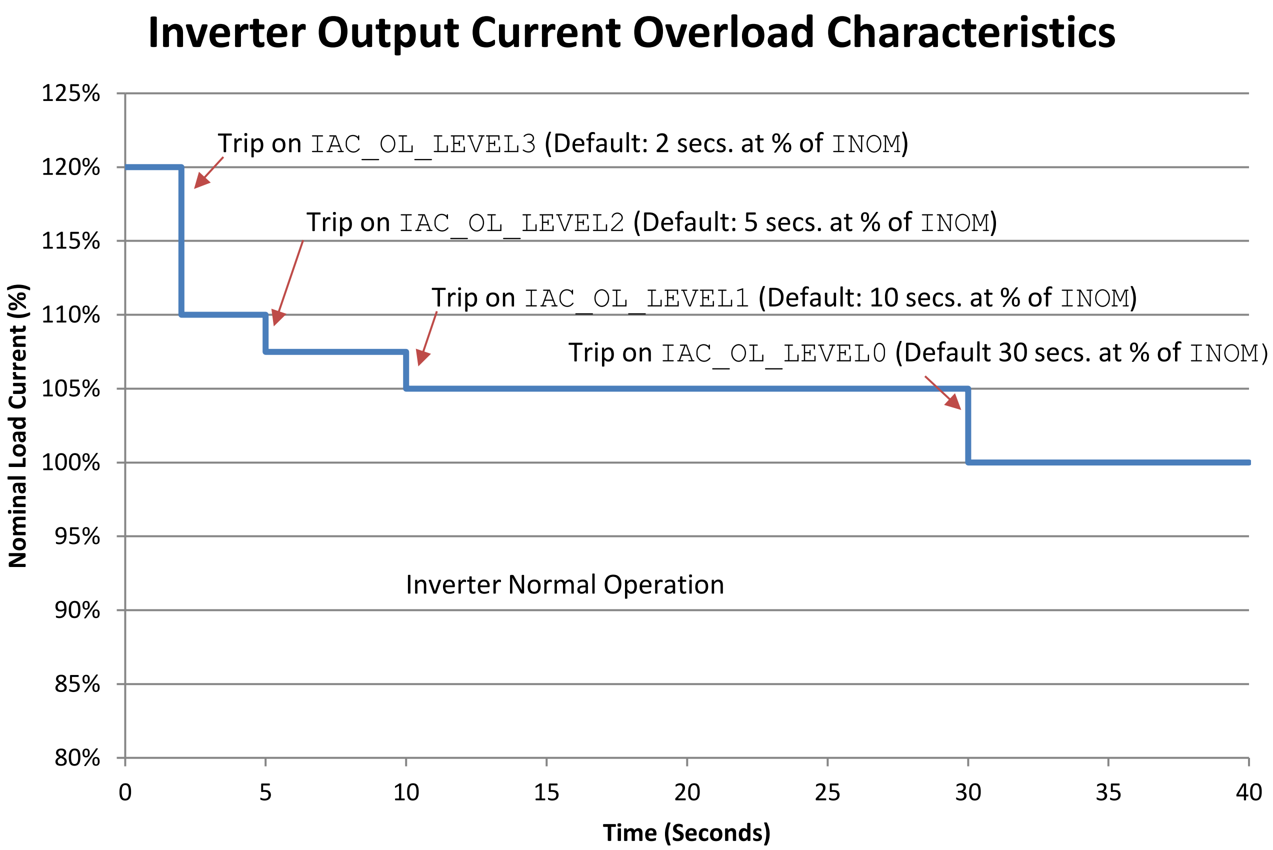

Figure 7-1: Inverter Overload Characteristics - I^2t equivalent

If an output AC over current is detected then the status LED pattern for *AC Over Current – Hardware Trip* is displayed, and the fault occurrence logged into the internal fault record.

If an output overload condition is detected the status LED pattern for *AC Current Overload* is displayed, and the fault occurrence logged into the internal fault record. Interrogation of the Fault Registers will indicate the cause of the fault shutdown.

A sustained short circuit on the Inverter at start-up, such as a dc bus fault, will be detected by the measurement circuitry, with fuses on the soft-charge relay board acting as an ultimate back-up protection if the software fails to trip the relay.

7.6.6 *DC Bus Over Voltage*

The MCU Controller continuously monitors the DC bus voltage. If the measured voltage exceeds the internally set hardware limit, DC Bus fault is triggered and the Inverter Module initiates a self-protection system shutdown. The front panel fault LED illuminates, and the fault occurrence is logged into the Fault Modbus registers for interrogation.

7.6.7 *Over Temperature*

A Temperature sensor is built into the 3 phase IGBT module. If the measured junction temperature exceeds the sensor trip point (`TEMP_TRIP`), the MCU Controller initiates a self-protection system shutdown.

The thermal measurement has a built-in hysteresis, which is set via `TEMP_HYST`. This ensures that the fault condition will remain until the measured junction temperatures is below (`TEMP_TRIP - TEMP_HYST`) at which point the system will reset and operation can be resumed. The front panel fault LED illuminates, and the fault occurrence is logged to the Modbus register.

Typically, at full power, the junction temperature sits about ~30°C above ambient, which is well below the 120°C default trip point.

7.6.8 *MCU Over Temperature*

The MCU controller supports internal monitoring of its core temperature. If the value exceeds the safe limit for the processor, then an MCU Over Temperature fault is triggered and the unit will be shut down.

An *MCU Over Temperature* is reported to the Modbus register, triggers the front panel fault LED to illuminate, and the fault occurrence is logged.

7.6.9 *Semiconductor Device Failure*

The status of the IGBT power switching device is continuously monitored by the Texas Instruments gate drive modules. If a fault is detected, it is reported to the MCU Controller, which then initiates a self-protection system shutdown. The module front panel fault LED illuminates, and the fault occurrence is logged to the Modbus register.

7.6.10 *Reverse Polarity Protection*

The Inverter DC connection is protected against reverse connection of the DC source.

If the DC supply is reversed the MCU Controller detects this condition and will not operate the DC contactor. The Inverter Module front panel fault LED illuminates, and the fault occurrence is logged to the Modbus register for interrogation.

7.6.11 *Loss of Phase*

If an AC input phase is removed for any reason, the Inverter Module front panel fault LED illuminates, and the fault occurrence is logged to the Modbus register for interrogation.

7.6.12 *Phase Sequence*

The Inverter Module software has built-in AC phase sequence detection as part of its synchronization process. This ensures that a phase wiring reversal will not prevent the

Inverter Module from operating. The Synchronisation light illuminates when the unit is “in sync”. It will be permanently illuminated for positive phase sequencing, and it will flash if synchronisation was achieved with negative phase sequencing.

7.6.13 *Emergency Stop*

Each Module has an Emergency Stop (ESTOP) button located on the front left that can initiate an Emergency Shutdown of the Inverter Systems. This should not be used as a means of controlling the Inverters as it does not go through the standard orderly shutdown but ensures everything is immediately made safe.

In additional an External Emergency Stop (ESTOP) can be wired to the EXT ESTOP connector on the rear of the Module. A shorting connector is provided by default for this Normally Closed connection. Pins 2 and 3 are used for the external clean contact ESTOP signal.

<u>Note:</u> The Inverters will not start while the Emergency Stop button is engaged.

7.6.14 *Hardware Error*

This fault indicates that a generic fault has been detected within the MCU relating to the hardware that is not covered by any of the other faults. Its presence will be reported to the status LEDs on the appropriate MCU controller, and the unit will be shut down. The fault occurrence is logged to the internal fault records.

7.6.15 *Software Error*

This fault indicates that a generic software fault has been detected within the MCU that is not covered by any of the other faults. Its presence will be reported to the status LEDs on the appropriate MCU controller, and the unit will be shut down. The fault occurrence is logged to the internal fault records.

7.6.16 *Unknown Error*

This fault indicates that a condition has been reached that cannot be explained by any other fault. Its presence will be reported to the status LEDs on the appropriate MCU controller, and the unit will be shut down. The fault occurrence is logged to the internal fault records.

8.0 Inverter System Module User Interface

The Inverter Module can be interrogated via an isolated RS485 Modbus interface, or alternatively via the USB connection on the front panel. A visual indication of the system status is available via LEDs located on the front of each module.

The RS485 Modbus interface is used for system operation, interrogation and logging. A detailed description of the available Modbus commands and registers is located in section 9.

8.1 Inverter Module Status LEDs

The Inverter Module has nine status LEDs on the front panel. These LEDs indicate the overall Modes of operation and system fault status.

Multiple LEDs may be illuminated simultaneously depending on the present state of the Inverter. Some of the LEDs have a Flash state with a flash rate of 2 Hz, or 0.5 seconds.

Further information pertaining to faults and modes of the Inverter Module can be obtained by querying the system via the RS485 Modbus interface or via the USB front panel interface.

The status LED panel layout is shown in the figure below, with the notional illuminated colour indicated.

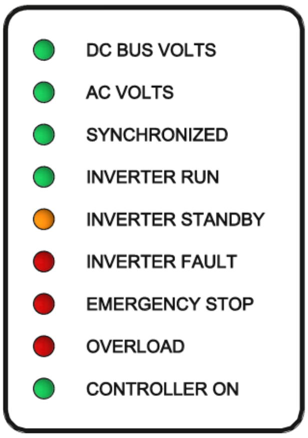

Figure 8-1 - Inverter Module Status LEDs

The following table outlines the LED definitions during normal operation.

LED Label	***Type***	***Default***	***Indication of:***
DC BUS VOLTS	Mode	ON	DC Voltage present at Inverter terminals FLASH – Indicates internal DC Bus is not suitable for the present mode of operation
AC VOLTS	Mode	ON	AC Voltage present at Inverter terminals FLASH – Indicates the AC voltage is not suitable for the present mode of operation
SYNCHRONISED	Mode	ON	Inverter has synchronised –to the grid / Microgrid ON – positive sequence synchronisation FLASH – negative sequence synchronisation
INVERTER RUN	Mode	ON	Inverter in Run Mode
INVERTER STANDBY	Mode	OFF	Inverter in Standby Mode
INVERTER FAULT	Fault	OFF	Fault Present **Warning:** Hazardous voltages may still be present.
EMERGENCY STOP	Fault	OFF	Emergency Stop Button pressed (front panel or External (Rear))
OVERLOAD	Mode	OFF	Average AC current is greater than nominal or total apparent power (VA) is greater than 5kVA
CONTROLLER ON	Mode	ON	Controller has power.

Table 8-1: Inverter Module Status LEDs

8.1.1 *LED Communications interface*

An isoSPI is used to communicate between the DFC4 and the LED display board. For reference the isoSPI configurations are as follows:

- DFC4 communications board: Polarity = 0, Phase = 0 – set on Connector S2
- NY03 (LED board): Polarity = 1, Phase = 0 – hardwired connection

8.2 Absolute Operational Limits

Description	***Value***	***Units***
AC Over Current Trip	8.0	Amps (rms)
AC Under Voltage Trip	338	Volts
AC Over Voltage Trip	482	Volts
Over Voltage Detect Hysteresis Range	5	Volts
AC Loss of Phase Detection	0.7 x VAC	Volts
DC Bus Voltage – Maximum Set Point	750	Volts
DC Bus Voltage – Minimum Set Point	150	Volts
Real Current Max. in Constant Current Mode	±12.0	Amps (peak)
Maximum Real Power	±5000	W
Maximum Reactive Power	±5000	VAr

Table 8-2: Inverter Module - Hardware Trip Limits

9.0 Detailed Modbus operation information

9.1 Introduction

The Inverter Module contains a MCU based controller which performs the analog measurements and PWM control. An overarching System Controller with a MODBUS interface can be used to connect the Inverter Module to the Microgrid system. The System Controller is linked to the MCU by an isolated RS485 serial connection using a Modbus protocol. Modbus is a very flexible and powerful control protocol designed to allow communications between Modicon programmable controllers. The following section describes the interaction between the System Controller and the Microgrid Modules.

The Modules can operate completely independent from the System Controller; however, the System Controller provides a centralized interface to change system settings and interrogate settings/measurements from the individual Modules.

Each Module stores a reference copy of its operating set points in flash and the System Controller has access to retrieve and modify this data. The reference copy must be kept in the Module to guarantee that they have valid operating parameters at all times. The System Controller can also read the analog voltage and current measurements made by the Inverter Module. Most importantly, the System Controller commands the Module to start and stop and provides new set points for the Module to follow as appropriate.

The MCU has no direct interface to the operator and no significant capacity for storage of results. It relies on the serial link to the System Controller to receive control commands and sends back status and results.

Section 9.2 provides an overview of the Communications Process with a brief description of how the external interface and system interact.

Section 9.3 describes the Modbus Protocol as used in this application.

Section 9.5 provides a list of the available Modbus Registers within the system

Section 9.12 provides a detailed description of Modbus Registers that contain bit definitions

Section 9.14 provides a guide as to what is required from a software perspective to commission and operate the system.

Section 9.16 provides sample Modbus messages as an aid to developing and debugging the Modbus communications.

9.2 Overview

The interaction between the external Modbus interface and the Inverter System can be divided into a number of different conditions:

- Power up
  The System Controller needs to establish the Modbus communications and interrogate the converter/inverter for data such as the software version numbers. The default slave address for the unit needs to be set to a unique value to avoid communications conflicts between different sub-systems in the Microgrid.

- Parameter Variation
  The operator sets configuration, calibration constants or set point variations via the System Controller. This information is stored within the Module's MCU controller.

- Operation
  The System Controller should be regularly polling the Exception Status Byte or Status register to monitor the Module status. The contents of this byte will indicate the Module operation and whether any other data is available for the System Controller. This data could be measurement results or error messages.

  The System Controller is able to start and stop the system operation. The external Modbus interface should regularly poll the Exception Status Byte or Status register for the system status.

  In addition, the System Controller can request specific data from the system, such as voltage and current measurements. The system's MCU stores updated values into its internal registers on a 0.5 second basis for external access.

At other times, when the system is idle, the System Controller should continue to regularly poll the Exception Status Byte. If the Module does not receive a message from the System Controller for an extended period, it declares a communications failure and attempts to restart the communications link.

9.3 Serial Port Access

There is a USB port on the front of the Inverter Module located behind a cover. A USB (RS232) serial port connection can be made to this port to allow interrogation of the Inverter Modules without using the Modbus interface.

The Serial Port outputs a standard one second status message which starts with the code `0030`. The format of this line can be seen within the Debug Codes of Section 11.0.

The Modbus Registers can be interrogated (Read or Write) by entering valid commands with the formats as shown in the following sections.

The Serial Port should be connected with the following settings:

Parameter	*Value*
Speed	**38.4kbaud**
Data Bits	8
Parity	None
Stop Bits	1
Flow Control	None

9.3.1 *Modbus Register Reading*

To Read a Modbus Register via the serial port interface enter:
R*<Modbus Address>[,2]*↵

Where *<Modbus Address>* is the Modbus Register for interrogation and if that Modbus Register is a 32-bit register, then add *,2* to retrieve both the low and high 16-bit words to create the 32-bit value.

As the command is being entered the screen will echo the message within a line that starts with
`0002 >`

Once the Enter key is pressed to submit the command, the interface will respond, if the command is valid, with

`0000 R` *<Modbus Address>[,2]* `command received`, and then display the register and its value.

Example 1:

Read Modus Register `0141`, which is the Inverter Nominal Current Settings Register, the following is entered:
R141,2↵

The system will respond with:
```
0000 R 141,2 command received
0023                    Reg: 141 val:6.0
```

Therefore, the present value of the Inverter Nominal Current Settings Register in this example is value `6.0`. This corresponds to a setting of 6.0Amps, as per Table 9-10.

Example 2:

Read Modus Register `1009`, which is the DC Bus Voltage Measurement Board, the following is entered:
R1009,2↵

The system will respond with:
```
0000 R 1009,2 command received
0023                    Reg: 1009 val:650.5
```

Therefore, the value of the DC Bus Voltage was measured at 650.5V.

9.3.2 *Modbus Register Writing*

Modbus Registers can be written to in either 16-bit or 32-bit form as follows.

To Write a value to a 16-bit Modbus Register via the serial port interface enter:
w<*Modbus Address*>,<*Value*>↵

To Write a value to a 32-bit Modbus Register via the serial port interface enter:
W<*Modbus Address*>,<*Value*>↵

As the command is being entered the screen will echo the message within a line that starts with
0002 >

Once the Enter key is pressed to submit the command, the interface will respond, with

0000 W <*Modbus Address*>,<*Value*> command received.

The command echo does not indicate that the write has been successful, only that the message has been received.

Not all Modbus Registers accept Write commands and many Modbus Registers have a protected status, which prevents their value from being modified without the correct Access code having been previously entered and accepted.

Typically, all protected Register values are set during testing and commissioning and there should be no need for field adjustment.

The COMMAND register can be used to download the error log, and that register's specific operation is detailed in section 9.3.3.

Example 1: (serial port data entry 32-bit register write)

Write the value 601 Volts to the *Target DC Voltage* Register. This is a 32-bit Modus Register at address 0193. Enter the following:
W193,601↵

The system will respond with:
0000 W 193,601 command received

To confirm the new value has been successfully written, complete a Modbus Read of the same address, as outlined in 9.3.1.

A 32-bit write to a 16-bit register may cause the next address value to be inadvertently overwritten.

9.3.3 *Modbus Command Register – Event/Error Log Download*

The Inverter System contains an event and error logging capability. There are two types of messages recorded by the system, EVENTS such as system start-up, and ERRORs that may be detected.

The Event and Error Log can be downloaded via the Modbus interface to allow interrogation of the system operation. This is most useful for diagnosing intermittent or permanent faults, as well as providing an overall status on the health of the system.

To download the Event and Error Log the `COMMAND` register must have the value `2100` written to it.

It is strongly recommended that text capture is enabled within the Terminal program before this command is issued to allow saving of the text to a file.

Please refer to the help for the specific terminal program that is being used.

Within HyperTerminal, which is CPT's preferred terminal program, this can be enabled via the menu item *Transfer* -> *Capture Text*

To start the log download, write the value `2100` to the Command Register as follows:
`W30,2100↵`

The system will respond with the standard Modbus Register write confirmation, followed by a command confirmation on the `0010` line. The lines following that start with `9041` are the event and error log entries. Examples are shown below

```
0000 W 30,2100 command received

0010 2100com, 1st

9041 0,0s,0401:0,0,50,0 : 0,0,0,0,0,0,0,0

9041 1,0s,4801:65535,43690,0,0 : 0,0,0,0,0,0,0,0

9041 2,0s,0921:14,65534,0,0 : 0,0,0,0,0,0,0,0
```

For specific information on the format of the `9041` entries, refer to the Debug Log table in sections 11.0 and the Log Code information within sections 12.0.

9.4 Modbus Protocol

The 5kVA Inverter System uses a sub-set of the Modbus protocol for RS485 serial communications. See the Modicon Modbus Protocol Reference Guide (http://www.modbustools.com/PI_MBUS_300.pdf) for details of the message format. This is a master-slave protocol and in this case, the Modules are the slave from the external operator's perspective. Thus, the system will only respond to correctly composed messages. Incorrect messages are ignored in this implementation of the protocol. The slave address is soft coded as the system serial number in the first instance.

The RTU mode (binary) is used. This is a binary data format which is preferable to the ASCII mode since it uses fewer bytes to encode a message. The RTU mode also specifies precise timing for message framing and the Modbus protocol has response time constraints relating to the PLC cycle time. The only timing restriction in this implementation is that the end of message is detected by the slave as a silent interval of more than 4 milliseconds. The slave (MCU) will reply as soon as possible, which is typically within 40-50 milliseconds after the end of message is detected.

The serial link operates without flow control. There is no hardware flow control in the Inverter end. If buffering problems are encountered that require flow control to be implemented, an XON/XOFF scheme can be implemented. This will also require the Modbus protocol to use the ASCII mode and is not part of the scope of this project.

The serial link is configured as **38.4kbaud, No Parity, Two Stop Bits**.

An overview of the Modbus protocol can be obtained from the Reference Guide referred to earlier, and sample messages for communicating with the MCU via Modbus are provided in Section 9.16 of this document.

9.4.1 *Supported Commands*

Not all the Modbus commands are supported by this implementation. The supported commands are listed below.

- 03 – Read Holding Register(s)
- 06 – Write Single Holding Register
- 07 – Read Exception Status
- 16 – Write Multiple Holding Registers

Note that the Read command and the Write Multiple command can only read a maximum of 100 registers. Consecutive reads and writes are required to access more registers.

Exception responses to incorrect messages are not supported. The slave will not respond to an incorrect message. The master needs to timeout on waiting for a response from the slave and record a serial link fault before attempting a message resend.

9.5 Available Registers

The read and write register commands are designed to access registers in the range 0 – 9999. Only some of these registers have meaningful values in the 5kVA Inverter System. Access to unsupported registers may give unpredictable results and is not recommended. Table 9-1 below lists the supported registers. The registers are listed in decimal format. Note that the Modbus message transmits the register value in hexadecimal and that register 0001 is addressed as 0000.

The registers are grouped to allow the use of multiple register read and write commands. There are gaps between the assigned registers to allow for future expansion of groups, if required. The groups and their address ranges are listed in Table 9-1. The registers in each group are listed in subsequent tables, with a detailed explanation of each register. The unassigned registers can be read but will return zero. Writes to unassigned registers have no effect but are not recommended as these registers may be used in subsequent software releases.

Group Name	***Range***	***Description***
System	0001-0056	System level information and control registers
Settings	0141-0240	Settings and Operation control registers
Measurement	1001-1036	Measurement registers
Calibration	2001 - 2024	Calibration registers for the Analog quantities

Table 9-1: Register groupings

9.5.1 *Register Formatting*

The Modbus protocol does not specify the contents of the register beyond it being a 16-bit word. There are a variety of formats used in this application to suit the different registers. This implementation supports pairs of registers forming a 32-bit floating-point number. There formats are described below.

<u>Number</u>: This format defines the register as a 16-bit signed integer with the range of values -32768 to 32767.

<u>Bit Field</u>: This format assigned a meaning to individual bits or groups of bits within the 16-bit register. For each bit field register there is a distinct definition of the bits provided in the detailed description of the register.

<u>Float</u>: This format defines two consecutive registers as the 32-bits that make up the floating-point type. This has the value range of ±1.18E-38 to ±3.39E38 with approximately 7 decimal digits of precision. The low address of the pair is always the low 16-bits of the 32-bit double, and the high address is the upper 16-bits. These two registers must be read or written together to ensure data integrity.

9.6 System Group

Register	Name	Access	Level	Description	Format
0001	ACCESS	W	-	Enables access to protected registers	Number
0002	STATUS	R/W	-	System status register	Bit Field
0003	EVENT_L	R/C	-	System Events register – Low Word	Bit Field
0004	EVENT_H	R/C	-	System Events register – High Word	Bit Field
0005	FAULT_L	R	-	Fault Register – Low Word	Bit Field
0006	FAULT_H	R	-	Fault Register – High Word	Bit Field
0007	DBG_LVL	W	-	Debug level setting	Number
0008 – 0009	unused		-		
0010	ADDRESS	R	1	MODBUS Address	Number
0011	VSI_VERSION	R	-	VSI MCU Software version number	Hundredths
0012	COMPATIBILITY	R	-	Software compatibility level	Number
0013	VSI_BUILD_DATE	R	-	VSI Software build date	Bit Field
0014	VSI_BUILD_TIME	R	-	VSI Software build time	Bit Field
0015	VSI_PCB_DFCC	R/W	3	VSI MCU board version	Hundredths
0016	VSI_SN_DFCC	R/W	3	VSI MCU serial number	Number
0017	PCB_DFM2	R/W	3	DFM2 Motherboard version	Hundredths
0018	SN_DFM2	R/W	3	DFM2 Motherboard serial number	Number
0019	PCB_DFJ	R/W	3	DFCJ Board version	Hundredths
0020	PCB_DFC4	R/W	3	DFC4 Board version	Hundredths
0021 – 0029					
0030	COMMAND	R/W	-	Command issued to the Master	Number
0031	MSG_GOOD	R	-	Count of good Modbus messages	Number
0032	MSG_BAD	R	-	Count of bad Modbus messages	Number
0033	ERR_LEN	R	-	Length of the VSI error log	Number
0034	ERR_INDEX	R/W	-	Present VSI error index	Number
0035-0040				Reserved	
0041	ERR_ID_L	R	-	VSI Error identifier (low word)	Number
0042	ERR_ID_H	R	-	VSI Error identifier (high word)	Number
0043	ERR_TIME	R	-	Time for present VSI error index	Number
0044	ERR_CODE	R	-	Code for present VSI error index	Number
0045	ERR_D1	R	-	Data for present VSI error index	Number
0046	ERR_D2	R	-	Data for present VSI error index	Number
0047	ERR_D3	R	-	Data for present VSI error index	Number
0048	ERR_D4	R	-	Data for present VSI error index	Number
0049	ERR_D5	R	-	Data for present VSI error index	Number
0050	ERR_D6	R	-	Data for present VSI error index	Number
0051	ERR_D7	R	-	Data for present VSI error index	Number
0052	ERR_D8	R	-	Data for present VSI error index	Number
0053	ERR_D9	R	-	Data for present VSI error index	Number
0054	ERR_D10	R	-	Data for present VSI error index	Number
0055	ERR_D11	R	-	Data for present VSI error index	Number
0056	ERR_D12	R	-	Data for present VSI error index	Number

Table 9-2: System Group

9.7 System Group Registers

All System Group Registers are 16-bit Registers or can be accessed via a 16-bit Read/Write command. Note the Fault Register has low and high, as an implicit 32-bit.

9.7.1 *Register 0001 –* `ACCESS`

The system contains protected registers. These registers can only be written to if the appropriate password/ACCESS has been entered. The `ACCESS` register is a write only register to which the password can be written.

There are 4 layers of Access within the system, as specified by the **Level** field within the Group definitions. By default, the user only has access to write to registers that are at the – or 0 level. All writes to a protected register will be ignored if the Access Level access is not correct.

Writing the appropriate Access level password to the `ACCESS` register will enable write access to the Registers corresponding to that Level.

For example, to change the Modbus Address, which is specified by Register 0010 within the System Group, the `ACCESS` register must first be written with the value `1793`, which is the LEVEL 1 password, see 9.7.27. This will enable external writes to any LEVEL 1 restricted access registers have any effect.

Once the writes are completed, this access register should be reset to 0 to prevent inadvertent writes to the restricted registers. In normal operation, the access register should never be set (i.e., It should be 0).

The system is always powered up with the `ACCESS` register set to 0, providing no protected level access enabled.

9.7.2 *Register 0002 –* `VSI_STATUS`

This read only register describes the status of the VSI system. The bit definition for this register is provided in Table 9-3. The module state machine is provided in the `VSI_STATE` bits and their definition is given in Table 9-4.

Bit	Name	Description
0	`RUN`	System is in the Run State 1 – Inverter Module is in Run Mode 0 – Inverter Module is in Stop/Wait Mode
1	`ERROR`	System is in an error state, check the Error register
2	`ACV_IMB`	AC Voltage Imbalance detected
3	`MCU_ALIVE`	System MCU has completed its start-up tests
4	`NO_MB`	System has detected No Modbus Communications
5	`BAD_PARAMS`	Bad Parameters in Flash
6	`SHUTDOWN`	System Shutdown Initiated
7	`OVERLOAD`	VSI Output Overload
8	`VSI_MODE_VG`	Constant Voltage Grid Connected Operating Mode
9	`VSI_MODE_CG`	Constant Current Grid Connected Operating Mode
10	`VSI_MODE_CL`	Constant Current Passive Load Operating Mode
11	`VSI_MODE_OL`	Open Loop Modulation Operating Mode
12 – 15	`VSI_STATE`	System Operating State (Simplified State Machine)

Table 9-3: Status Register Bit Definitions

Mode	Bit(15-12)	Name	Description
0	0000	INIT	System is Initialising
1	0001	LEM CHECK	LEM check for faults
2	0010	CAL	Analog calibration check
3	0011	VDC WAIT	System is waiting for correct DC voltage
4	0100	VAC WAIT	System is waiting for correct AC voltage
5	0101	CHARGE	System is Charging the DC Bus
6	0110	CLOSE	System is closing the main contactor
7	0111	STOP	System is Waiting for the RUN/ENABLE signal
8	1000	RAMP UP	System is Ramping to the Target Output
9	1001	RUN	System is Operating Normally
10	1010	RAMP DOWN	System is Ramping Down before stopping
11	1011	FAULT	System is in a Fault condition
12-15		Undefined	Not Used

Table 9-4: Status Register – VSI_STATE Bit Definitions

9.7.3 *Register 0003* – VSI_EVENT_L, *Register 0004* – VSI_EVENT_H

These registers describe any events that have occurred in the VSI system. The register bits are defined in Table 9-5. This prevents new events being cleared by accident when an old event is being cleared. For this system only the VSI_EVENT_L register is valid.

Register	Bit	Name	Description
EVENT	0	RESET	VSI system has reset
	1	VSI INIT	MCU Flash Parameter Retrieval initialisation complete
	2	ADC INIT	MCU ADC initialisation complete
	3-7		Reserved
	8	COM_GOOD	Modbus command succeeded
	9	COM_FAIL	Modbus command failed
	10 - 13		Reserved
	14	HARD_ERR	Hardware error detected
	15	SOFT_ERR	Software error detected

Table 9-5: VSI Event Register Bit Definitions

9.7.4 *Register 0005 –* `VSI_FAULT_L`, *Register 0006 –* `VSI_FAULT_H`

These read only registers list the faults that are present within the VSI. There are more than 16 possible faults, so two registers are used. The fault words can be accessed as low and high 16-bit registers. The bit definition is given in Table 9-6 below.

Register	Bit	Name	Description
FAULT_L	0	GATE	Hardware Gate Fault – Fatal Error
	1	SW_IAC_OC_FST	AC Over Current - Peak Trip
	2	AC_OL	AC Current Overload
	3	HVDC_OV	DC Bus Over Voltage
	4		Reserved
	5	LOW_HVDC	Low DC Voltage Present with AC and Contactors Closed
	6	SW_VAC_OV	Input AC Over Voltage - RMS
	7	PH_LOSS	Input Single Phasing (Phase Loss)
	8	SOFT_CHARGE	Soft Charge Contactor Failure
	9	CONT_FAIL	Main AC Contactor Failure
	10	TSKiiP	Thermal Sensor on the SKiiP is over temperature limit
	11	TC	MCU Internal over temperature fault
	12		Reserved
	13	ESTOP	Emergency Stop Button Pressed (front or rear)
	14	UNKNOWN	Software Error
	15	SW_VAC_OV_FST	Input AC Over Voltage – Peak Trip
FAULT_H	16	AC_OC_FST	Output AC Over Current – Comparator Trip
	17	HW	Hardware Fault
	18	LEM_FAIL	AC Current LEM Measurement Failure
	19	HI_HVDC	High DC Voltage Present with AC and Contactors Closed
	20	CONT_DC_FAIL	DC Contactor(s) Failed to Operate
	21		Reserved
	22	HVDCE_OV	DC Bus External Terminals Over Voltage
	23 – 31		Reserved

Table 9-6: VSI Fault Bit Definition for `FAULT_H` **and** `FAULT_L` **Registers**

9.7.5 *FAULT Register - Inverter*

Table 9-6 lists the bits in the FAULT register for the Inverter module and gives brief descriptions of each bit. More detailed descriptions of the bits are given below.

9.7.5.1 `Bit 0 - Gate Fault`

One or more of the IGBT gate drivers has detected a fault. The fault can be due a sudden very high load current, device failure or gate driver failure. Inverter switching is halted, and the system remains in the lock-out state until the fault has been cleared.

9.7.5.2 `Bit 1 , 16 - Software AC Overcurrent detected`

Inverter AC current has exceeded the set threshold. The fault can be caused by an instantaneous overcurrent (Bit 1) or one of the additional overcurrent settings. Inverter switching is halted, and the system remains in the lock-out state until the fault has been cleared.

9.7.5.3 Bit 2 – Hardware AC Overload detected

The hardware AC overload trip limit has been exceeded. This fault triggers a system shutdown when the AC current has a sustained overload condition. Inverter switching is halted, and the system remains in the lock-out state until the fault has been cleared.

9.7.5.4 Bit 3 – DC Bus Over Voltage Detected

The DC bus voltage has exceeded the software trip limit. Switching is halted and the system remains in the lock-out state until the fault has been cleared.

9.7.5.5 Bit 4 –

Not used in this application.

9.7.5.6 Bit 5 – Low DC Detected

The system has detected that the measured AC Voltage has a mismatch with the DC Bus on the system. This can be caused by an internal connection issue, such as a loose connector or a faulty component. The DC voltage is too low for the corresponding AC supply voltage. The system should be electrically isolated, and the connections checked.

9.7.5.7 Bit 6 – AC Over Voltage Detected

Fault triggered when the Microgrid output voltage exceeds the predefined upper voltage limit (RMS). Switching is halted and the system remains in the lock-out state until the fault has been cleared.

9.7.5.8 Bit 7 – AC phase loss

A Phase voltage loss has been Detected. Verify that all 3 phase AC banana plugs are connected externally. If the condition persists, the system should be electrically isolated, and the connections checked.

9.7.5.9 Bit 8 – Soft Charge Contactor Failure

The system has detected that the soft charge contactor did not close correctly – Fault may occur in conjunction with the Soft-Charge Failure Fault or Emergency Stop button being pressed.

9.7.5.10 Bit 9 – Main AC Contactor Failure

The system has detected that the AC contactor did not close correctly – Fault may occur in conjunction with the Soft-Charge Failure Fault or Emergency Stop button being pressed.

9.7.5.11 Bit 10 – SKiiP Module Junction Over Temperature

Fault is triggered when the heatsink temperature sensor exceeds the value of `TEMP_TRIP` °C. Switching is halted and the system remains in the lock-out state until the fault has been cleared, which requires the temperature to reduce below the restart threshold value. The hysteresis amount is specified by the `TEMP_RST` register. Therefore, to restart the junction temperature must be below (`TEMP_TRIP` – `TEMP_RST`)°C before the fault will clear.

9.7.5.12 Bit 11 – MCU Temperature

Fault triggered when the MCU internal temperature sensor exceeds the value of 85°C. Switching is halted and the system remains in the lock-out state until the fault has been cleared. The fault has an internal built-in hysteresis, which requires the MCU to have reduced temperature by 10-15°C before the fault will clear.

9.7.5.13 Bit 12 –

Not used in this application.

9.7.5.14 Bit 13 – Emergency Stop button pressed

Front Panel Emergency Stop Button or external ESTOP has been pressed to stop operation. The system stops switching and waits for a start signal. Note that the Emergency Stop Button must be released to remove this fault.

9.7.5.15 Bit 15 – AC Over Voltage Peak Detected

Fault triggered when the Microgrid output voltage exceeds the predefined upper voltage limit (peak). Switching is halted and the system remains in the lock-out state until the fault has been cleared.

9.7.5.16 Bit 16 – Hardware AC Over Current

See Section 9.7.5.2.

9.7.5.17 Bit 17 – Hardware Fault

System has detected a fault with the hardware and has shutdown. Reset the unit and try again. If this fault repeats, the unit may require servicing.

9.7.5.18 Bit 18 – LEM Failure

System has detected a LEM module has failed the initial self-calibration checks has shutdown. Reset the unit and try again. If this fault repeats, the unit may require servicing.

9.7.5.19 Bit 19 – High DC Voltage Detected

The DC bus voltage has exceeded the peak AC voltage by an excessive amount. Switching is halted and the system remains in the lock-out state until the fault has been cleared.

9.7.5.20 Bit 20 – DC Contactor(s) Closure Failure Detected

The two DC bus voltage measurements have detected an imbalance between them larger than the permissible limit whilst the DC contactors are meant to be closed. Switching is halted and the system remains in the lock-out state until the fault has been cleared.
System has detected that one or both of the DC bus contactors did not correctly when requested.

9.7.5.21 Bit 21 –

Not used in this application.

9.7.5.22 Bit 22 – External DC Voltage Error

The system has detected that the measured DC Voltage on the external terminals is over the permitted maximum limit to allow the system to start for the selected mode. Reduce the output voltage to enable the system to start.

9.7.6 *Register 0007 –* DBG_LVL

This write only register contains the debug level setting for the system. It is currently disabled as it is not required within this system.

9.7.7 *Register 0010 – ADDRESS*

This register contains the Address of the Module. The Default Values are `1` and `247`. To enable operation in a multi-slave system the address value should be modified to a unique system address.

This is achieved by connecting the Modbus System Controller to the Slave Module on its own and writing the new Slave address to the ADDRESS register.

Warning: This modification must be completed with only one slave device on the Modbus Network. This is a read/write only register.

9.7.8 *Register 0011 –* VSI_VERSION

This read only register contains the Inverter MCU software version number and is hardcoded at compile time.

9.7.9 *Register 0012 –* COMPATIBILITY

This read only register contains the software compatibility number. This is used to allow the external system to check its compatibility with the VSI software.

9.7.10 *Register 0013 –* VSI_BUILD_DATE

This read only register contains the date on which the VSI MCU software was generated. The date is packed into a 16-bit word with the first 7 bits providing the year offset from 2000, the next 4 bits are the month, and the last 5 bits are the day.

Bit number	Description
0-4	Day of the month
5-8	Month
9-15	Year offset from 2000

Table 9-7: Build Date Format

9.7.11 *Register 0014 –* VSI_BUILD_TIME

This register contains the time at which the Inverter MCU software was generated. The time is packed into a 16-bit word with the first 5 bits providing the hours in 24-hour time, the next 6 bits are the minutes, and the last 5 bits are reserved. This is a read only register.

Bit number	Description
0-4	Reserved – read as 0
5-10	Minutes
11-15	Hours

Table 9-8: Build Time Format

9.7.12 *Register 0015* – VSI_PCB_DFCC

This is a protected register that contains the version of the CPT-DFCC VSI MCU card. This register can be read at any time but can only be written after the ACCESS value is set correctly. This register is saved in flash and its value is restored on power-up.

9.7.13 *Register 0016* – VSI_SN_DFCC

This is a protected register that contains the serial number of the CPT-DFCC VSI MCU card. This register can be read at any time but can only be written after the ACCESS value is set correctly. This register is saved in flash and its value is restored on power-up.

9.7.14 *Register 0017* – PCB_DFM2

This is a protected register that contains the version of the CPT-DFM2 motherboard. This register can be read at any time but can only be written after the ACCESS value is set correctly. This register is saved in flash and its value is restored on power-up.

9.7.15 *Register 0018* – SN_DFM2

This is a protected register that contains the serial number of the CPT-DFM2 motherboard. This register can be read at any time but can only be written after the ACCESS value is set correctly. This register is saved in flash and its value is restored on power-up.

9.7.16 *Register 0019* – PCB_DFJ

This is a protected register that contains the version of the CPT-DFJ communications and JTAG Programming card. This register can be read at any time but can only be written after the ACCESS value is set correctly. This register is saved in flash and its value is restored on power-up.

9.7.17 *Register 0020* – PCB_DFC4

This is a protected register that contains the version of the CPT-DFC4 communications card. This register can be read at any time but can only be written after the ACCESS value is set correctly. This register is saved in flash and its value is restored on power-up.

9.7.18 *Register 0030 –* `COMMAND`

This is a protected register that enables commands to be sent to the VSI for execution. The supported commands are:

Command	Name	Description
0	NONE	No command
1	CLEAR FAULTS	Clear any Faults present in the system
2	RUN	Start the Unit
3	STOP	Ramp down and stop
6	SET_VG	Set the Module to Constant Voltage Grid Connected Mode Default for Inverter Module
7	SET_CG	Set the Module to Constant Current Grid Connected Mode
8	SET_OL	Set to Module to Open Loop Modulation Mode
9	SET_CL	Set the Module to Current Regulated – Passive Load Mode
10	SET_SYNC_VAC	Set the Module to use Vac synchronisation
11	SET_SYNC_SELF	Set the Module to use self-synchronisation
800	UPDATE_SETT	The VSI operation is updated with changes made to the Settings Registers. Requires the appropriate ACCESS code level to be written.
900	UPDATE_CAL	The ADC operation is updated with changes made to the Calibration Registers. Requires the appropriate ACCESS code level to be written.
1300	RESET_SYS	Reset all VSI system parameters to default values. Requires the appropriate ACCESS code level to be written.
1400	RESET_SETT	Reset all VSI settings parameters to default values. Requires the appropriate ACCESS code level to be written.
1500	RESET_CAL	Reset all VSI calibration parameters to the default values. Requires the appropriate ACCESS code level to be written.
2000	CLEAR_ERROR_LOG	Clear the VSI error log. Requires ACCESS code to be written.
2100	DOWNLOAD_ERROR_LOG	Triggers download of the VSI error log from the debug port.

Table 9-9: Inverter Commands

Examples:

To request the unit to **RUN**
Write the value **2** to the `COMMAND` register

To commit a change in MODBUS register address to internal flash memory
Write the value **700** to the `COMMAND` register

9.7.19 *Register 0031 –* `MSG_GOOD`

This read only register contains the count of the number of good Modbus messages received since power-up.

9.7.20 *Register 0032 –* `MSG_BAD`

This read only register contains the number of bad Modbus messages received since power-up. Ideally it should always be zero.

9.7.21 *Register 0033 –* `ERR_LEN`

This read only register contains the number of errors stored in the VSI error log.

9.7.22 *Register 0034 –* `ERR_INDEX`

This register contains the index for the present VSI error log. A number written to this register represents one of the entries within the VSI error log. This write triggers the VSI MCU to read the specified entry into the error log registers (0041 – 0056).

9.7.23 *Registers 0041 – 0042 –* `ERR_ID_x`

These two read only registers contain the low and high words of the VSI 32-bit error log entry identifier. This is a unique identifier for this particular instance of an error. It is used for the internal storage process and provided for information only.

9.7.24 *Register 0043 –* `ERR_TIME`

This read only register contains the error time for the present VSI error log entry. It identifies when the error occurred and is measured in seconds from the last power up.

9.7.25 *Register 0044 –* `ERR_CODE`

This read only register contains the error code for the present VSI error log entry. It identifies what error has occurred. Refer to sections 12.0 on Inverter Debug and Error Codes for details.

9.7.26 *Registers 0045 – 0056 –* `ERR_Dx`

These read only registers contain the error data associated with the present VSI error log entry. The data can help identify the cause of the error and is different for each error code. Refer to sections 12.0 on Inverter Debug and Error Codes for details.

9.7.27 *System Passwords*

The passwords for the system are hardcoded in and cannot be modified by the user.

WARNING: These passwords are provided here for reference. It is recommended NOT to change the LEVEL 3 variables without careful consideration of the possible implications, hence this password is not provided by default.

The settings in System, Settings and Calibration can be individually returned to their factory defaults using the appropriate commands. Note that the Factory Default values are listed within Table 9-2 (System), Table 9-10 (Settings) and Table 9-12 (Calibration) in the Default column.

The Access Level passwords are as follows:

LEVEL 1: 1793
LEVEL 2: 4077

9.8 Settings Group

ID	Name	Description	Level	Min	Default	Max	Units
0141	INOM	System nominal current setting	2	1.0	7.5	9.0	A
0143	VAC_OV	Input AC RMS over voltage trip	2	200	450	550	V_{rms}
0145	VAC_PK_OV	Input AC peak over voltage trip	2	300	750	800	V
0147	VDC_OV	DC bus trip over voltage	2	100	750	800	V
0149	IAC_INST_OC	Output AC current Instantaneous trip	2	1.0	15.0	15.0	A_{rms}
0151	IAC_OL_LEVEL0	AC Current Default Overload Percentage	2	0.800	1.050	1.200	
0153	IAC_OL_LEVEL1	AC Current 1 Overload Percentage	2	0.800	1.0750	1.200	
0155	IAC_OL_LEVEL2	AC Current 2 Overload Percentage	2	0.800	1.100	1.200	
0157	IAC_OL_LEVEL3	AC Current 3 Overload Percentage	2	0.800	1.20	1.200	
0159	SET_FREQ	Inverter Output Frequency Set Point	2	45.0	50.0	65.0	Hz
0161		Reserved	2	380	400	450	
0163	VAC_IMB_DIFF	Permissible AC Voltage Imbalance	2	0	30.0	100.0	%
0165	VAC_IMB_LIM	Min. AC Voltage to start imbalance check	2	0	50	150	V
0167	VAC_IMB_CNT	Time condition must persist before AC Voltage Imbalance Trip Occurs	2	1	2	10	seconds
0169	VDC_IMB_DIFF	Allowable VDC to VAC peak margin	2	0	200	250	V
0171	VDC_IMB_CNT	Time condition must persist before No HVDC Trip Occurs	2	1	5	10	seconds
0173	VDCE_IMB_DIFF	Permissible DC Voltage Measurement Imbalance (before / after DC contactors)	2	0	20.0	30.0	%
0175	VDCE_IMB_LIM	Min DC Voltage to start imbalance check	2	0	50	150	V
0177	VDCE_IMB_CNT	Time condition must persist before DC Voltage Imbalance Trip Occurs	2	1	2	10	seconds
0179	VDC_START	DC Bus Voltage at which the VSI will automatically start	2	100	550	800	V
0181	VDC_MIN	DC Bus Voltage at which the VSI will enter the under voltage wait state	2	100	300	800	V
0183	TEMP_HSYT	Temperature Sensor Hysteresis Value	2	5	20	40	°C
0185	TEMP_TRIP	Temperature Sensor Trip Value	2	0	120	150	°C
0187	SOFT_TIME	Soft Charge Contactor Close Time	3	1.00	5.00	20.00	seconds
0189	MAIN_TIME	Main Contactor Close Time	3	0.50	1.00	100.00	seconds
0191	DC_TIME	DC Contactor Close Time	3	0.50	1.00	100.00	seconds
0193	SET_VDC	Desired DC Bus Voltage	0	150	650	750	V
0195	SET_QOUT	Reactive Power Set Point	0	-5000	0	5000	VAr
0197	SET_ID	Inverter Real Current	0	-8.0	0	8.0	A
0199	KP_VDC	Control Loop DC – Proportional Gain	2	0	0.10	1.000	
0201	TINT_VDC	Control Loop DC – Integral Time	2	0.01	0.050	1.000	
0203	STEP_VDC	Step Size for the Voltage (CV Mode)	2	0	1	5.0	V
0205	STEP_IAC	Step Size for the Current (CI Mode)	2	0	0.1	2.0	A
0207	L1_IN	Inductance – 1st Stage Inductors in LCL	2	0	1.5	10	mH
0209	L2_IN	Inductance – 2nd Stage Inductors in LCL	2	0	1.5	10	mH
0211	PHASE_MARGIN	Phase Margin in Degrees	2	40.0	50.0	359.0	°
0213	TRANS_DELAY	Value for the Trans Delay Calculation	2	0	0.75	10.00	
0215	TINT_IAC	Integral Time - requires scaling by ω_{crit}	2	0	10.0	100.0	
0217	ACI0_OLOAD_TIME	AC Current Default Overload Limit time	2	1.0	30.0	100.0	seconds
0219	ACI1_OLOAD_TIME	AC Current 1 Overload Limits time	2	1.0	10.0	100.0	seconds
0221	ACI2_OLOAD_TIME	AC Current 2 Overload Limits time	2	1.0	5.0	100.0	seconds
0223	ACI3_OLOAD_TIME	AC Current 3 Overload Limits time	2	1.0	2.0	100.0	seconds
0225	EPWM_DB_UPPER	Dead Band values - Upper	2	3.0	40.0	100.0	100ns
0227	EPWM_DB_LOWER	Dead Band values– Lower	2	3.0	40.0	100.0	100ns
0229	ADC_FUND_MAX	No. of fundamental cycles to average over	3	1	5	10	1

ID	Name	Description	Level	Min	Default	Max	Units
0231	MIN_VAC_SOFT	Minimum AC volts required before soft charging starts	2	50.0	320.0	450.0	V
0233	STEP_V_TARG	Ramp Rate in V_{rms} (l-l) / 10 ms	2	1	5	10	V
02325	TRIP_VAC_TIME	Time for a Vac over voltage trip in seconds	2	0.1	0.2	1.0	Seconds
0237	HARDWARE_CONFIG	Hardware Specific Bits		0x8000	0	0x7FFF	
0239	SOFTWARE_CONFIG	Software Specific Bits		0x8000	0	0x7FFF	

Table 9-10: Overview of Modules Settings Registers

9.9 Settings Group Register Definitions

All Settings Registers can be read. Write access is controlled via the Access Level

9.9.1 *Register 0141 –* INOM

This read/write 32-bit register sets the nominal rated output current for the Inverter. It is in units of Amps.

9.9.2 *Register 0143 –* VAC_RMS_OV

This read/write 32-bit register sets the maximum RMS input voltage (line-line) that the inverter can accept at its input. It is in units of V_{rms}.

9.9.3 *Register 0145 –* VAC_PK_OV

This read/write 32-bit register sets the maximum peak input voltage (line-line) that the inverter can accept at its input. It is in units of V_{rms}.

9.9.4 *Register 0147 –* VDC_OV

This read/write 32-bit register sets the trip point for the inverter DC Bus Voltage. It is in units of Volts.

9.9.5 *Register 0149 –* IAC_INST_OC

This read/write 32-bit register sets the instantaneous trip point for the inverter AC Current output. It is in units of Amps.

9.9.6 *Register 0151 –* IAC_OL_LEVEL0

This read/write 32-bit register sets the current for the Level 0 inverter overload trip point. It is in units of %. The Inverter will trip if any phase output current remains at the trip level for more than ACI0_OLOAD_TIME seconds.

This register should be set in co-ordination with all of the Overload/Overcurrent trips at Level 0 -3 Currents (Registers 151-157) AND the Level 0-3 Times (Register 217-223) that are specified.

For example, the nominal value for IAC_OL_LEVEL0 is 1.050, or 105.0% rated output current INOM. Therefore, an overload trip will occur if the current remains above 105% of INOM, or 1.05 x INOM for ACI0_OLOAD_TIME seconds.

9.9.7 *Register 0153 –* `IAC_OL_LEVEL1`

This read/write 32-bit register sets the current for the Level 1 inverter overload trip point. It is in units of %. The Inverter will trip if any phase output current remains at the trip level for more than `ACI1_OLOAD_TIME` seconds.

This register should be set in co-ordination with all of the Overload/Overcurrent trips at Level 0 -3 Currents (Registers 151-157) AND the Level 0-3 Times (Register 217-223) that are specified.

For example, the nominal value for `IAC_OL_LEVEL1` is 1.200, or 120.0% rated output current `INOM`. Therefore, an overload trip will occur if the current remains above 120% of `INOM`, or 1.2 x `INOM` for `ACI1_OLOAD_TIME` seconds.

9.9.8 *Register 0155 –* `IAC_OL_LEVEL2`

This read/write 32-bit register sets the current for the Level 2 inverter overload trip point. It is in units of %. The Inverter will trip if any phase output current remains at the trip level for more than `ACI2_OLOAD_TIME` seconds.

This register should be set in co-ordination with all of the Overload/Overcurrent trips at Level 0 -3 Currents (Registers 151-157) AND the Level 0-3 Times (Register 217-223) that are specified.

For example, the nominal value for `IAC_OL_LEVEL2` is 1.100, or 110.0% rated output current `INOM`. Therefore, an overload trip will occur if the current remains above 110% of `INOM`, or 1.1 x `INOM` for `ACI2_OLOAD_TIME` seconds.

9.9.9 *Register 0157 –* `IAC_OL_LEVEL3`

This read/write 32-bit register sets the current for the Level 3 inverter overload trip point. It is in units of %. The Inverter will trip if any phase output current remains at the trip level for more than `ACI3_OLOAD_TIME` seconds.

This register should be set in co-ordination with all of the Overload/Overcurrent trips at Level 0 -3 Currents (Registers 151-157) AND the Level 0-3 Times (Register 217-223) that are specified.

For example, the nominal value for `IAC_OL_LEVEL3` is 1.075, or 107.5% rated output current `INOM`. Therefore, an overload trip will occur if the current remains above 107.5% of `INOM`, or 1.075 x `INOM` for `ACI3_OLOAD_TIME` seconds. Refer to section 7.6.4 for further details.

9.9.10 *Register 0159 –* `SET_FREQ`

This read/write 32-bit register sets the nominal inverter output frequency. It is in units of Hertz. (Open Loop Mode Only)

9.9.11 *Register 0161 –* `RESERVED`

9.9.12 *Register 0163* – `VAC_IMB_DIFF`

This read/write 32-bit register sets the permissible phase imbalance in the input AC line-line voltage to the inverter. An excessive imbalance may indicate a problem with the supply, or the downstream inverter rectifier. It is in units of %.

9.9.13 *Register 0165* – `VAC_IMB_LIM`

This read/write 32-bit register sets the minimum VAC line-line voltage at which the VACI Imbalance check becomes active. It is in units of V_{rms}.

9.9.14 *Register 0167* – `VAC_IMB_CNT`

This read/write 32-bit register sets the time that the detected AC line-line Voltage imbalance can be present before a fault is triggered. It is in units of 10 milliseconds.

9.9.15 *Register 0169* – `VDC_IMB_DIFF`

This read/write 32-bit register sets the allowable margin between the peak inverter AC Voltage and the actual DC bus voltage. An excessive imbalance may indicate a problem with the supply, the internal contactor, or the inverter rectifier. It is in units of Volts.

9.9.16 *Register 0171* – `VDC_IMB_CNT`

This read/write 32-bit register sets the time that the DC Bus Voltage must be outside the `VDC_MARG` margin from the peak of the AC voltage before a fault is triggered. It is in units of seconds.

9.9.17 *Register 0173* – `VDCE_IMB_DIFF`

This read/write 32-bit register sets the allowable percentage imbalance allowed in the DC voltage measurement taken within the unit, compared to the value on the DC terminals. Nominally the two DC voltage measurements should be the same. An excessive imbalance may indicate a problem with the DC contactors operation. It is in units of %.

Not used in this application

9.9.18 *Register 0175* – `VDCE_IMB_LIM`

This read/write 32-bit register sets the minimum VDC voltage at which the VDC Imbalance check becomes active. It is in units of Volts.

Not used in this application

9.9.19 *Register 0177* – `VDCE_IMB_CNT`

This read/write 32-bit register sets the time that the detected DC Voltage imbalance can be present before a fault is triggered. It is in units of seconds.

Not used in this application

9.9.20 *Register 0179* – `VDC_START`

This read/write 32-bit register sets the VDC voltage at which the VSI will automatically start. It is in units of Volts. The VSI is designed to automatically start when there is sufficient voltage on the DC bus to produce an acceptable DC output. Once started, the inverter will continue to operate until the voltage falls below the VDC_MIN limit. It is in units of Volts.

9.9.21 *Register 0181* – VDC_MIN

This read/write 32-bit register sets the voltage below which the inverter will enter an under-voltage lockout condition. This implies that there is insufficient DC bus voltage to maintain an acceptable AC output. The system will remain in this under voltage state until the DC bus voltage rises above the VDC_START value. It is in units of Volts.

9.9.22 *Register 0183* – TEMP_RST

This read/write 32-bit register provides the reset/restart temperature for the inverter's IGBT modules, as part of the hysteresis temperature structure. The temperature value is measured using the SKiiP Module's on-chip temperature sensor. If the junction temperature is in a tripped state, the fault will only be cleared/reset once the measured value is equal to or below the TEMP_RST value. This value must be set lower than TEMP_TRIP to ensure hysteresis operation. It is in units of Degrees Celsius.

9.9.23 *Register 0185* – TEMP_TRIP

This read/write 32-bit register sets the trip temperature for the inverter's IGBT module as read by the SKiiP Module's on-chip temperature sensor. If the junction temperature reaches the TEMP_TRIP value, the inverter will shutdown to protect the hardware and remain in an overtemperature fault state until the measured temperature is below TEMP_RST. It is in units of Degrees Celsius.

9.9.24 *Register 0187* – SOFT_TIME

This read/write 32-bit register sets the soft charge contactor charging time. At the completion of the SOFT_TIME period the DC bus voltage should have reached 85% of the peak AC input voltage. If this has occurred the main contactor can close and the start-up process will continue, otherwise a soft charge fault will be triggered. It is in units of 1 millisecond.

9.9.25 *Register 0189* – MAIN_TIME

This read/write 32-bit register sets the main contactor check time. At the completion of the MAIN_TIME period the following is checked to confirm the inverter is ready to start. Firstly, the auxiliary contact on the main contactor should be closed, and secondly the DC bus voltage should be greater than 85% of the peak AC input voltage. It is in units of seconds.

9.9.26 *Register 0191* – DC_TIME

This read/write 32-bit register sets the DC contactors check time. At the completion of the DC_TIME period the following is checked to confirm the inverter is ready to start. Firstly, the DC contactors should be closed, and secondly the DC bus voltage on either side of the contactors should be the same (or within an error margin). It is in units of 1 seconds.

9.9.27 *Register 0193* – *SET_VDC*

This read/write 32-bit register contains the desired DC bus voltage. It is specified in tenths of a Volt and must be within the range 150 - 750V. The voltage will vary depending on whether the system is in charge or discharge mode. This is only used in Grid Connected Voltage Control Mode.

9.9.28 *Register 0195 –* `SET_QOUT`

This read/write 32-bit register contains the desired reactive power output from/to the grid connected inverter. A positive output is defined as reactive power out of the inverter, and a negative output is defined only for the bi-directional battery charger to indicate real power into the inverter. It is specified in VAr and has a range of ±5000. This register can be read and written. If the power is changed while the source is running, in constant power mode, the source output power will ramp towards the new target. This is only used in Grid Connected Voltage Control Mode.

9.9.29 *Register 0197 –* `SET_ID`

This read/write 32-bit register contains the default real current setting for the Inverter Module. It is specified in Amps and must be within the range -8.0 – 8.0A (-80 – 80). This is only used in the Current Control Modes.

9.9.30 *Register 0199 –* `KP_VDC`

This read/write 32-bit register contains the proportional gain of the Voltage control loop.

9.9.31 *Register 0201 –* `TINT_VDC`

This read/write 32-bit register contains the integral time of the Voltage control loop.

9.9.32 *Register 0203 –* `STEP_VHI`

This read/write 32-bit register contains voltage step size for the ramping of the DC Voltage in Voltage Control mode.

9.9.33 *Register 0205 –* `STEP_IAC`

This read/write 32-bit register contains current step size for the ramping of the AC Current in Current Control mode.

9.9.34 *Register 0207 –* `L1_IN`*, Register 0209 –* `L2_IN`

These read/write 32-bit registers contain the nominal inductance of the filter inductors contained within the LCL filter. L1 refers to the first stage inductor and L2 refers to the second stage inductor. This value is stored in milliHenries, mH.

9.9.35 *Register 0211 –* `PH_MARGIN_DEG`

This read/write 32-bit register contains the Phase Margin in Degrees that is used as part of the resonant PR control loop for current regulation.

9.9.36 *Register 0213 –* `TRANS_DELAY`

This read/write 32-bit register contains the Transport Delay that is used as part of the resonant PR control loop for current regulation.

9.9.37 *Register 0215 –* `TINT_IAC`

This read/write 32-bit register contains the Integral Time that is used as part of the resonant PR control loop for current regulation.

9.9.38 *Register 0217 –* `ACI0_OLOAD_TIME`

This read/write 32-bit register is the Time, in seconds, for which the AC Level 0 current must be above `IAC_OL_LEVEL0` before an AC overload current fault will trigger. Refer to section 7.6.4for further details.

9.9.39 *Register 0219 – ACI1_OLOAD_TIME*

This read/write 32-bit register is the Time, in seconds, for which the AC Level 1 current must be above IAC_OL_LEVEL1 before an AC overload current fault will trigger. Refer to section 7.6.4for further details.

9.9.40 *Register 0221 – ACI2_OLOAD_TIME*

This read/write 32-bit register is the Time, in seconds, for which the AC Level 2 current must be above IAC_OL_LEVEL2 before an AC overload current fault will trigger. Refer to section 7.6.4 for further details.

9.9.41 *Register 0223 – ACI3_OLOAD_TIME*

This read/write 32-bit register is the Time, in seconds, for which the AC Level 3 current must be above IAC_OL_LEVEL3 before an AC overload current fault will trigger. Refer to section 7.6.4 for further details.

9.9.42 *Register 0225 – EPWM_DB_UPPER, Register 0227 – EPWM_DB_LOWER*

These read/write 32-bit registers contain the switching dead time values for the inverter. They are stored in units of 10ns.
Register 0225 refers to the dead time between the lower switch turn off and the upper switch turn on
Register 0227 refers to the dead time between the upper switch turn off and the lower switch turn on
The numbers are positive as no overlap is permitted in this system.

9.9.43 *Register 0229 – ADC_FUND_MAX*

This read/write 32-bit register is the number of fundamental cycles that should occur before RMS and DC average values are calculated. It is used as an integer.

9.9.44 *Register 0231 – MIN_VAC_SOFT*

This read/write 32-bit register is the minimum AC Voltage (RMS line-line) at which the open loop system will run. This setting is available for system use only, when the unit is running in a test mode.

9.9.45 *Register 0233 – STEP_V_TARG*

This read/write 32-bit register is the Step Size or Ramp Rate of the AC Voltage. The voltage will be ramped each 10ms ramp function call at the rate specified in volts. This value is only used in Open Loop Mode.

9.9.46 *Register 0235 – TRIP_VAC_TIME*

This read/write 32-bit register is the time it takes for an AC Over voltage trip to be triggered within in Seconds. By default, this is set at 0.2 seconds and it is measured at the interrupt level.

9.9.47 *Register 0237 – HARDWARE_CONFIG*

This read/write 32-bit register is for system use only.

9.9.48 *Register 0239 – HARDWARE_CONFIG*

This read/write 32-bit register is for system use only.

9.10 Measurements Group

Register	Name	Description	Min	Default	Max	Units
1001	VAC_ALL	AC RMS Input Voltage – Average		-		Vrms
1003	VAC_AC	AC V_{ac} RMS input voltage		-		Vrms
1005	VAC_BC	AC V_{bc} RMS input voltage		-		Vrms
1007	VAC_AB	AC V_{ab} RMS input voltage		-		Vrms
1009	VDC	DC bus voltage		-		V
1011	VDCE	DC External voltage		-		V
1013	TEMP_J	IGBT Module Junction Temperature				°C
1015	POUT	Output power in Watts		-		W
1017	QOUT	Output reactive power in VAr				VAr
1019	IACA	AC Phase A RMS Internal Current		-		A
1021	IACB	AC Phase B RMS Internal Current		-		A
1023	IACC	AC Phase C RMS Internal Current		-		A
1025	IGDA	AC Phase A RMS Grid Current		-		A
1027	IGDB	AC Phase B RMS Grid Current		-		A
1029	IGDC	AC Phase C RMS Grid Current		-		A
1031	FREQ	Output frequency		-		Hz
1033	TC	MCU core temperature		-		°C
1035	UPTIME	Uptime Low Word		-		seconds

Table 9-11 – VSI Measured Quantities Group

9.11 Measured Group Register Definitions

9.11.1 *Register 1001 –* `VAC_ALL`

This read only 32-bit register contains the average of all 3 RMS line-line AC Input Voltages as measured by the VSI. It is stored in units of V_{rms}.

9.11.2 *Register 1003 –* `VAC_AC`

This read only 32-bit register contains the RMS line-line AC Voltage for phase A to C as measured by the VSI. It is stored in units of V_{rms}.

9.11.3 *Register 1005 –*`VAC_BC`

This read only 32-bit register contains the RMS line-line AC Voltage for phase B to C as measured by the VSI. It is stored in units of V_{rms}.

9.11.4 *Register 1007 –* `VAC_AB`

This read only 32-bit register contains the RMS line-line AC Voltage for phase A to B as measured by the VSI. It is stored in units of V_{rms}.

9.11.5 *Register 1009 –*`VDC`

This read only 32-bit register contains the inverter DC bus Voltage as measured by the VSI. It is stored in units of V.

9.11.6 *Register 1011 –* `VDCE`

This read only 32-bit register contains the inverter DC bus External Voltage (at the terminals of the Module) as measured by the VSI. It is stored in units of V.

9.11.7 *Register 1013 –* `TEMP_J`

This read only 32-bit register contains the SKiiP Module junction temperature. It is stored in units of °C.

9.11.8 *Register 1015 –* `POUT`

This read only 32-bit register contains the Output Real Power as measured by the Inverter. It is in units of Watts.

9.11.9 *Register 1017 –* `QOUT`

This read only 32-bit register contains the Output Reactive Power as measured by the Inverter. It is in units of Watts.

9.11.10 *Register 1019 –* `IACA`

This read only 32-bit register contains the AC Phase A current (with switching ripple) produced by the Inverter as measured by the VSI. It is stored in units of Amps.

9.11.11 *Register 1021 –* `IACB`

This read only 32-bit register contains the AC Phase B current (with switching ripple) produced by the Inverter as measured by the VSI. It is stored in units of Amps.

9.11.12 *Register 1023 –* `IACC`

This read only 32-bit register contains the AC Phase C current (with switching ripple) produced by the Inverter as measured by the VSI. It is stored in units of Amps.

9.11.13 *Register 1025 –* `IGDA`

This read only 32-bit register contains the AC Phase A Grid current produced by the Inverter as measured by the VSI. It is stored in units of Amps.

9.11.14 *Register 1027 –* `IGDB`

This read only 32-bit register contains the AC Phase B Grid current produced by the Inverter as measured by the VSI. It is stored in units of Amps.

9.11.15 *Register 1029 –* `IGDC`

This read only 32-bit register contains the AC Phase C Grid current produced by the Inverter as measured by the VSI. It is stored in units of Amps.

9.11.16 *Register 1031 –* `FREQ`

This read only 32-bit register contains the output frequency of the inverter as measured by the VSI. It is stored in units of Hertz.

9.11.17 *Register 1033 –* `TC`

This read only 32-bit register contains the MCU Core temperature. The MCU contains an internal sensor that provides a core temperature estimate. This should be used as a guide only as it is not overly accurate. It is stored in units of °C.

9.11.18 *Register 1035 –* `UPTIME`

This read only 32-bit register contains time that the Inverter MCU controller has been running since it was last powered on or reset. It is in units of seconds.

9.12 Calibration Group

ID	Name	Description	Min	Default	Max	Units
2001	VAC_AC_G	VSI Output AC Voltage gain – V_{ac} l-l	0.800	1.000	1.200	
2003	VAC_BC_G	VSI Output AC Voltage gain – V_{bc} l-l	0.800	1.000	1.200	
2005	VDC_G	VSI DC Bus Voltage gain	0.800	1.000	1.200	
2007	VDCE_G	VSI DC Bus Midpoint Voltage gain	0.800	1.000	1.200	
2009	TEMP_G	SKiiP Temperature Sensor gain	0.800	1.000	1.200	
2011	IACA_G	VSI output Phase A current gain	0.800	1.000	1.200	
2013	IACB_G	VSI output Phase B current gain	0.800	1.000	1.200	
2015	IACA_G	VSI output Phase A current gain	0.800	1.000	1.200	
2017	IACB_G	VSI output Phase B current gain	0.800	1.000	1.200	
2019	VDC_DC	VSI DC Bus Voltage offset	-10.00	0.000	10.00	
2021	VDCE_DC	VSI DC Bus Midpoint Voltage offset	-10.00	0.000	10.00	
2023	TEMP_DC	SKiiP Temperature Sensor offset	-10.00	0.000	10.00	

Table 9-12: Calibration Registers

9.13 Calibration Settings Registers

9.13.1 *Registers 2001 – 2023 –* `xxx_G` *– Gain calibrations*

These protected 32-bit registers allow calibration adjustment to the absolute gains on the analog inputs within the VSI MCU Controller. The stored register values are applied as a percentage variation from the default gain. This allows a ±20% adjustment to be made to the absolute gain in per unit. The default value of 1.000 corresponds to a gain adjustment of 1.

$$Gain(used) = Gain(hard\ coded) \times \text{VSI\_xxx\_G}.$$

9.13.2 *Registers 2010 – 2012 –* `xxx_DC` *– DC offset*

These protected 32-bit registers adjust the DC offset for non-cumulative, non-calculated value parameters within the Inverter MCU Controller.

9.14 5kVA Standard Operating Procedure

This section provides the detailed description of the interaction between an external Modbus controller and the 5kVA Inverter System.

Note: It is assumed that all hardware connections have been completed as outlined in the manual.

9.14.1 *On Power Up*

When the 5kVA Inverter System is powered up, there are two communications objectives: firstly, to verify that the MCU and the communications link are working properly and secondly to exchange the necessary data between the MCU and the Operator.

Table 9-13 lists the minimum registers that should be read or written on system initialization. If these registers are read correctly, then the communications link and MCU are working. If not, then there is a fault present and no further operation is possible. The Status register will show if there are any internal problems with the system on power up. The software version and build date are needed for the first screen shown on power up. Other registers can be read, but some registers will not have meaningful data on power up.

Register	R/W	Name	Description
0002	R	`STATUS`	System status register
0011	R	`VERSION`	MCU Software version number
0013	R	`BUILD_DATE`	MCU Software build date

- Table 9-13: Minimum Register Reads at Power Up

9.14.2 *Commissioning*

When the 5kVA Inverter System is first commissioned the non-volatile registers need to be reset to sensible values to ensure correct operation. This is achieved by writing to the Command register the following commands:

- FACTORY_RESET

Next the correct values must be written to the settings registers that have just been cleared. The Settings registers should be written according to the hardware installed in the particular 5kVA Inverter System

The Address of the Module should be made unique on the Modbus Network. The default Module address is **247**.

WARNING: If a Module's Modbus Address is changed ensure that the new address is recorded and safely stored.

9.15 Running

The procedure for initializing the 5kVA Inverter System to the Run state is as follows.

1) Check that the external wiring to the Inverter Module is correct.
2) Connect the Inverter Module to mains power and power up the IEC cable (switch on rear left of the unit). (MCU controller is powered separately to the power stages). Ensure that the Controller ON LED is illuminated on the front of the unit.
3) Close the external circuit breaker to connect the Inverter Module terminals to the Microgrid.
4) Check to confirm that no faults have been detected at power-up. This includes reading the status, version and build date registers via Modbus to ensure sensible values exist.
5) The appropriate values can now be fed into the (volatile) settings register group (0193 – 0197) via the Modbus link and read back to ensure that values were correctly written. These include target currents, voltages and target power outputs.
6) Close the circuit breakers to connect the DC Source to the Inverter Module.
7) Check to confirm that no faults have been detected.
8) The Inverter System is now ready to be moved into the Run State.
9) To move to the Run State a START message is sent to the Command register (0030), which will initiate the Inverter synchronization to the grid with the parameters defined in the settings register group.
10) The system is now functional, and values / measurements can be queried via the Modbus Measurements register group, or operating conditions changed via the Settings register group.

9.15.1 *Stopping*

The 5kVA Inverter System should be shutdown by sending a STOP command to the Command register (0030) via the Modbus link. This will cause a graceful system shutdown (i.e., input/output currents will ramp-down and stop).

9.16 Sample Messages

Below are a set of sample messages between a Modbus master and a MCU system. Each pair of characters forms the hexadecimal value of the byte transmitted.

Read the `Version` System Group register:
Master sends: `0x01, 0x03, 0x00, 0x0C, 0x00, 0x01`, (16-bit checksum)
Master receives: `0x01, 0x03, 0x02, 0x00, 0x65`, (16-bit checksum)
The value `101` was read back from the Version register, which converts to V1.01 of the code

Read the `MEAS_POUT` register:
Master sends: `0x01, 0x03, 0x03, 0xF7, 0x00, 0x01`, (16-bit checksum)
Master receives: `0x01, 0x03, 0x04, 0x80, 0x00, 0x44, 0x6D`,(16-bit checksum)
The value `0x005F` was read back which converts to 950W.

Write the value 500 to the `Q_OUT` register:
Master sends: `0x01, 0x10, 0x00, 0xC3, 0x00, 0x02, 0x04, 0x00, 0x00, 0x43, 0xFA`, (16-bit checksum)
Master receives: `0x01, 0x10, 0x00, 0xc3, 0x00, 0xF4`, (16-bit checksum)
The `Q_OUT` register is now set to 500 Var.

11.0 5kVA Inverter Module Debug Codes

A serial debug capability is present on the Inverter Module. This allows debugging of the Inverter Module's Operation. The following is a comprehensive list of the display lines for this Module. Every line of text displayed will start with a debug code and then contain data, in the format outlined within the Description. This log code can be used to analyse the performance of the unit. It should be used in conjunction with the internal logging.

Note that codes that are not valid for this product have been greyed out.

This information is designed for use by Creative Power Technologies or other suitably trained technicians.

Debug Code	***Description***
`0000`	String displayed at start-up of the Voltage Regulator Data is: `NYV3 5kVA Inverter V`<*version*>, <*build date and time*>
`0001`	Second string displayed at start-up. Data is: <*high word runtime_hours*>, <*low word runtime_hours*>, <*version*>
`0002`	Hourly update string Data is: <*high word runtime_hours*>, <*low word runtime_hours*>, <*vdc_max*>, <*vdc_min*>, <*vdc_avg*>, <*vac*>, <*ia_max*>, <*ia_avg*>, <*ib_max*>, <*ib_avg*>, <*ic_max*>, <*ic_avg*>
`0010`	Modbus – Command Register – Command Received Data is: <*sys_vsi.command*> `com`, <*sys_vsi.command_status*> `st` **Key:** <*sys_vsi.command*> Command issued to the Modbus <*sys_vsi.command_status*>Command type `0` No new Modbus command `1` New Modbus Command received - Access OK `2` New Modbus Command received - No Access

Debug Code	***Description***
0023	Action Response to a keyboard press, with the data displayed dependent on the command, as shown below. Modbus Read: `Reg:` *<register>* `val:`*<value>* Flash Read Page: (CPT testing purposes only) `Flash read page:` *<page>* `byte:`*<byte>* Flash Read Data: (CPT testing purposes only) `Flash read data:` *<log_data[0]>*`,`*<log_data[1]> …<log_data[15]>* Error Log Read Page: (CPT testing purposes only) `Err log read page:` *<page>* `byte:`*<byte> , <log_data[0]>:<log_data[1]>* Grab Code (CPT Debug purposes only) `grab started` **Key:** *<register>* Modbus Register Address *<value>* Value of the specified Modbus Register Address

Debug Code	*Description*
0030	At start-up the first 0030 line displayed is the status of the debug set by DIP switch 2. One second debug display Data is: `S:`*SSSS* `E:`*EEEE* *{MM}/*`F`*ffffffff}*, `m:`*vvv*`Vt` *FF.FF*`Hz`, *ddd.d*`Vdc`, *ggg.g*`Aa` *aaa.a*`Ab` *bbb*`Vac` *00*`occ` **Key:** `S:`*SSSS* — `VSI_STATUS` – Inverter Status Register `E:`*EEEE* — `VSI_EVENT` – Inverter Event Register *{MM/*`F`*ffffffff}* *MM* VSI Operating Mode `Init` – Under Voltage State `Stop` – Stop State `Chrg` – Charging DC Bus State `Ramp` – Ramp State `Run` – Run State `Fault` – Fault State `Error` – Error State `F`*ffffffff* Fault Present: *ffffffff* is the Fault Code (See `VSI_FAULT_H and VSI_FAULT_L` Register definition for fault details) `m:`*vvv*`Vt` — *vvv* is the reference output AC Voltage *FF.FF*`Hz` — Output Frequency in Hz *ddd.d*`Vdc` — DC Bus voltage *ggg.g*`Aa` — Output A Phase Current *aaa.a*`Ab` — Output B Phase Current *bbb*`Vac` — AC Input Voltage RMS *00*`occ` — AC Overcurrent Count
0032	Displays the Miscellaneous additional data Data is: `db:u`*EEE*`,l`*GGG*`, m:`*vvv*`Vdc, tc:`*TTT*`degC` **Key:** `db:u`*EEE* — Upper Switch Dead Band Time Delay `l`*GGG* — Lower Switch Dead Band Time Delay *vvv.v*`Vdc` — Midpoint Voltage `tc:`*TTT*`degC` — Voltage Regulator MCU Core Temperature

Debug Code	***Description***
0033	Help String – This is the list of available commands for the debug entry. The displayed data is: Keyboard commands: e/d(D) - Enable/Disable switching F - Clear faults i/m - Inc/dec modulation depth(1) I/M - Fast Inc/dec modulation depth(500) j/l - Inc/dec fundamental frequency(0.1) J/L - Fast Inc/dec fundamental frequency(1.0) a/A - Select Mode - a=Constant Voltage, A=Open Loop b - Select Mode - b=Constant Current R<m> - read Modbus register m W<m>,<n> - write Modbus register G - Start Grab c - Clear Grab <space> - Show misc data c/C - Save settings/System flash to default values y/b - Inc/dec Upper device rising edge delay (1) Y/B - Fast Inc/dec Upper device rising edge delay (10) t/T - Inc/dec Lower device rising edge delay (1) v/V - Fast Inc/dec Lower device rising edge delay (10) !/# - Flash Read / with Error Log @/# - Display Log Data */(/) - Dither Enable / Rate / Magnitude ? - Time Scheduler times
0100	Slow System Parameters Reset finished – *st_slow_sys_reset()* No Data
0101	Slow System Parameters Reset, Write not successful – *st_slow_sys_reset()* Data is: *<Modbus Register Address>, <register value>*
0102	Slow Settings Parameters Reset finished – *st_slow_sett_reset()* No Data
0103	Slow Settings Parameters Reset , Write not successful – *st_slow_sett_reset()* Data is: *<Modbus Register Address>, <register value>*
0104	Slow Calibration Parameters Reset finished – *st_slow_cal_reset()* No Data
0105	Slow Calibration Parameters Reset , Write not successful – *st_slow_cal_reset()* Data is: *<Modbus Register Address>, <register value>*
0121	Slow Error Log reset finished – *st_slow_log_reset()* No Data
0122	Slow Error Log download finished – *st_slow_log_dl()* No Data
0123	Slow System Update finished – *st_slow_sys_update()*
0125	Slow Settings Update finished – *st_slow_sett_update()*
0127	Slow Calibration Update finished – *st_slow_cal_update()*

Debug Code	***Description***
`0280`	Grab Display Title Line – *GrabDisplay()* Data is: `i` `g1` `g2` `g3` … as many columns in the grab list
`0281`	Grab Display Data Line – *GrabDisplay()* Data is: <*Grab Data*>
`0300`	Command parser Data is: <*command*> *{*<*parameter1*>*,*<*parameter2*>*}* `command received`
`0301`	Command parser Data is: <*command string with syntax error*>
`0302`	Command string display Data is: <*command string entered so far*>
`0380`	Time Scheduler Report Header Data – *time_sys* structure Data is *count_msec, overrun_flag, overrun_data*
`0381`	Time Scheduler Report Task Data – *time_sys* structure Data is task number and time
`2007`	VSI Set Frequency – Fundamental Frequency – *vsi_set_freq()* Data is: <*f*>, <*ps_scale*> **Key:** <*f*> Target fundamental frequency in Hz <*ps_scale*> Frequency in integer timer counts (`PS_SCALE`**f*)
`2010`	VSI State – Initialization Entered – *st_vsi_init()* No Data
`2011`	VSI State – LEM Checking Entered – *st_vsi_lem_check()* No Data
`2012`	VSI State – Calibration Entered – *st_vsi_cal()* No Data
`2013`	VSI State – Soft Charge Entered – *st_vsi_input_charge()* No Data
`2014`	VSI State – Close Main Contactor Entered – *st_vsi_close_contact()* No Data
`2015`	VSI State – Stop Entered – *st_vsi_stop()* No Data
`2016`	VSI State – AC Voltage Wait State Entered – *st_vsi_vac()* No Data
`2017`	VSI State – Ramp Up Entered – *st_vsi_ramp()* No Data
`2018`	VSI State – Ramp Down Entered – *st_vsi_down()* No Data
`2019`	VSI State – Run Entered – *st_vsi_run()* No Data

Debug Code	***Description***
`2020`	VSI State – Fault Entered – *st_vsi_fault()* Data is: *<fault_get_reported_high()>*, *<fault_get_reported_low()>*, `0`, `0` **Key:** *<fault_get_reported_high()>* Detected VSI faults – refer to `FAULT_H` list in Table 9-6 *<fault_get_reported_low()>* Detected VSI faults – refer to `FAULT_L` list in Table 9-6
`2025`	VSI State – DC Voltage Wait State Entered – *st_vsi_vac()* No Data
`4000`	Parameter module read data – *para_read_data()* Data is: *<parameter data>*
`4001`	Parameter module write data – *para_write()* Data is: *<Modbus Register Address>*, *<parameter index>*, *<data>*
`7000`	Modbus communications – *modbus_process()* – message too long No Data
`7001`	Modbus communications – *modbus_process()* – bad message Data is: *<mb.message_status>*
`7002`	Modbus communications – *modbus_process()* – bad command Data is: *<mb.command>*
`7003`	Modbus communications – *modbus_process()* – bad crc No Data
`7010`	Modbus communications module decode message – *comms_decode_message()* Data is: *<command>*, *<register addr>*, *<length>*, *<result[0]>*
`7020`	Dump data – Modbus decode errors found – *dump_data()* Data is: *<modbus message>*
`9000`	Event/Error Logging Initialised – *err_init()* Data is: *<err.head>*, *<err.tail>*, *<err.len>*, *<err.entry_code>*, *<runtime>*, *<err.index>* **Key:** *<err.head>* Log Queue Head *<err.tail>* Log Queue Tail *<err.len>* Log Queue Length *<err.entry_code>* Unique number for the Log Entry *<runtime>* Uptime for the MCU *<err.index>* Log Index Entry

Debug Code	***Description***
9010	Event/Error Log – *err_log()* Data is: *<TYPE:><err.entry_code>*,*<code>*,*<action>*,*<d1>*,*<d2>*,*<d3>*,*<d4>* **Key:** *<TYPE:>* Log Type `EVENT:` Event Log Entry Type `ERROR:` Error Log Entry Type *<err.entry_code>* Unique number for the Error Entry *<code>* Log Code – See Section 10.0 *<action>* Determines the action to take based on the error type `0` Event `1` Non-Fatal Error – Log and continue running `2` Fatal Error – Shutdown initiated to allow MCU reset `4` Fatal Error – Immediate reset of the MCU required *<d1>* to *<d4>* Data stored with the Log Entry
9020	Event/Error Log Clear process – *err_process_clear()* No Data
9030	Event/Error Log Read Entry – *err_read()* Data is: *<index>*,*<page>*:*<byte>* **Key:** *<index>*`idx` Event/Error Log Index Entry *<page>* Serial Flash Page Number *<byte>* Serial Flash Page Byte Number
9040	Event/Error Log Download process – *err_process_download()* No Data
9041	Event/Error Log Download entry – *err_process_download()* Data is: *<data_head>*,*<time_stamp>*`s`,*<code>*:*<d1>*,*<d2>*,*<d3>*,*<d4>* : *<d5>*,*<d6>*,*<d7>*,*<d8>*,*<d9>*,*<d10>*,*<d11>*,*<d12>* **Key:** *<data head>* Unique Error Log Number *<time stamp>* Time since the unit was powered up in seconds *<code>* Log Code, refer to Section 10.0 *<d1>* to *<d4>* Data stored with the Log Entry *<d5>* to *<d12>* Data stored with the Log Entry
9100	Set Debug Level – *debug_level()* Data is: *<new debug level>* Not implemented in existing code

12.0 Static Inverter Module: Logging Error Codes

An error and event log recording capability is present on the Inverter Module. Any error that occurs within the unit is written to the debug screen as well as being recorded to the internal log for later analysis. When the Inverter starts operation it will write a start-up status string to the internal log. There will also be an hourly status log added after every hour of operation. This provides a basic snapshot of the operation at this time and also aids in diagnostic processes.

Event / Error Code	***Description***
`0401`	Start-up Status String Data is: *<HIGH(runtime_hours)>*, *<LOW(runtime_hours)>*, *<Software Version>* Message written to the log at start-up. The data is the time in hours. If the number exceeds the 16-bit limit it will roll over into the *HIGH()* data location.
`0402`	Hourly Status String Data is: *<HIGH(runtime_hours)>*, *<LOW(runtime_hours)>*, *<Vdc_max>*, *<Vdc_min>*, *<Vdc_avg>*, *<Vac>*, *<Ia_max>*, *<Ia_avg>*, *<Ib_max>*, *<Ib_avg>*, *<Ic_max>*, *<Ic_avg>* Message written to the log after each full hour of operation. The data is the time in hours. If the number exceeds the 16-bit limit it will roll over into the *HIGH()* data location. *<Vdc_max>* The maximum value of the DC bus voltage 0.1 second average measured in the previous hour in Volts. Vdc_min is the equivalent minimum value. *<Vdc_avg>* Average DC bus voltage over the previous hour in Volts. *<Vac>* Incoming AC supply voltage in Volts averaged across the 3-phases line to line. *<Ix_max>* Largest RMS current measured over a 0.1 second period in the previous hour in tenths of an Amp, where *x* is the phase current – *a*, *b* or *c*. *<Ix_avg>* Average of the RMS current in the previous hour in tenths of an Amp, where *x* is the phase current – *a*, *b* or *c*.
`0500`	Slow System Parameters Reset finished Data is: *<Final Modbus address + 1>*, `0, 0, 0`
`0502`	Slow Settings Parameters Reset finished Data is: *<Final Modbus address + 1>*, `0, 0, 0`
`0504`	Slow Calibration Parameters Reset finished Data is: *<Final Modbus address + 1>*, `0, 0, 0`
`0810`	Unknown Modbus Command received. Non-Fatal Error condition Data is: *<sys_vsi.command>*, *<sys_vsi.command_status>*, `0, 0`

Event / Error Code	***Description***
0927	This function is triggered to write the updated System parameters to flash Slow System Update Flash Write Error – *st_slow_sys_update()* Data is *<addr>, <ret_val>* The flash data returned for the Modbus Register Address is invalid. The error is logged, operation will continue. **Key:** *<addr>* Register address that was being read *<ret_val>* Returned status from *para_write()* `65535` Bad Values found in flash `0` Read OK `65534` Read did not complete correctly
0928	This function is triggered to write the updated Settings parameters to flash Slow Settings Update Flash Write Error – *st_slow_sett_update()* Data is *<addr>, <ret_val>* The flash data returned for the Modbus Register Address is invalid. The error is logged, operation will continue. **Key:** *<addr>* Register address that was being read *<ret_val>* Returned status from *para_write()* `65535` Bad Values found in flash `0` Read OK `65534` Read did not complete correctly
0929	This function is triggered to write the updated Calibration parameters to flash Slow Calibration Update Flash Write Error – *st_slow_cal_update()* Data is *<addr>, <ret_val>* The flash data returned for the Modbus Register Address is invalid. The error is logged, operation will continue. **Key:** *<addr>* Register address that was being read *<ret_val>* Returned status from *para_write()* `65535` Bad Values found in flash `0` Read OK `65534` Read did not complete correctly

Event / Error Code	*Description*
1800	Serial Flash Process – *sf_process()* Data is: *<flash.state>*, *<flash.q_head>*, *<flash.q_tail>*, *<flash.q_len>* A bad state was found in the Serial Flash state machine. The error causes the flash state machine to be reinitialised. **Key:** *<flash.state>* Detected invalid state *<flash.q_head>* Current Serial Flash Queue Head Pointer *<flash.q_tail>* Current Serial Flash Queue Tail Pointer *<flash.q_len>* Current Serial Flash Queue Length
1801	Serial Flash write – *sf_write()* Data is *<flash.q_len>*, *<paddr>*, *<baddr>*, *<len>* The flash queue was full when a flash write was requested. **Key:** *<flash.q_len>* Current Serial Flash Queue Length *<paddr>* Flash Page Address requested *<baddr>* Flash Byte Address requested *<len>* Length of write
1802	Serial Flash read – *sf_read()* Data is: *<flash.q_len>*, *<paddr>*, *<baddr>*, *<len>* The flash queue was full when a flash read was requested. **Key:** *<flash.q_len>* Current Serial Flash Queue Length *<paddr>* Flash Page Address requested *<baddr>* Flash Byte Address requested *<len>* Length of write
1803	Serial Flash Dequeue entry – *dequeue_entry()* Data is: *<flash.q_len>*, 0, 0, 0 The flash queue was empty when a request to remove an entry was made. **Key:** *<flash.q_len>* Current Serial Flash Queue Length
1804	Serial Flash Process entry – *process_entry()* Data is: *<flash.head->type>*, *<flash.q_head>*, 0, 0 An invalid entry was found in the flash queue. The error causes the flash state machine to be reinitialised. **Key:** *<flash.head->type>* Invalid flash queue entry type (valid values are 0 – 7) *<flash.q_head>* Current Serial Flash Queue Head Pointer

Event / Error Code	***Description***
1805	Serial Flash Erase – *sf_erase()* Data is: <*flash.q_len*>, <*paddr*>, 0, 0 The flash queue was full when a Serial Flash erase call occurred. **Key:** <*flash.q_len*> Current Serial Flash Queue Length <*paddr*> Flash Page Address requested
1806	Serial Flash Set Sector Protect Register – *sf_protect_sw()* Data is: <*flash.q_len*>, <*protect*>, 0, 0 The flash queue was full when a Serial Flash set sector protect call occurred. **Key:** <*flash.q_len*> Current Serial Flash Queue Length <*protect*> Non-zero value indicates apply software sector protection
1807	Serial Flash Erase Sector Protection Register – *sf_prot_erase()* Data is: <*flash.q_len*>, 0, 0, 0 The flash queue was full when a Serial Flash erase sector protect call occurred. **Key:** <*flash.q_len*> Current Serial Flash Queue Length
1808	Serial Flash Read Sector Protection Register – *sf_prot_read()* Data is: <*flash.q_len*>, 0, 0, 0 The flash queue was full when a Serial Flash read sector protect call occurred. **Key:** <*flash.q_len*> Current Serial Flash Queue Length
1809	Serial Flash Write Sector Protection Register – *sf_prot_write()* Data is: <*flash.q_len*>, 0, 0, 0 The flash queue was full when a Serial Flash write sector protect call occurred. **Key:** <*flash.q_len*> Current Serial Flash Queue Length
2800	VSI Fault State Entered – *st_vsi_fault()* Data is: <*fault_get_reported_high()*>, <*fault_get_reported_low()*>, 0, 0 The VSI detected a fault and moved to the fault state. Remains in fault state until cleared. **Key:** <*fault_get_reported_high()*> Detected VSI faults – refer to FAULT_H list in Table 9-6 <*fault_get_reported_low()*> Detected VSI faults – refer to FAULT_L list in Table 9-6
4800	Flash parameters read start – *para_read_start ()* Data is: <*para*>, 0, 0, 0 An invalid parameter reference, <*para*>, was passed to the function. **Key:** <*para*> Parameter Reference

Event / Error Code	***Description***
4801	Flash parameters read data – *para_read_data()* Data is: *<data1>*, *<data2>*, *<data3>*, 0 The data in flash is invalid. Three copies of the data are stored and must match for the data to be considered valid. The returned Data is the actual received values from the serial flash. The error is logged and operation continues. **Key:** *<data1>* First serial flash data returned *<data2>* Second serial flash data returned *<data3>* Third serial flash data returned
4802	Flash parameters write – *para_write()* Data is: *<para_ref>*, *<val>*, 0, 0 An invalid parameter reference, *<para_ref>*, was passed to the serial flash write command with the value *<val>*. **Key:** *<para_ref>* Parameter Reference *<val>* Value passed to be written
4803	Flash parameter limits check – *para_val_check()* Data is: *<para>*, *<val>*, 0, 0 The value, *<val>*, for parameter, *<para>*, passed to the function for limit checking is outside its acceptable limits. **Key:** *<para_ref>* Parameter Reference *<val>* Value passed to be checked against limits
7800	Modbus Communications Process – *modbus_process()* Data is: *<mb.state>*, 0, 0, 0 An invalid state was called by the Modbus state machine. The Modbus state machine is reinitialised. **Key:** *<mb.state>* Modbus State Machine State (valid values are 0 – 2, 6 – 11)
7805	Modbus Communications Process idle state – *modbus_process()* Data is: 0, 0, 0, 0 There was no Modbus message received in time (10s). The error is logged and operation continues. The Modbus communications process moves to a fail state.

Event / Error Code	***Description***
`7905`	Modbus Message Handler, register map read – *reg_map_read()* Data is: *<map.action>*, *<HIGH(map.addr)>*, *<LOW(map.addr)>*, `0` A read from a mapped register failed due to an invalid action in the register map. The error is logged and operation continues. **Key:** *<map.action>* Requested invalid Modbus Action *<HIGH(map.addr)>* High 16 bits of the 32-bit address or function *<LOW(map.addr)>* Low 16 bits of the 32-bit address or function
`7906`	Modbus Message Handler, register map write – *reg_map_write()* Data is: *<map.action>*, *<HIGH(map.addr)>*, *<LOW(map.addr)>*, `0` A write to a mapped register failed due to an invalid action in the register map. The error is logged and operation continues. The write data is ignored. **Key:** *<map.action>* Requested invalid Modbus Action *<HIGH(map.addr)>* High 16 bits of the 32-bit address or function *<LOW(map.addr)>* Low 16 bits of the 32-bit address or function

13.0 Fault Corrective Actions

WARNING!
Hazard of Electrical Shock! Capacitors retain charge after power is removed. Wait until the voltages across the Main DC bus is less than 10 VDC before servicing the Inverter (The voltage decay time from full 600V DC is ~10 minutes)

FAULT INDICATION	*FAULT DETAIL*	*DESCRIPTION/ACTION*
AC Over Voltage *[via LED or Modbus]*	Voltage at the Inverter Module AC terminals > 450V AC	If the voltage at the Inverter Module AC terminals exceeds 450V AC: • Reduce the input voltage • When the input voltage is within the upper maximum, restart the unit If the input voltage is less than 450V AC and the fault indication persists: • Electrically isolate the system and wait for the DC bus capacitors to discharge as per the safety instructions provided • Check the control cables are correctly seated • Restart the unit If the situation cannot be remedied • Inform the Manufacturer
AC Under Voltage *[via LED or Modbus]*	Voltage at the Inverter Module AC terminals < 320V AC	• No action is required • Monitor the Input Voltage via the Modbus registers. When this voltage rises above 320V AC, the system will commence/resume operation If the input is not expected to return to normal, the attendant may switch OFF the units. If the input voltage is above 320V AC, and the fault indication persists: • Electrically isolate the system and wait for the DC bus capacitors to discharge as per the safety instructions provided • Check for any loose connection If the fault persists: • Inform the Manufacturer
Overload *[via LED or Modbus]*	Current in the unit has exceeded the maximum allowable limits	If the system is being used as a battery charger • Check load on DC-DC Converter output If the system is feeding energy into the AC Microgrid/Grid • Reduce demanded output power on Inverter module If the fault persists • Inform the Manufacturer
Emergency Stop	The Emergency Stop Button (front or rear panel) has been pressed	• Check the ESTOP on the front of the module. Ensure that it is not depressed. If it is, push and turn to release it. • Check the ESTOP connector on the rear of the Module (labelled EXT ESTOP) and ensure either the supplied shorting link connector or an equivalent external clean contact is connected.

FAULT INDICATION	*FAULT DETAIL*	*DESCRIPTION/ACTION*
No Indication	Communication between the Inverter Module and the Modbus Interface has been interrupted / did not initiate	• This system is designed to operate as a MODBUS slave. Ensure a MODBUS master is being used to communicate with it, as defined within Section 9.0. • If the problem persists, check the RS485 cable is securely attached and that conductivity exists in the connecting cable • Power modules on (or power cycle if not previously powered down) and check to see the fault has cleared. If the fault persists: • Inform the Manufacturer
Phase A Voltage Loss *[via Modbus]*	No voltage is present on 'A Phase' terminal	• Electrically isolate the system and wait for the DC bus capacitors to discharge as per the safety instructions provided • Confirm the status of any external fuses and wiring to the Inverter Module
Phase B Voltage Loss *[via Modbus]*	No voltage is present on 'B Phase' terminal	• Electrically isolate the system and wait for the DC bus capacitors to discharge as per the safety instructions provided • Confirm the status of any external fuses and wiring to the Inverter Module
Phase C Voltage Loss *[via Modbus]*	No voltage is present on 'C Phase' terminal	• Electrically isolate the system and wait for the DC bus capacitors to discharge as per the safety instructions provided • Confirm the status of any external fuses and wiring to the Inverter Module
Over Temperature *[via Modbus]*	Heat sink temperature very high The unit reports a fault and shuts down at 90ºC to protect the power stage	• Let the unit cool down • Do not attempt to restart or bypass the thermal switches until the temperature has cooled down • Confirm the heatsink is overtemperature • The IGBT thermal measurement protection has a hysteresis • Restart the unit If the reset is successful, during the next service: • Thoroughly clean the heatsink If the reset is unsuccessful: • Electrically isolate the system and wait for the DC bus capacitors to discharge as per the safety instructions provided • Check the cable connections to the heatsink, including the power connection. If the problem persists: • Inform the Manufacturer
DC Bus Charging Fault	DC Bus has failed to charge to the minimum required limit within the specified time	• Remove any resistive load from the DC Bus • Restart the unit If the problem persists: • Check the correct Voltage is supplied to the unit • For the Inverter: Ensure the circuit breaker is closed • For the DC Modules: Ensure the fuses are intact • Check the status of the fuses located on the soft charge circuit board

Other faults that may occur and are reported via the Modbus Fault register (`0005–0006`) are generally an indication of hardware failure and the Manufacturer should be informed.

14.0 Routine maintenance instructions

This section gives guidelines for routine maintenance of the Inverter and DC-DC Converter Modules to minimise the chance of a system breakdown and to enhance the overall life and reliability of the unit. For maintenance/remedial procedures after fault occurrence, refer to Section 13.0 'Fault Corrective Actions'.

14.1 Safety Instructions

- Maintenance work on this product shall only be undertaken by authorised and trained personnel. Any attempt by unauthorised and/or untrained persons, may not only result in damage to this equipment and the equipment connected to this, but could lead to fatal accidents.
- Before undertaking any maintenance work, read these instructions carefully and strictly follow them. If in any doubt, seek advice / clarification from the manufacturer, before proceeding further.
- Keep the manual/instruction sets readily accessible for future needs.
- No liquids should be allowed in contact with the system.
- BEWARE: Opening or removal of the equipment covers potentially exposes you to dangerous voltages. Open them only when necessary.

The following routine maintenance work shall be undertaken on a frequent/regular basis as indicated below:

14.2 Heatsink

- The Inverter Module heatsink should be kept clean to ensure proper cooling and hence efficient and reliable functioning of the Inverter System.
- The airflow through the heatsink should not be impeded at any time.
- Ensure that all 4 fans are not obstructed in any way and that they are all operational when the system is running. Fans are located 2 x 40mm on the left side panel, 2 x 80mm heatsink fans on the right-side panel.
- Ensure that the output vent (right side rear) is not obstructed in any way.
- Fans can be replaced with the same or similar parts. Lifetime is anticipated to be 10+ years in this application.

14.3 Visual Verification of Mechanical fixtures and their rigidity

- Mechanical fixtures shall be inspected, and their rigidity shall be ascertained periodically, at least once in twenty-four months as a minimum, by checking and tightening all the fixing points, such as fixing bolts and nuts.
- Cubicle mounting (mounting bolts and nuts) to the 19" rack, as well as the various subassemblies to the cubicle/ supporting structures within the cubicle shall be checked.

14.4 Visual Verification of Cable connections and their tightness

- All the cable connections shall be checked at least once in six months as a minimum.
- Ensure all 4mm banana plugs connected to the rear power terminals are fully inserted and that there is no bare metal visible.
- If any loose contacts are found or any arcing damage is noticed, the terminals shall be either cleaned thoroughly or replaced with new fasteners/cables.

14.5 Replacement of Electrolytic capacitors

- The main DC bus electrolytic capacitors have a fixed lifetime. Their life expectancy also depends on operating conditions such as the ambient temperature. Harsh operating conditions may reduce the capacitance value over a period of time.
- Given the likely operating regime for the Inverter System, the unit should be able to operate for 10+ years without need for capacitor replacement.
- Optional: The capacitance of these capacitors may be verified periodically and if necessary replaced. A guide is if their measured capacitance has dropped below 80% of their nominal value.
- The replacement capacitor shall be exactly the same type/make, as specified in the relevant data sheets. If the exact replacement is not available, seek advice from the Inverter System manufacturer for a suitable substitute.
- During the capacitor replacement, strictly follow the procedure given below :
  - Isolate the unit from the input source by switching off the any external MCBs.
  - Isolate the unit from the DC output source/load.
  - Remove any and all cables from the module.

WARNING!

Hazard of Electrical Shock! Capacitors retain charge after power is removed. Wait until the voltages across the Main DC bus is less than 10 VDC before servicing the Inverter or DC-DC Converter Modules (approximately 10 minutes)

  - Allow a minimum of 10 minutes after the Inverter System has been deenergized to allow the DC capacitors to discharge, before accessing the internals of the Modules. **Confirm the voltage across the capacitors has reduced to a safe limit with a multimeter set to DC Volts before proceeding**
  - Replace the faulty/old capacitors with new ones of the same type/make, ensuring the correct polarity has been maintained.
  - Remove the screws securing the lid. Remove the Lid.
    - Remove the screws securing the Right-Side Panel and carefully move the panel out of the way. Note that the heatsink fan cables are connected to this panel.
    - Using a socket wrench loosen and remove the two screws from each capacitor and slide it out of the rack. There are brackets that hold the capacitors in position. The top bracket can be removed at this stage as well.
    - Replace the capacitors and use the socket wrench to tighten them into position.
    - Ensure the top capacitor bracket is inserted back into position.
    - Reattach the side panel.
    - Reattach the lid.
  - The 4 capacitors configuration is 2 Parallel strings of 2 capacitors in Series.
  - Follow the start-up procedures to power up the Inverters, following all precautions.