Leading Conversion Technology for Power Resilience

STABILITI^{TM} 25/30C3-CE

User Manual

SMART POWER CONVERSION FOR THE ENERGY REVOLUTION

- MULTIPORT (AC/DC/DC) CONVERTER
- INTEGRATES SOLAR AND STORAGE IN ONE COMPACT ENCLOSURE
  Simplifies system installation, maintenance and control
- SUPPORTS WIDE RANGE OF ENERGY MANAGEMENT APPLICATIONS
  AC Microgrids
  DC Microgrids
  Peak Shaving and Energy Arbitrage
  Electric Vehicle Support Equipment "EVSE"
- PROVIDES GALVANIC ISOLATION BETWEEN AC AND DC PORTS
  Extends Battery Life
  Enhances Safety

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VERSION 1.1

Leading Conversion Technology for Power Resilience

Table of Contents

Leading Conversion Technology for Power Resilience

Leading Conversion Technology for Power Resilience

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Release Note:

Version	Release date (DD/MM/YYYY)	Modified page number	Modifications
1.0	05/06/2024	-	First release of the Manual.
1.1	20/06/2024	35, 37 to 40	Added AC and DC information

Disclaimer

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References

This document points to the following ones for further explanations on several topics.

- Stabiliti 25/30C3-CE Modbus Programming
- TMP101 – Stabiliti Fault Monitoring & Management
- TMP102 – Stabiliti General Purpose IOs
- TMP103 – Stabiliti Remote Control
- TMP104 – Stabiliti Grid Interactive Behaviour
- TMP105 – DC Port Usage
- TMP201 – Stabiliti Grid Connection
- TMP202 – Ground Fault Management
- TMP203 – Stabiliti Grid Port Parametrization
- TMP303 – Stabiliti in Microgrid Operation

1. CE+T Power at a glance

CE+T Power is your trusted partner in advanced power solutions engineered to meet the demands of modern and dynamic industrial applications. With over 60 years of experience in power conversion technology, CE+T Power nurtures the industry with innovative solutions designed for critical power backup and energy management.

Our complete range of power solutions includes modular inverters (DC to AC), UPS (securing AC loads with batteries), and multi-directional converters (inverter, rectifier, and UPS all-in-one). Coupled with our state-of-the-art monitoring solution, you have a real energy blender to connect multiple sources of energy seamlessly!

Whether you require robust backup power solutions, energy management solutions, or a combination of both, CE+T Power delivers tailored solutions to meet your specific needs. Our products are designed with integration in mind, ensuring seamless compatibility with other components of your system. CE+T Power is committed to providing you with the expertise and resources needed to maximize the performance of your power systems.

Thank you for choosing CE+T Power as your partner in advanced power management. Let's power the future together.

2. Abbreviations

Acronym or Term	Full Expression
AWG	American Wire Gauge
CEC	California Energy Commission
CPU	Central Processing Unit
Converter	CE+T Power Converter: Stabiliti 25C3-CE, Stabiliti 30C3-CE
CSA	Canadian Standards Association
DMM	Digital Multi-Meter
FRU	Field Replaceable Unit
GFDI	Ground Fault Detection Current
IFM	Insulation Fault Measurement
IMI	Isolation Monitor Interrupter
Inverter	CE+T Power Inverter: 30PV+S
LCD	Liquid Crystal Display
MPPT	Maximum Power Point Tracking
PCB	Printed Circuit Board
PCS	Power Conversion System
PV	Photovoltaic

3. Introduction

3.1 Purpose, Scope, and Audience

This manual describes the features and capabilities of the Stabiliti™ 25C3-CE and Stabiliti 30C3-CE Multiport Power Conversion System (PCS or Converter). It should be used in conjunction with other product documentation provided by (“CE+T”), which are referenced throughout this manual.

Since both units are technically similar and that the documentation here below is mostly common, except when otherly stated, both devices will be named by the single identification Stabiliti 25/30C3-CE.

The intended audience is engineering lab personnel familiar with high-voltage/high-power systems and the general safety issues related to the wiring and use of 3-phase AC power and high-voltage battery and PV systems.

The **Stabiliti™ 25/30C3-CE User Manual** must be used to ensure safe installation and operation of this Converter. Please review this entire document prior to starting your system evaluation. Many other CE+T Power PCS operation and application documents are referenced in this manual and highlighted with **bolded blue text**.

Contact customer.support@cet-power.com for technical support as needed.

3.2 Important Notes Before Starting the PCS

- The PCS control system does not contain any built-in battery charge profiles or discharge algorithms for any battery types and does not communicate with any batteries directly. An external system controller must dictate battery charge & discharge levels in real-time with current or power commands according to your economic use case of the overall Energy Storage System.
- The PCS includes many configuration limits to constrain operation, including voltage limits, ramp rates and more. It is the operator’s responsibility to review the PCS configuration to ensure safe operation for their unique application. In particular, maximum voltage limits and maximum current limits should be updated from the factory default and saved to flash to reflect your battery or PV array’s safe operating voltage ranges. Refer to **section 10.4, page 76** and 10.5, page 76 for more information.
- Before electrically connecting an energized, high-voltage battery to the PCS, the integral pre-charge circuit should be used to minimize current inrush into the PCS capacitors. Refer to the stand-alone battery scenario example in **section 10.2, page 74** for more information.
- Ensure the run enable connection is made before attempting to start-up the PCS. Refer to **section 6.2, page 25** for more information. If this connection is not made, the PCS will not be able to run and present a persistent fault.
- The factory default configuration of the DC power ports is 2-wire, unipolar, and negatively grounded with a GFDI fuse. Before energizing any components, ensure this is the desired setup for your application. Also, note that the two DC ports of the Stabiliti 25/30C3-CE have opposite terminal layouts. Refer to **section 6.3, page 31** for more information.

4. Warranty and Safety conditions

Converter models covered in this manual: CE+T Power Stabliti 25C3-CE and Stabiliti 30C3-CE

Save these instructions

This manual contains important instructions for the CE+T Power Stabiliti 25/30C3-CE Converters. All wiring must be in accordance with the Local Electrical Safety regulations.

The following safety notices are used in this manual:

Danger - Procedures or situations that require action to prevent personal injury or damage to equipment.

Warning - Indicates a potentially hazardous situation that, if not avoided, can result in serious injury or death.

Important information: Includes key information for the operation of this equipment or specific instructions to maintain the warranty.

4.1 Safety Instructions: All Installations

Danger - This product is able to be used for both grounded and ungrounded operation of PV systems. All instructions regarding the configuration of this device must be followed. Failure to follow may result in injury, death, or damage to equipment.

Danger – To avoid an electric shock, verify that the Converter's external AC and DC Disconnects are open (off). A minimum wait time of five (5) minutes is required after opening AC and DC Disconnects to assure that the Converter's internal capacitors have discharged to zero voltage before performing any work on the Converter. Utilize lockout /tagout procedures to ensure that both AC and DC Disconnects remain in the off position during all service periods.

Warning – The Stabiliti does not include any photovoltaic rapid shutdown equipment (RSE) that might be required by some local jurisdictions in relation with firefighters safety. This RSE must consequently be installed with other equipment to form a complete RSS that meets the local requirements. Other equipment installed in or on this PV system may adversely affect the operation of the PVRSS. It is the responsibility of the installer to ensure that the completed PV system meets the rapid shut down functional requirements. This equipment must be installed according to the manufacturer's installation instructions.

4.2 Safety Instructions: Battery Installations

Danger – The enclosure contains exposed high voltage conductors. The enclosure front access door must remain closed, except during installation, commissioning, or maintenance by trained service personnel. Do not open the front door if extreme moisture is present (rain, snow, or heavy dew).

Danger – To avoid an electric shock, verify that the Converter's external AC and DC Disconnects are open (off). A minimum wait time of five (5) minutes is required after opening AC and DC Disconnects to assure that the Converter's internal capacitors have discharged to zero voltage before performing any work on the Converter. Utilize lockout/tagout procedures to ensure that both AC and DC Disconnects remain in the off position during all service periods.

Warning – These instructions DO NOT contain any information on the operation of battery systems outside of this product. Refer the manufacturer of the battery system for installation and servicing instructions.

4.3 Safety Instructions: Additional

Danger – The enclosure contains exposed high voltage conductors. The enclosure's front door must remain closed, except during installation, commissioning, or maintenance by trained service personnel. Do not open the front door if extreme moisture is present (rain, snow, or heavy dew).

Danger – Ensure that the equipment is adequately installed and grounded per this manual and all applicable codes.

Danger – Do not leave foreign objects in the Converter enclosure. Keep the area around the enclosure clear of trash, debris, and other combustible materials.

Warning – Personnel Qualification: Inspections and operations requiring access to lethal AC or DC voltages, should only be performed by qualified personnel.

Warning – All field wiring must conform to the codes set forth in the local electrical safety regulations.

Warning – Electrostatic Discharge (ESD) Damage: The Converter contains ESD-sensitive equipment. Failure to use ESD control measures while servicing the equipment may result in component damage and void the warranty.

Warning – Service and maintain the Converter in accordance with applicable CE+T Power procedures. Discontinue Converter use until all equipment defects and safety hazard have been cured. Replace any damaged warning or precautionary labels.

4.4 Safety Instructions: Handling

Warning – The Stabiliti 25/30C3-CE Converter weights approximately 70kg. It is designed to be transported and wall-mounted by two people, without the use of lift or power equipment. If lift or power equipment is used to move, or lift the Converter, follow all safety rules. Failure to do so could result in personal injury or equipment damage.

Warning – An unpacked Converter should be stored on its back, in a secure and dry location prior to vertical mounting installation.

4.5 Construction Safety Features

The Stabiliti 25/30C3-CE is providing a reinforced insulation safety level. This is true for each AC and DC to Earth, but also between AC and DC ports of the converter.

4.6 Integrated Safety Features

The Stabiliti 25/30C3-CE Converters incorporate the following safety features:

Feature	Action
Hinged Front Door	Prevents access to hazardous voltages and protects internal circuitry.
Internal Overcurrent and Overvoltage Detection	The converter will shut down immediately if internal voltages or currents are out of safe working range. AC1 is physically disconnected from the grid. No conversion is allowed on any port.
Phase missing or grid low	The converter will disable immediately its converter link but keep it in free-wheeling in order to restart immediately if ride-through conditions are met.
AC Voltage or Frequency Out of Range	The converter will disable its AC port once a combined level and duration condition on voltage or frequency under/over level is detected.
DC Overcurrent and Under/ Overvoltage Detection	The converter will disable a DC port immediately if its related DC input voltages or currents are out of specified ranges.

Table 1: Converter Safety Features

4.7 External required safety equipment

The Stabiliti 25/30C3-CE is able to protect itself against internal errors but must be fitted with some additional equipment outside to provide regulation required protection level.

The following safety equipment are typically required in a Stabiliti operated system :

- AC breaker on the AC1 port
- Depending on AC grid type, RCD on AC1 port may be required. Likely handled at system level.
- Certified grid relay protection – at system level
- Fuses on the DC ports
- Optional manual contactor on DC ports
- Depending on chosen mode for DC ports (floating or earth referenced), RCD or IMI detection device on DC port is required. This is likely handled at system level.
- Lightning protection on AC and/or DC depending applications

4.8 Ground Fault Detection – Ground Referenced Systems

For ground referenced battery and/or PV array connections, the negative common leg of DC2 and DC3 can optionally be referenced to earth ground through a 1 A fuse.

If the ground fault fuse shared between DC2 and DC3 is blown as a result of a fault event, it must be replaced in order for the Converter to attempt restart.

4.9 AC Phase missing or deep AC undervoltage

The Stabiliti 25/30C3-CE has an AC under-voltage detector loop that continuously sense the AC phases. Once it does not have at least one phase pair exhibiting at least 200 Vpk, it will immediately set the converter link in free-wheeling mode. Meaning it is kept in resonance for fast restart, but no power transfer is handled on any port.

Once the fault disappears, the conversion may restart instantaneously if not delayed by a possible AC voltage fault detection occurring in the mean time (see next chapter).

4.10 AC Voltage and Frequency Fault Detection

The quality of the power delivered to the utility line must meet or exceed the requirements as specified by the local grid authority. If the utility frequency or voltage shifts outside the regulatory specified limits, the required external grid protection relay will disconnected the Stabiliti. However, the Stabiliti 25/30C3-CE has its own under/over voltage and frequency limits, associated with time tolerance windows that will prevent it to work on its AC1 port as long as fault is present. Specified connect and reconnect times are set in accordance with local grid authority requirements.

The local grid authority settings are programmed in specific factory defined files that must be selected upon installation of the device.

4.11 DC Over/Under Voltage Fault Detection

The Stabiliti 25/30C3-CE has DC over-voltage (default is 1000 Vdc) and DC under-voltage (default is 200 Vdc) detection circuitry. If these limits are exceeded the converter will disable that DC port, or if commanded to make power, will not start. These default limits are easily changed via the Modbus interface. However, they cannot be programmed above the 1000 Vdc factory maximum. The power conversion restarts on this port after a programmable reconnect time once the fault disappears.

4.12 Regulatory Information

The Stabiliti 25/30C3-CE Converters are certified to the following standards for the European market:

- EN 50549-10:2022: Standard for Battery Converters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources
- VDE-AR-N 4105:2018-11: Distributed Resources Interconnection and Interoperability with the Grid.

5. System Specifications

The Stabiliti™ Series PCS uses a novel Link Transformer coupled with CE+T's proprietary Power Packet Switching Architecture™ (PPSA) to deliver full galvanic isolation between the AC and DC power ports. This isolation also delivers greater flexibility with regards to DC wiring options, either floating or grounded are supported which are hardware configured on the DC power connection board.

All ports support bi-directional power flows up to 25 (30) kW max for the AC port and up to 45kW max for the DC ports. Their highly flexible operating modes are managed via Modbus TCP over an Ethernet network connection. Modbus RTU is also supported.

5.1 Device Datasheet

The Stabiliti 25/30C3-CE PCS uses PPSA to efficiently transfer and manage power flows among three power ports: AC1, DC2 and DC3.

- AC1 is a 3-Wire, 3-Phase AC power port
- DC2 and DC3 power ports are similar in terms of capabilities and can both be used for battery, PV array, etc.. However, only DC2 incorporating an additional battery precharge circuit is the preferred port for easy battery connection.

Model	Stabiliti 25C3-CE	Stabiliti 30C3-CE
General		
Part Number	T831890201	T831990201
Size (W x H x D)	525 x 1008 x 405 mm	
Weight	64 kg	
Enclosure protection	Ingress Protection IP44 (powder-coated aluminum)	
Mounting	Wall mount (vertical)	
Wiring	Hinged access panel	
Isolation between AC and DC ports	Galvanic isolation (AC to DC)	
International Certifications (Pending)	Grid interactive certifications: VDE-4105, EN50549-10 (pending), C10/11 (pending)	
Compliances	CE, RoHS and Reach	
AC1 Bidirectional port – AC Grid Interactive port		
Maximum Output power AC1 port	25 kW	30 kW*
Nominal current (maximum)	50 Hz: 39 A (44 A rms per phase max)	
Nominal output voltage	3 x 400 Vac	3 x 480 Vac*
Nominal output frequency (range)	50 Hz (45 to 55 Hz)	
Power factor (programmable range)	> 0.99 at rated output power (0.8 leading to 0.8 lagging)	
Reactive power range (programmable)	+21 kVAR to -21 kVAR	
Apparent power range (programmable)	-28 to +28kVA	-30 to +30kVA
Conversion efficiency (EU)	94% @peak (92.0%)	94.8% @peak (93.3%)
Current harmonics	< 5% THD	
Microgrid features	Voltage forming and load following	
Microgrid black start	Integrated	

DC2 Bidirectional port – Battery default port	
Maximum Power	45kW (above 750 Vdc – derating below)
Maximum Current	60 A
Operating Voltage range	200 to 1000 Vdc
Open-circuit voltage (Voc)	1000 Vdc
DC Filter	Integrated differential choke
DC Disconnect	External
Wiring configurations	+ or - ground referenced mono-polar, bipolar or floating
DC3 bidirectional port – Auxiliary default port	
Maximum Power	45kW (above 750Vdc – derating below)
Maximum Current	60 A
Operating Voltage range	200 to 1000 Vdc
Open-circuit voltage (Voc)	1000 Vdc
DC Filter	Integrated differential choke
DC Disconnect	External
Wiring configurations	+ or - ground referenced monopolar, bipolar or floating
Monitoring and control	
Available control methods	AC1 port: Idle, Net, Grid Following, Grid Forming DC2 & DC3 port: Idle, Current, Power, Voltage, MPPT, Net
Monitoring / Control interfaces	RS-485 Modbus RTU - 2W / Modbus TCP over Ethernet
Fault logging	Saves all operating data when a fault occurs
Firmware updates	Remote via HTTP Request**
Environmental	
Transient overvoltage protection	AC and DC MOVs at AC & DC input terminal
Operating temperature	-25 to 60°C (derating starting at 50°C)
Storage temperature	-40 to 85°C
Relative humidity	0 to 100% (non-condensing)
Cooling	Forced air (with variable speed fan)
Highest working altitude	2000 m

Table 2: Stabiliti Datasheet

* 30 kW Stabiliti 30C3-CE requires an autotransformer 3x400 to 3x480 VAC to provide full power.

** Not available in current release

5.1.1 Grid Interactive settings

Besides its basic intrinsic settings, the Stabiliti can be programmed to fulfill the requirements of several grid interactive specific behaviours. This is summarized in the following table.

Grid Code	Voltage Setting	Phase Voltage range (VAC) Min … (Nominal) … Max	Frequency range (Hz) Min… (Nominal) … Max
None 400V	400VAC	195.5 … (230) … 304.75	48.5 … (50) … 50.5
	480VAC	235.5 … (277) … 365.75	48.5 … (50) … 50.5
EN50549	400VAC	195.5 … (230) … 264.75	47 … (50) … 52
	480VAC	235.5 … (277) … 318.5	47 … (50) … 52
VDE4105	400VAC	195.5 … (230) … 276	47.5 … (50) … 51.5
	480VAC	235.5 … (277) … 332.5	47.5 … (50) … 51.5

Table 3: Grid Interactive settings

5.2 Stabiliti 25/30C3-CE Performance considerations

5.2.1 Active/reactive working area

The following diagram shows the P(Q) working area for 400VAC and 480VAC AC voltages.

Stabiliti 25C3-CE - 400 VAC

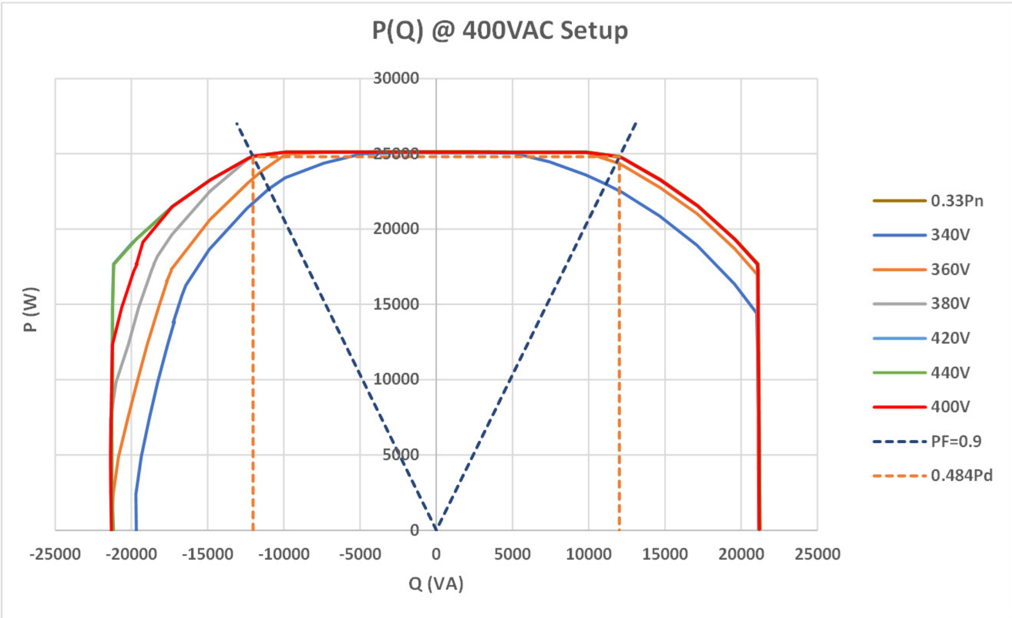


Figure 1: P(Q) - 25C3-CE

Stabiliti 30C3-CE - 480 VAC

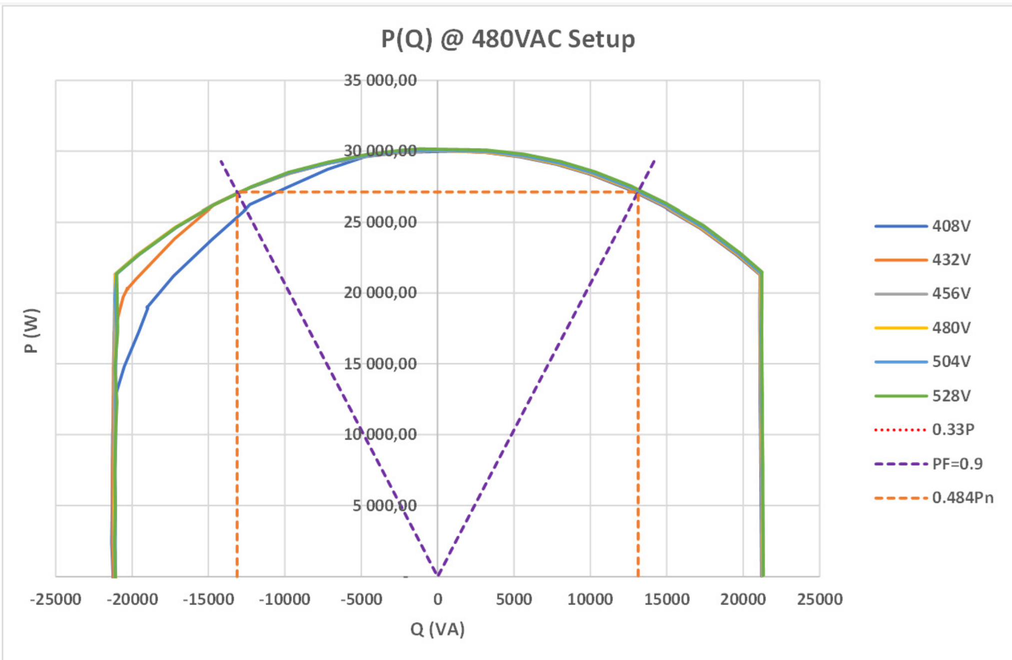


Figure 2: P(Q) - 30C3-CE

The following diagram shows the Q(U) working area for 400VAC and 480VAC AC voltages.

Stabiliti 25C3-CE - 400 VAC

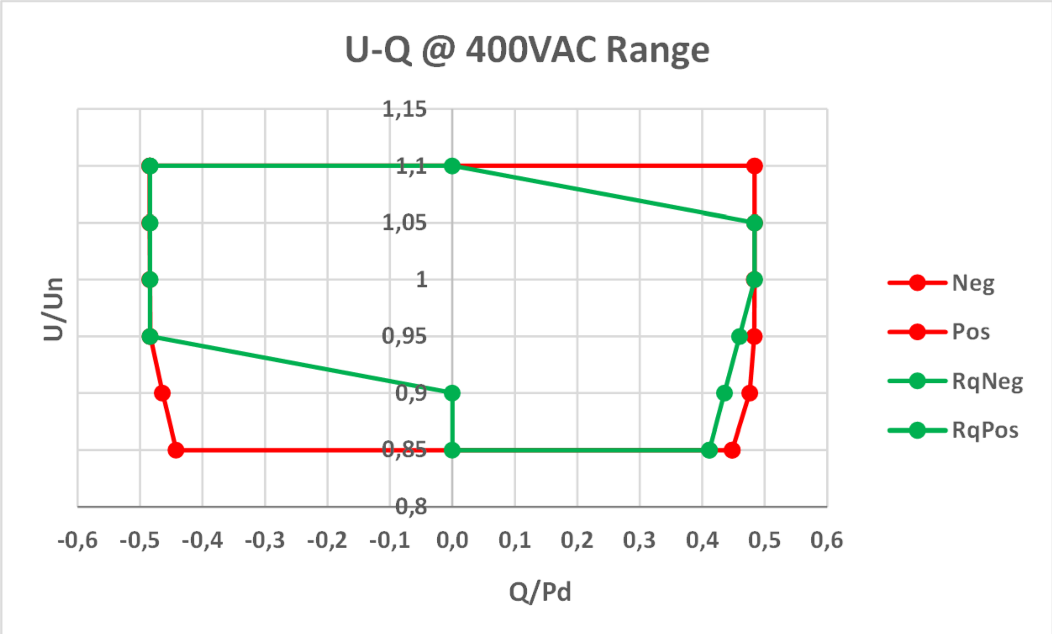


Figure 3: Q(U) - 25C3-CE

Stabiliti 30C3-CE - 480 VAC

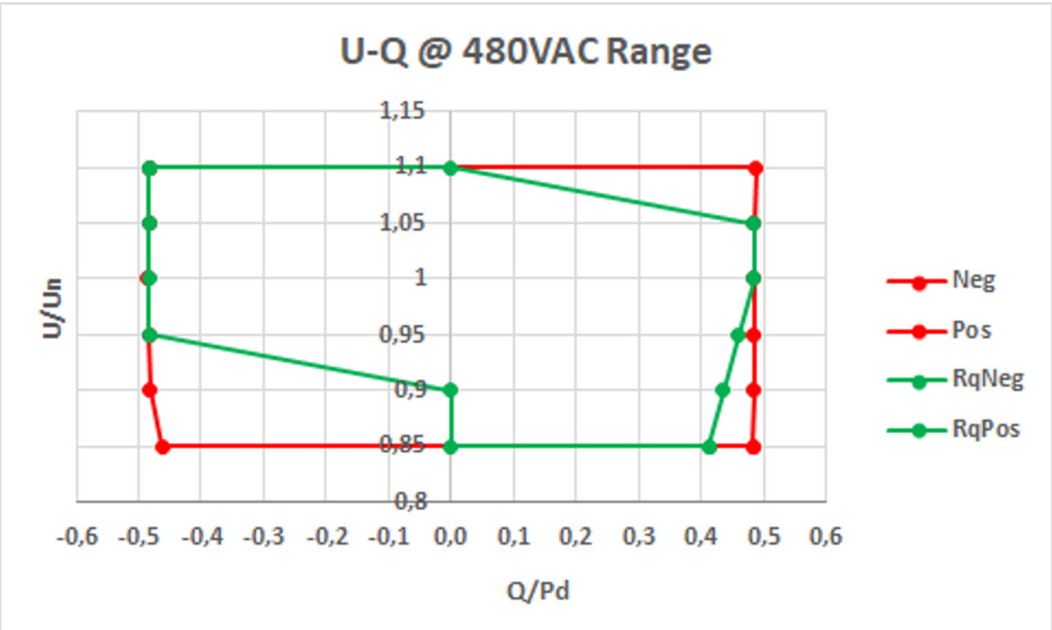


Figure 4: Q(U) - 30C3-CE

5.2.2 Cos Phi

The Stabiliti can manage cos Phi in the following ranges :

Stabiliti 25C3-CE - 400VAC:

- 1 leading to 1 lagging with 21kVAr max
- 0.8 leading to 0.8 lagging with 25kW max

Stabiliti 30C3-CE - 480VAC:

- 1 leading to 1 lagging with 21kVAr max
- 0.8 leading to 0.8 lagging with 30kW max

The cos Phi can be adjusted either indirectly by setting active and reactive power, or directly using dedicated grid interactive response control method.

5.2.3 RoCoF

The Rate of Change of Frequency equals or exceeds 4 Hz/sec on the whole working frequency range.

5.2.4 AC power vs DC voltage

The AC power capability is partly dependent on the voltage present on the DC side. Please find power and efficiency characteristics here below for various DC voltages.

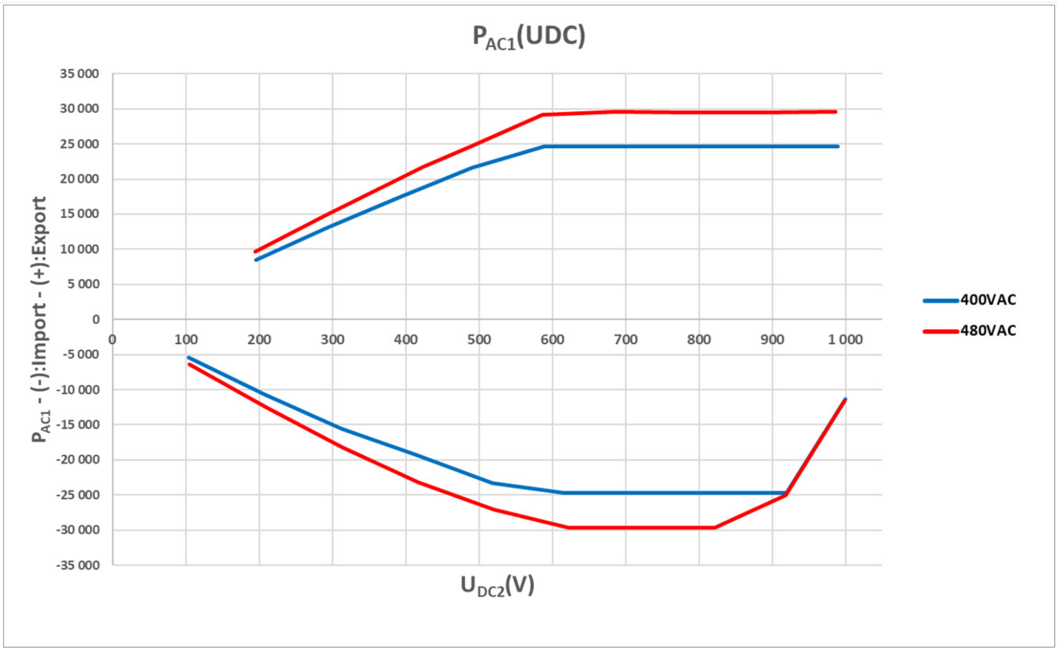


Figure 5: P_{AC} vs U_{DC}

5.2.5 DC power vs DC voltage

The DC ports power is limited by the combined limits on :

- Voltage : 1000VDC
- Current : 60A
- Power : 45kW

The following curve shows the actual power that is available on DC ports wrt working voltage. (to be updated)

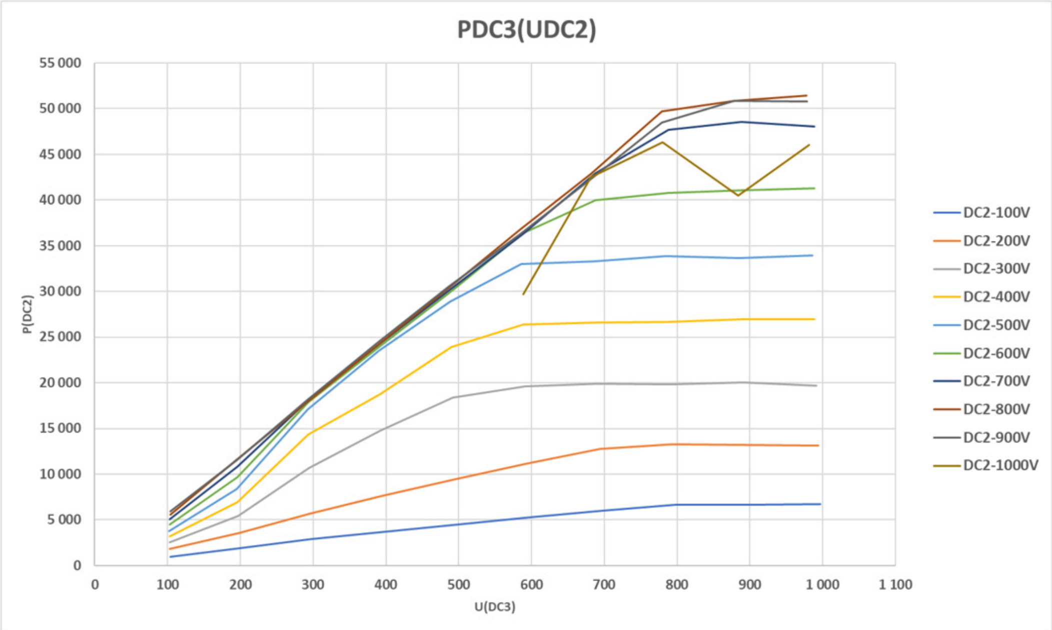


Figure 6: P_{DC} vs U_{DC}

5.2.6 Efficiency

AC1 / DCx

The efficiency is also dependent of the voltage of the port on the DC side. Here are the efficiency curves at full power, AC / DC conversion.

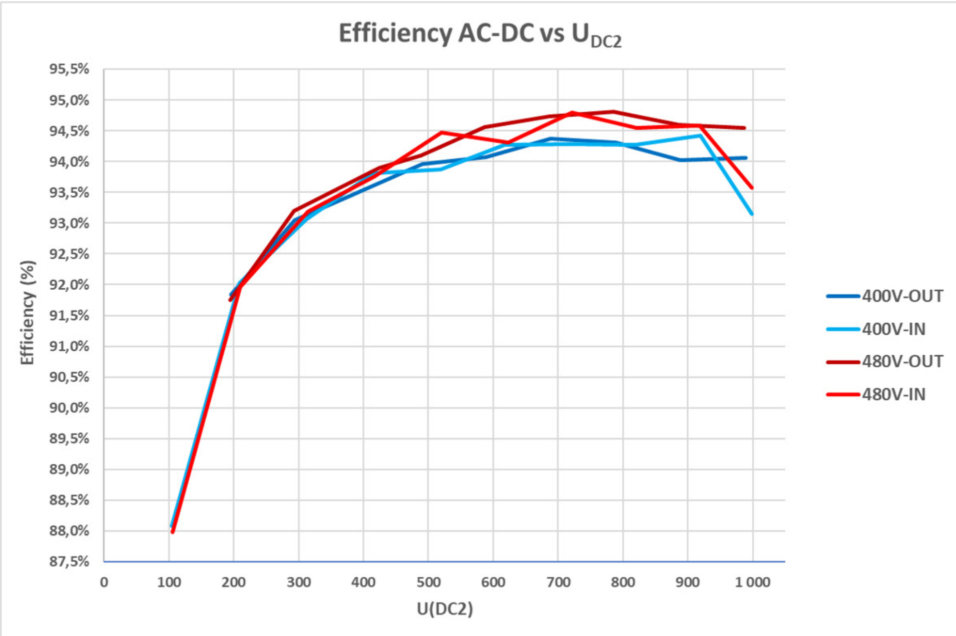


Figure 7: AC-DC Efficiency vs U_{DC}

DC2 <--> DC3

The following curves show the efficiency in DC to DC conversion mode for various voltages at full power.

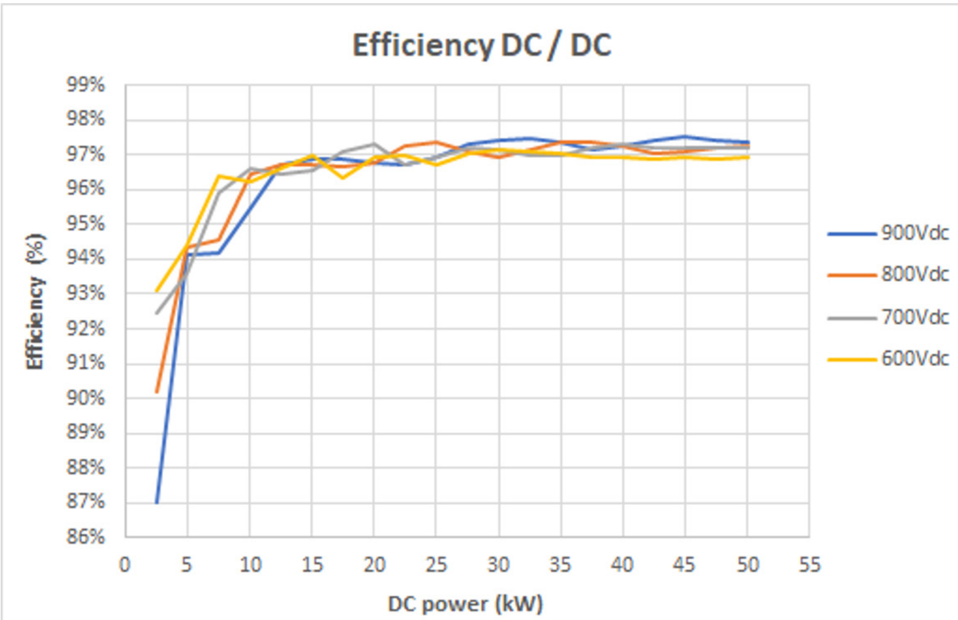


Figure 8: DC2-DC3 Efficiency vs P_{DC}

5.2.7 Stabiliti Phase Jump

Phase jump is not supported in the Stabiliti.

5.2.8 Stabiliti 30C3-CE Temperature derating

The Stabiliti is able to work in ambient temperatures up to 60 °C. However, there is some power derating at the highest temperatures that is driven by the actual temperature sensed on the critical components. In particular:

- Full power AC is slightly derated above 55°C
- Full power DC may derate, depending on the voltage difference between both DC ports, the larger, the more the derating.

6. PCS Installation

6.1 Physical Installation

6.1.1 Unpacking and Inspecting the PCS

1. Box

2. Mounting Bracket

3. Mounting Hardware

4. Foam

5. Customer Quick Link Card

6. Converter

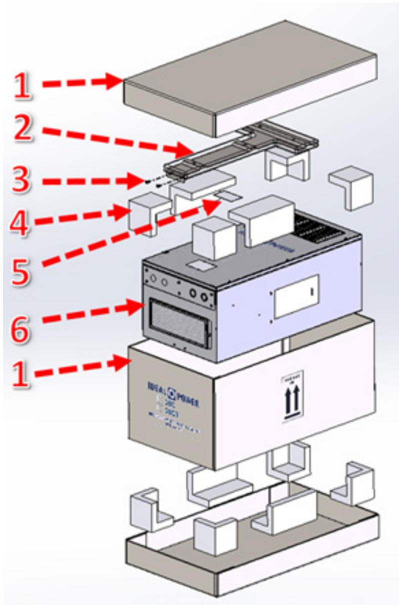


Figure 9: CE+T Power Solutions Approved Shipping Container

6.1.2 PCS Installation location

Since the Stabiliti 25/30C3-CE is not equipped with a specific PV insulation measurement, the device must be installed in a closed electrical area.

6.1.3 Converter Mounting

The Stabiliti 25/30C3-CE, when installed on its their wall mounting bracket, weighs approximately 70kg. External dimensions are 52 x 102 x 41 cm (WxHxD). The PCS MUST always be installed in a vertical upright position for final installation, as well as valuation purposes. Do not block cooling airflow to the bottom air intake filter, or the exhaust output, which is located on the upper door face of the unit.

6.1.4 Clearances for PCS Mounting

- Minimum bottom clearance requirement: Outdoors or Indoors: 45cm above. Violation of this clearance will void the warranty.
- Minimum front clearance requirement: 1m from the front of the Converter must be clear of flammable materials or obstructions.
- Minimum side clearance requirement: 10cm from the left and right sides of the Converter must be observed. The Converter's product label must be clearly visible at all times.

Warning – the unit must be mounted upright and level for the closed loop liquid cooling system to work correctly.

Warning – The unit CAN NOT be placed on its bottom during handling – Danger to damage the air input filter !!!

Figure 10: Enclosure Exterior

Step 1. Secure the wall mounting bracket to the desired surface using either a metal Uni-strut type railing rated for the Converters weight or a concrete wall. Ensure mounting bracket is level within +/- 5 degree.

Step 2. Using a two-man lift procedure carefully lift the Converter and set it on the provided wall bracket.

Step 3. Secure the two bolts located at the bottom plate of wall bracket to the Converter. Torque these to 4.5 Nm.

Step 4. Confirm that the Converter is mounted level and that the minimum clearance has been met.

30C3-CE	~70 kg
Mounting Bracket	~4 kg

Table 4: Converter Weight

Secure the wall mounting bracket to the desired surface using either a metal Uni-strut type railing rated for the Converters weight or a concrete wall. Ensure mounting bracket is level within +/- 5 degree.

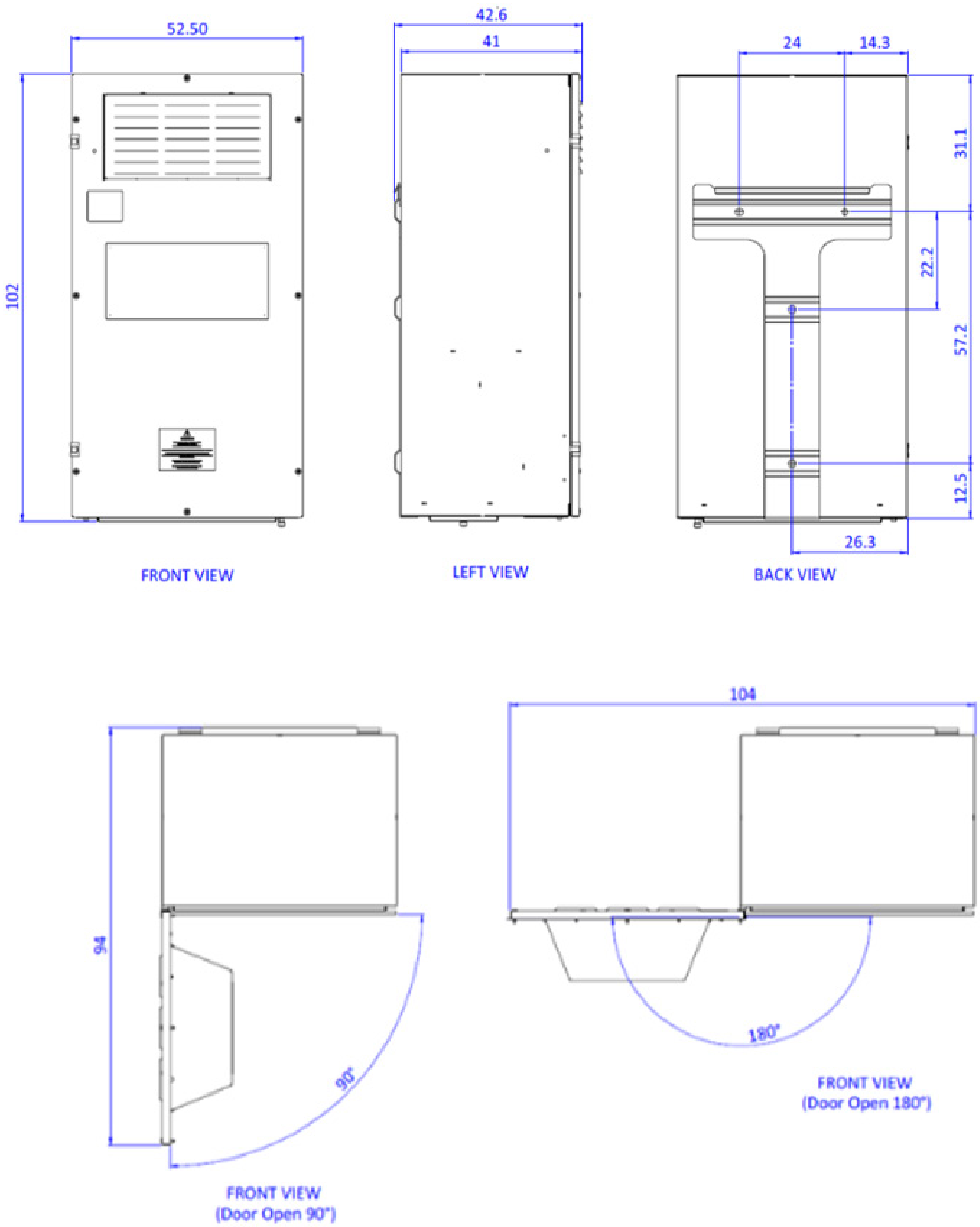


Figure 11: Dimensions and Door Clearance Guide

The PCS installation must allow the front door to swing freely open for service purposes. Although 90-degree and 180-degree swing angles are shown above, a minimum swing angle of 135 degrees is required to ensure that access for initial system wiring and ongoing maintenance of the unit is not compromised.

6.1.5 Converter Removal and Preparation for Shipment

1. Open external AC Disconnect.
2. Open external DC Disconnect(s).
3. Wait five (5) minutes for capacitors to discharge.
4. Open the enclosure's hinged front door using a 2.5 mm Allen Wrench.
5. Using an external DMM, verify that residual AC and DC voltages present at power connectors present no shock risk.
6. Disconnect the AC and DC power cables.
7. Disconnect all Conduit connections.
8. Disconnect Modbus Interface cables, and other low-voltage cables.
9. Disconnect chassis ground connections.
10. Close and secure the front door.
11. Remove the Converter from the wall mount bracket.
12. Package the Converter in CE+T Energy Solutions approved packaging (Double wall, B/C fluting box, and foam packing).

Warning – The unit CAN NOT be placed on its bottom during handling – Danger to damage the air input filter !!!

6.2 Low Voltage Comms and Control Wiring

6.2.1 Wiring AC port

The PCS wiring compartments are accessible by eight (8) M4 socket cap screws which open the full-sized (52 x 102 cm) hinged front door. All low-voltage wiring is directly terminated to connectors located on the Control Board, located on the upper left side of the enclosure.

- Other than Ethernet connections, low-voltage terminations are made bare wire in screw terminal blocks. Sourcing appropriate low-voltage cables, conductors and wiring are the customer's responsibility.
- Care should be taken when making up, routing, and connecting low-voltage cables. The PCS should be disconnected from AC and DC power source and a grounding strap should be worn by the equipment installer.

In all Stabiliti™ 25/30C3-CE applications, an outside system controller is required to configure, control, and monitor the PCS in real-time via the Modbus TCP interface. These energy storage systems may also utilize other low-voltage interface shown in the below figure.

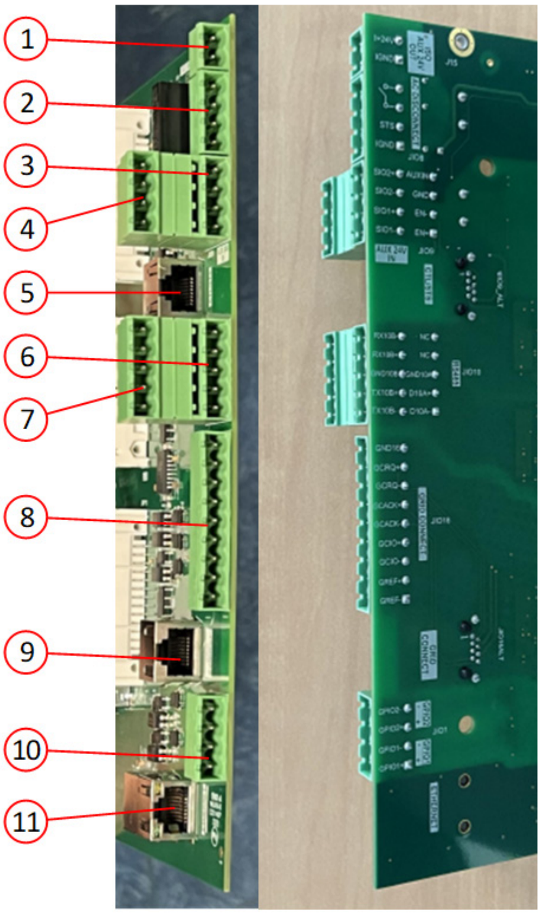


Figure 12: Control Board Low-Voltage Connectors

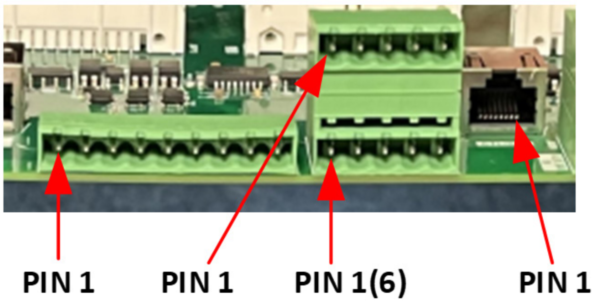
Shown in Figure 4, there are eleven (11) low-voltage interfaces on the Control Board.

From top to bottom:

1. ISO AUX 24V OUT (J15)
2. AC Disconnect (JIO8)
3. CTL/STS (JIO9)
4. AUX 24V IN / RUN (JIO9)
5. CTL/STS (JIO9 – ALT)
6. FPGA RS422 (JIO10)
7. System RS485 (JIO10)
8. Grid Connect (JIO16)
9. Grid Connect (JIO16 - ALT)
10. GPIO (JIO1)
11. Ethernet (J7COM)

Except for AUX 24 VIN, which is galvanically referenced to the controller digital GND, all other connectors I/Os have a functional isolation vs any section in the Stabiliti and between themselves.

6.2.2 Wiring Low-Voltage Interface



Please take care of the actual position of Pin1 for these connectors.

Figure 13: Controller connectors Pin 1 convention

#1 – ISO AUX 24V OUT

This 2-Pin terminal block connector provides an isolated +24V supply for various +24VDC usage that might be required in the direct vicinity of the Stability. Maximum current is 500mA continuous.

It is only available when the Stabiliti is powered either by its AC power port, either by its AUX 24V IN connector (see #4 below).

Pin	Signal Name	Description
1	IGND	AUX 24V power supply output – NEG
2	I+24V	AUX 24V power supply output – POS

Table 5: ISO AUX 24V OUT controller connector pinout

#2 – AC Disconnect

Not applicable, reserved for future use.

#3 – CTL / STS

4-Pin terminal block connector that provides System Control and Status signals. Can be programmed for various usage as additional device remote control or specific status output to outside. Floating contacts and input suitable for 24VDC signals.

Usage :

- SYS_OK as output. Floating contact closed when PCS is not in fault condition.
- SYS_IO is programmable as input or output and as output can be connected to various control internal signals (not implemented). Default usage is as output, with floating contact closed when PCS is not in warning condition.

Pin	Signal Name	Description
1 (5)	SYS_OK-	SYSTEM STATUS – NEG
2 (6)	SYS_OK+	SYSTEM STATUS – POS
3 (7)	SYS_IO-	SYS IO – NEG
4 (8)	SYS_IO+	SYS IO – POS

Table 6: CTL / STS controller connector pinout

#4 – AUX 24V IN / RUN

4-Pin terminal block connector that connects to control power supply and enable signals.

For normal PCS operation, the RUN_ENABLE input must be supplied with a 24VDC supply. This input is floating and is typically used to be paralleled with similar inputs of other Stabiliti, supplied by a system 24VDC through a chain of external alarm NC contacts (system emergency HALT, fire alarm, intrusion, ….). If +24VDC disappears while the PCS is converting, the conversion stops immediately and fault status is reported. Conversion may resume (manually or automatically following related control condition) upon fault condition disappears.

The 24 Vdc auxiliary input will supply power to the PCS control board for communications and cooling fan operation. Connect a 100 W, 24 Vdc power supply between Ground (pin 3) and Aux In (pin 4). Ensure the power supply is appropriately rated for the expected operating temperature range.

This external power supply should be supported by a UPS to keep the control board active during grid-outages, transitions to back- up power mode or when the PCS is black-starting a microgrid in grid-forming mode.

For applications that are only grid-tied (voltage-following) operation this power supply is not required as internal control board and fan power is also derived from AC1 Port grid input.

Pin	Signal Name	Description
1	RUN_ENABLE+	Device run enable control signal POS
2	RUN_ENABLE-	Device run enable control signal NEG
3	24V_GND	+24V power supply input NEG
4	24V_AUX_IN	+24V power supply input POS

Table 7: Aux 24VIN / RUN controller connector pinout

#5 – CTL / STS

This RJ45 connector gathers signals from #3 and #4 in a single connecting point. It is present to allow easier installation by using a single standard FTP cable instead of cabling each wire separately on terminal blocks.

Pin	Signal Name	Description
1	SYS_OK+	SYSTEM STATUS – POS
2	SYS_OK-	SYSTEM STATUS – NEG
3	RUN_ENABLE+	Device run enable control signal POS
4	RUN_ENABLE-	Device run enable control signal NEG
5	RUN_ENABLE+	Device run enable control signal POS
6	RUN_ENABLE-	Device run enable control signal NEG
7	SYS_IO+	SYS_IO – POS
8	SYS_IO-	SYS_IO – NEG

Table 8: CTL / STS RJ45 controller connector pinout

#6 – FPGA RS422

5-Pin terminal block connector. Used as direct FPGA control port (bypassing COMMs processor entity).

This interface is fully isolated towards all inner circuitry. This should not be connected in Stabiliti nominal usage.

Pin	Signal Name	Description
1 (6)	TX1_N	FPGA direct port – RS422 – TX output – POS
2 (7)	TX1_P	FPGA direct port – RS422 - TX output – NEG
3 (8)	RS422_GND	FPGA debug port – GND
4 (9)	RX1P	FPGA direct port – RS422 – RX input – POS
5 (10)	RX1N	FPGA direct port – RS422 – RX input – NEG

Table 9: FPGA RS422 controller connector pinout

#7 – System RS485

5-Pin terminal block connector. This connector provides the RS485 interface of the Stabiliti that is used to support the Modbus RTU Stabiliti protocol.

RS-485 serial communication is a legacy format in the inverter industry and ces offers this interface support for backwards compatibility. CE+T highly recommend operators employ Ethernet TCP communications for enhanced reliability, speed and functionality.

The RS-485 media layer employs 2-wire differential signaling to support the Modbus RTU protocol to monitor and control the PCS. External 120 Ohm termination resistors are sometimes necessary as determined by a number of factors including RS-485 wiring run length, wiring type, number of slave device on the RS-485 bus and the baud rate parameters. CE+T recommends testing performance with a terminating resistor at the PCS connector in cases of long wire runs or multiple slave devices.

This interface is fully isolated towards all inner circuitry

Pin	Signal Name	Description
1	A/A'	System RS485 – A/A' (POS)
2	B/B'	System RS485 – B/B' (POS)
3	GND	System RS485 – GND
4	-	
5	-	

Table 10: System RS485 controller connector pinout

#8 – Grid Connect

9-Pin terminal block connector. Supports signalling input for rapid transfers to and from back-up power.

These signals are all isolated one from each other and towards inner of device and are intended to be used with +24VDC logic, except GRID_REF which is an RS485 physical layer.

For Grid Interactive purpose, the GRID_CONNECT_IO can be used to remotely control AC grid power injection (see description in programming AC1 port.

For usage please refer to CE+T Power Application Note **TMP104 - Stabiliti Grid Interactive Behaviour**.

Pin	Signal Name	Description
1	GRID_REF_N	Reserved for future use
2	GRID_REF_P	Reserved for future use
3	GRID_CONNECT_IO_N	Grid injection enable / tbd – NEG
4	GRID_CONNECT_IO_P	Grid injection enable / tbd – POS
5	GRID_CONNECT_ACK_N	Grid connection acknowledge status – NEG
6	GRID_CONNECT_ACK_P	Grid connection acknowledge status – POS
7	GRID_CONNECT_RQ_N	Grid connection transfer request – NEG
8	GRID_CONNECT_RQ_P	Grid connection transfer request – POS
9	GRID_REF_GND	Reserved for future use

Table 11: Grid Connect controller connector pinout

#9 – Grid Connect

This RJ45 connector gathers signals from #8. It is present to allow easier installation by using a single standard FTP cable instead of cabling each wire separately on terminal blocks.

Pin	Signal Name	Description
1	GRID_CONNECT_RQ_P	Grid connection transfer request – POS
2	GRID_CONNECT_RQ_N	Grid connection transfer request – NEG
3	GRID_CONNECT_IO_P	Grid injection enable / tbd – POS
4	GRID_REF_P	Reserved for future use
5	GRID_REF_N	Reserved for future use
6	GRID_CONNECT_IO_N	Grid injection enable / tbd – NEG
7	GRID_CONNECT_ACK_P	Grid connection acknowledge status – POS
8	GRID_CONNECT_ACK_N	Grid connection acknowledge status – NEG
SHIELD	GRID_REF_GND	Reserved for future use

Table 12: Grid Connect RJ45 controller connector pinout

#10 – GPIO

4-Pin terminal block connector. This connector provides two fully programmable general purpose I/Os for various usages in the vicinity of the Stabiliti (i.e. checking status of DC fuses, with combined use of ISO AUX 24 VOUT).

These signals are fully isolated one from each other and towards inner device electronics. They are intended to handled +24VDC logic.

See further programming details in the Stabiliti programmer's guide.

Pin	Signal Name	Description
1	GPIO1_P	General purpose I/O1 – POS
2	GPIO1_N	General purpose I/O1 – NEG
3	GPIO2_P	General purpose I/O2 – POS
4	GPIO2_N	General purpose I/O2 – NEG

Table 13: GPIO controller connector pinout

#11 – Ethernet

Standard 8-pin RJ45 Connector

Provides support for multiple TCP-based communications services:

- Modbus TCP at port 502
- HTTP web server at port 80
- FTP at port 21
- Telnet at port 23

CE+T Power strongly recommends incorporating TCP-based communications into your Energy Storage System (ESS). Note that most ESS will involve remote communications for system operations and monitoring where these remote communications are also typically based on a TCP architecture.

The Modbus TCP interface is used to monitor and control the PCS. The HTTP webserver is used for downloading black-box historical fault logs. FTP is used for loading new firmware image files and is therefore crucial for timely PCS updates. Telnet is only used by trained CE+T Power Technicians for in-depth diagnoses. When configuring firewall permissions, please make accommodations for TCP data transfer on the four (4) ports noted above.

Refer to **section 7.2, page 45** of this document for more information on TCP Ethernet communications.

Pinout being standard to Ethernet devices is not explicitly provided here.

6.3 High-voltage Wiring

During initial setup of the PCS and before connecting AC and DC power sources, it is recommended that the user first operate the PCS with only the Aux 24 Vdc power supply connected. Doing so enables validation of communications and access to the Modbus control interface and the various configuration, control, and monitoring features supported by the Stabiliti™ Series PCS and detailed later in this document.

6.3.1 Tools Required:

- To open enclosure door – 2.5 mm Allen Wrench.
- To connect field AC and DC wiring – flat blade Screwdriver.
- To connect earth ground safety wiring – flat blade Screwdriver.

Danger – Do not remove or reconfigure the converter's factory wiring. Contact CE+T Power at customer.support@cet-power.com

Warning – Changing the Converter's DC jumper configuration as it was received from the factory may result in unexpected or unsafe operation. DC jumper configuration must match the approved field wiring configuration. Consult a certified professional before changing the Converter's factory defaults. All ground-referenced and ungrounded connection must be field wired local applicable standards.

Warning – All AC wire connections are to be made with 10mm2 copper wire rated for 600 Vac; 40A. All wires shall be torqued to 5Nm. Use of non-copper conductors is prohibited and will void the Converter's warranty.

Warning – The PCS default configuration supports a 400 Vac line-to-line 50 Hz grid connection.

Warning – Grounding the PCS must be done using the provided ground lug.

Warning – A separate fused AC Disconnect (or AC breaker) and a separate fused DC Disconnect must be installed externally with this Converter.

Important information: - CE+T Power Stabiliti™ 25/30C3-CE's AC power interfaces are galvanically isolated from all DC source(s).

6.3.2 High voltage wiring overview

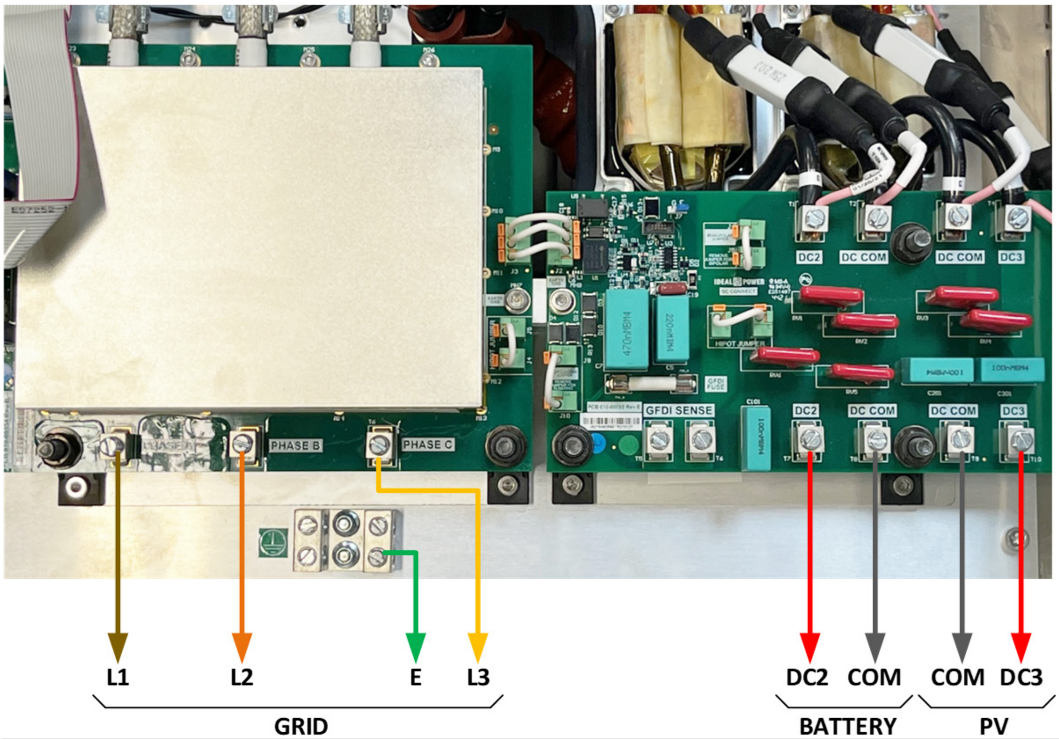


Figure 14: AC1, DC2 and DC3 power connection terminals

- High-voltage AC1 connection points are located on the bottom left section of the converter enclosure.
- High-voltage DC2 and DC3 connections are located on the bottom right section of the converter's. The shielding panel must be dismantled to allow access to the port terminals.
- An earth chassis grounding lug is located just below the PHASE C terminal, refer to Figure 5. Ensure that the chassis/enclosure is correctly grounded by utilizing this connector for earth ground from the AC service.

Once preliminary system communication is established, connect AC and DC power sources. The PCS high-voltage interconnect boards inside the enclosure are accessed by eight (8) M4 socket cap screws which open the full-sized hinged front door. Punch-outs have been marked on the underside wiring access panel for conduit mounting.

Note! Do not disturb or change the factory wiring connections, which are made to the top of the AC1 interconnect board and the DC2/DC3 interconnect board.

The Converter has an Earth Ground compression terminal that supports up to 4-gauge copper wire for ground connections. All terminations are made to bare wire, using a flat blade screwdriver drive head. No crimping is required when making the ground connection.

Torque all high-voltage wiring terminals to 5 Nm.

6.3.3 Wiring AC1 Interconnect Board

Warning – Use the provided conduit knockouts located just below the AC Connect Board for all AC conduit connections, any other penetrations to the Converter's enclosure could result in damage, or unsafe operation and will void the unit's warranty

6.3.3.1 AC Phase wiring

The bi-directional AC1 port shown in Figure 3 is configured as a 3-wire delta interface, without neutral. operating frequency is 50 Hz for both versions.

AC connections are made to the bottom terminals designated as PHASE A, PHASE B, and PHASE C, refer to Figure 5.

Note that the right phase rotation must be ensured by the wiring. Otherwise, this will prevent Stabiliti to start, signalling a phase rotation fault.

In particular, voltage forming applications require that all 3 AC phases MUST respect correct rotation sequencing. The converter will immediately fault if an incorrect phase sequence is detected if configured for voltage forming. An external phase sequence tester should be utilized to verify or correct rotation sequencing.

6.3.3.2 AC Grounding

The AC1 port is floating but its input filtering is referenced to the chassis grounding. It is assumed that the AC1 grid connected is externally referenced to earth, either intrinsically through the grid or locally when the device is used in grid forming mode. In this latter mode, additional transformers might be required to generate a Neutral wire that can consequently be connected to earth. Please refer to CE+T Application Note **TMP303 – Stabiliti in Microgrid Operation**.

6.3.3.3 AC Full power voltage matching

The Stabiliti being a product first developed for 480Vac AC grids, most of its characteristics are optimized when used in this voltage range. In particular, as the AC power is limited by the maximum AC current, only 480Vac ensures full 30kW power availability.

When considering connecting the Stabiliti to a 400Vac grid, two approaches are to be examinated:

- Stabiliti 25C3-CE directly connected to the 400Vac grid. In this case, since the maximum current remains the same, the resulting maximum available power is 25kW.
- Stabiliti 30C3-CE connected to the grid/source through an (auto)transformer to step the existing grid/source voltage up to 480Vac. When multiple Stabiliti are present in the installation, this (auto)transformer can be a single unit for all. Typical power rating is min 5kVA per Stabiliti when connecting to a 400Vac grid/source.

Depending type selected, the Stabiliti is factory configured with specific settings to adjust all working parameters and alarm levels with the chosen nominal working voltage range.

CE+T does not provide the (auto)transformer but can help in selecting or specifying the right device. Please refer to CE+T Power Application Note **TMP201 - Stabiliti Grid Connection**.

6.3.3.4 AC Neutral referencing

The Stabiliti is intrinsically a pure triphased device. It doesn't sport any Neutral connection.

When dealing in grid-following applications, this is never a problem, since all phases are referenced to ground somewhere else.

When dealing with grid-forming applications, the neutral and ground referencing of the AC port of the Stabiliti are of concern:

- The AC port of Stabiliti is floating and nothing inside or outside specifically references it to ground. Only internal protection will clamp the floating area to internal safe limits towards Earth.

- No Neutral connection is available for a load that would require it.

A zig-zag transformer placed in parallel with the 3 generated phases is the typical solution to tackle both issues. It will create a neutral point that can be used for loads. This Neutral Point should be connected locally to Protective Earth. Typical rating is min 10kVA per Stabiliti. CE+T Power does not provide the (auto)transformer but can help in selecting or specifying the right device. Please refer to CE+T Power Application Note TMP201 - Stabiliti Grid Connection.

6.3.3.5 AC External Circuit Protection

The Stabiliti™ must be installed with external circuit protection. A 50 A 3-Phase 3-wire AC breaker, rated at 480 Vac, is recommended for this purpose.

6.3.3.6 AC External Circuit Protection and Disconnect

The Stabiliti can't be directly connected to the grid. In order to be compliant with safety and grid interactive regulations, a certified disconnection relay programmed with ad hoc grid code must be inserted between the grid and the Stabiliti.

CE+T Power does not provide the disconnection relay but can help in selecting the right device.

Please refer to CE+T Power Application Note TMP104 – Stabiliti Grid Interactive Behaviour.

6.3.3.7 AC Lightning and Ground Fault protections

Refer to "6.4.1 Lightning protection", page 36.

6.3.4 Wiring DC2/DC3 Connect Board

Once the shielding top cover is removed, the DC connect board and its various features and connectors are made accessible.

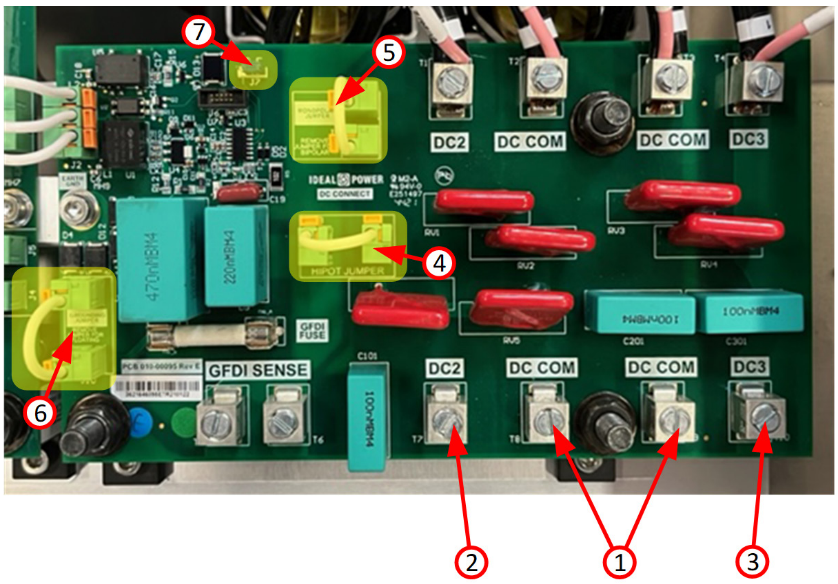


Figure 15: Stabiliti 25/30C3-CE - DC2 and DC3 Connect Board

6.3.4.1 DC Grounding

The battery and PV array connections share a common negative connection via DC COM (1). They are not electrically isolated from each other. In the factory default configuration, this common negative DC connection is earthed within the PCS through a 1 A fuse thanks when jumper (6) set.

6.3.4.2 DC Grounding handling

The Stabiliti is equipped with integrated GFDI and IMI units. However, these are not suitable for use in CE regulated areas and should not be used on the Stabiliti 25/30C3-CE device. Nevertheless, some configuration of the DC board must be done to ensure proper functioning:

(4) Hi-Pot jumper must always be set (only removed for production tests)

(5) Unipolar/bipolar jumper must be set. Bipolar is only intended for the rare cases where bipolar batteries are to used. Please contact CE+T Power for more information for this specific case.

(6) Grounding jumper must be set only if DC COM must be grounded in Stabiliti (see 6.3.4.1, page 35 for more information)

(7) Switch J7 positioned on the right position when in front of it.

6.3.4.3 DC Wiring

The DC wiring interconnect board shown in Figure 6 reflects a 30C3-CE PCS with DC2 and DC3 components installed. DC cables are landed on the bottom terminals.

Despite both ports have the same power capabilities, the DC2 port is equipped with a precharge circuitry to help connect to a battery if this latter is not equipped with a built-in precharge.

DC-COM for both DC ports are DC connected together within the Stability. However, output filterings are separated for both ports, so they should be considered as two separate signals.

Note that the two DC ports of the Stabiliti 25/30C3-CE have opposite terminal polarity layouts.

Important notes

- **Battery connect**: the battery positive is connected to DCx and the battery negative to the DC COM.
- **PV connect**: typically, a PV array installation for the Stabiliti 25/30C3-CE will employ a 3rd-party combiner box with a single MPPT output wire pair. Each DC port can act as one independent MPPT input. The negative connection is made to DC COM and positive PV array connection to DCx.
- The Stabiliti PCS does not include arc-fault detection or rapid shutdown functionality for PV systems. External third party equipment may be necessary to meet these requirements whenever required.
- The two terminals labelled GFDI Sense on the lower left of the DC interconnect board are not used for standard 2-wire battery or PV connections. These accommodate legacy 3-wire or 4-wire bipolar DC configurations but are not applicable in the scope of CE certified device.
- When connecting distant devices that can act as sources to the DC ports, it is mandatory to have a local manual contactor to disconnect it from the Stabiliti to allow safe servicing.

6.3.4.4 DC External Circuit Protection and Disconnect

The Stabiliti 25/30C3-CE must be installed with external fused circuit protection on their DC power ports. A 1000 Vdc rated, 75 A fused PV Disconnect with PV-type fuses is recommended for this purpose on both ports. However, CE+T Power recommends that you confirm specific DC disconnect and safety requirements with your local authorities for electrical safety matters.

6.3.4.5 DC Lightning and Ground Fault Protection

Refer to “6.4.1 Lightning protection”, page 36.

6.4 Additional features

6.4.1 Lightning protection

6.4.1.1 AC Side

CE+T Power highly recommends to have one lighting protection between the (local) grid and the Stabiliti. See lightning protection devices guidelines for appropriate installation.

The AC port is protected with GDT + VDR combinations.

6.4.1.2 DC Side

Since the DC section is isolated and can also be connected to external wide exposed DC grids or connections (i.e. PV field area), it is also very advisable to install a lighting protection in these specific cases. In the particular case of PV panels, the Stabiliti is very likely expected to be used with a combiner box which is typically the right location for such protection.

The DC port is protected with VDR components.

6.4.1.3 EMC concerns

In order to be fully compliant with EMC compliance configuration, it is required to add some ferrite filters on the cables getting out of the Stabiliti. This concerns all the cables, low and high voltage.

The filters, delivered with the Stabiliti, must be installed in the following way:

- AC1 : Large ferrite clipped on 3L+E wires, outside the Stabiliti
- DC2 & DC3 : Large ferrite clipped on + & - wire pair, one for each pair, outside the Stabiliti.
- Control : free ferrite installed inside Stabiliti, with 2 turns of wiring through the ferrite core, plus one small ferrite clipped on the cable outside Stabiliti.
- Ethernet : Small ferrite clipped on Ethernet cable outside Stabiliti

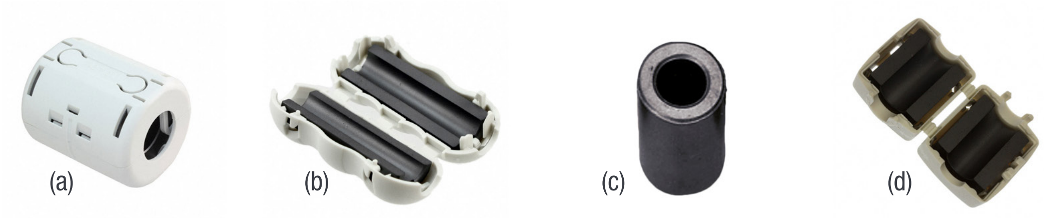


Figure16: Ferrites – (a) : AC1, DC2, DC3 – (b) & (c) : Control – (d) : Ethernet

The ferrites to place outside must be located as close as possible from the removable bottom panel of the Stabiliti. All ferrites are delivered with the Stabiliti.

6.4.1.4 Ground fault

Since the Stabiliti has two isolated power sections, both circuit should have its own ground fault protection somewhere in the system. Due to the versatile profile of the Stabiliti and its possible integration in large scale systems, no specific protection is embedded in the device. This must so likely be handled at system scale level, outside of the converter, and in relation with the system topology. For more information, please refer to CE+T Application Note TMP202 – Ground Fault Management.

6.4.1.5 AC Side

Typically, the AC grid is earthed somewhere, either at grid level, either through a local ground referencing item (i.e. zig-zag transformer).

Grid connected installation

In this case, the installation should be protected by an RCD at the head of the local network, very likely shared with the existing installation. As the Stabiliti converter process is isolated, only AC ground leakage is of concern, so an A-type RCD is likely sufficient, unless otherwise required by the local grid authorities.

The RCD might be a modular all in one device that will only open the AC circuit. When multiple Stabiliti are installed in parallel, it is very likely that the RCD function will be handled by a split design with separate current loop and contactors. In this case, alarm signals are also available that be used to control the RUN_ENABLE of the Stabiliti and stop the conversion upon AC RCD trip. Otherwise, a simple AC loss will be observed that will not necessarily stop conversion for DC side.

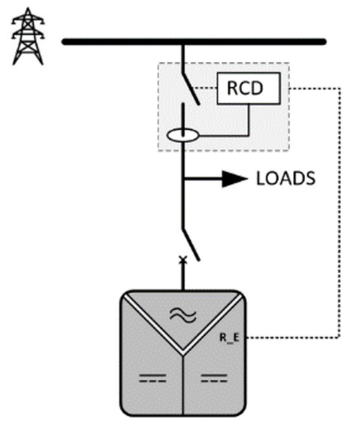


Figure17: AC Grid connected Residual Current protection

The selection criteria for the RCD are the following:

- Rated for 400VAC (25C3-CE) or 480VAC (30C3-CE)
- Nominal breaking current: at least 63A per Stabiliti
- Tripping residual current: 30mA
- Type A
- Frequency: 50Hz

Microgrid installation

If the Stabiliti is also expected to be used in a microgrid configuration, the base RCD becomes useless, and another one should be located down the contactor between Stabiliti and load.

The RCD might be a modular all in one device that will only open the AC circuit. When multiple Stabiliti are installed in parallel, it is very likely that the RCD function will be handled by a split design with separate current loop and contactors. In this case, alarm signals are also available that be used to control the RUN_ENABLE of the Stabiliti and stop the conversion upon AC RCD trip. Otherwise, the Stabiliti will not notice the issue and continue providing AC voltage.

The selection criteria for the RCD are the following:

- Rated for 400VAC (25C3-CE) or 480VAC (30C3-CE)
- Breaking nominal current: at least 63A per Stabiliti
- Tripping residual current: 30mA
- Type A
- Frequency: 50Hz

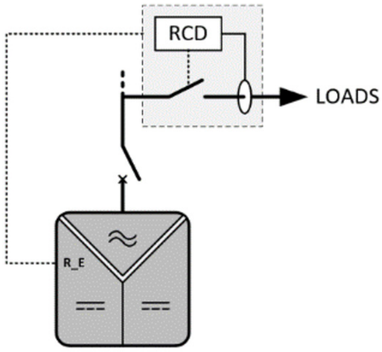


Figure 18: AC Microgrid Residual Current protection

6.4.1.6 DC Side

As the Stabiliti has an isolation between the AC and both DC ports, the protection set on AC side is totally useless for DC side. Since DC side is intrinsically floating, two variants are to take into account.

DC floating installation

Detection at system level that acts on the whole DC2/DC3 network using real-time isolation leakage monitoring devices is preferred, that will act on both the converter enable input as well as on other system level sources also present on this DC network. The rating of the breaking device(s) and their location in the DC network must be specified in relation with the nature of the topology.

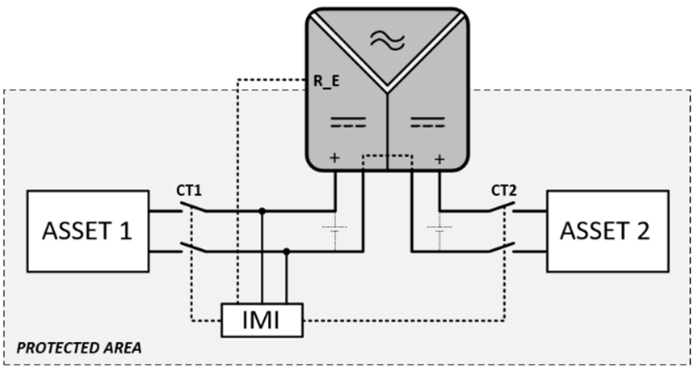


Figure 19: DC floating protection with IMI device

Jumper in position 6 (Grounding jumper) must be removed.

Since DC2 and DC3 wiring share the same ground, are both floating and since for both sides, DC+ and DC- will be connected through a low impedance somewhere in the schematic, sensing only one side (DC2 or DC3) is sufficient to cover both sides. In this case, an IMI device wil sense the insulation resistance for al the DC section. In case of failure, it must stop the conversion through RUN_ENABLE input from the Stabiliti and might also open the DC assets circuitry (relevance depending on application and nature of assets).

It must be observed that if the DC ports are shared among multiple Stabiliti, only one detection device must be placed in the system for reliable detection.

The rating criteria for IMI selection:

- Sensing rated up to 1000VDC
- Insulation resistance programmable depending on max DC voltage to sense to provide a 30mA max leakage current, based on Ohm's law. Minimum range 5.50 kohms (33.3 kohms typical for tripping on 1000VDC following regulation).

CT1 and CT2 are optional and depending on the application. It is the responsibility of the system integrator to size the breaking contactors.

DC grounded installation

RCD/RCMU protection is required. Due to the nature of the DC network, B-type RCDs are to be considered. The rating of the breaking device(s) and their location in the DC network must be specified in relation with the nature of the topology. See examples here below

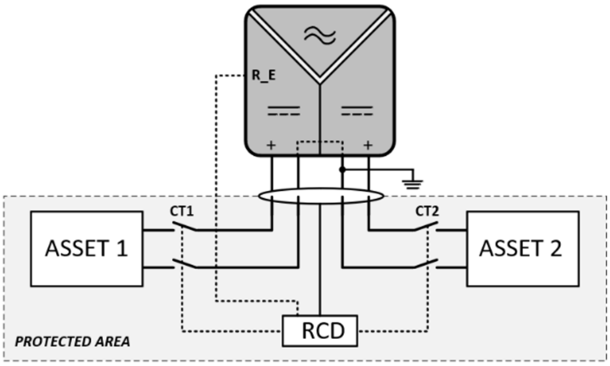


Figure 20: RCD protection at DC connected asset level

Jumper in position 6 (Grounding jumper) is doesn't care since superseded by external ground connection.

This scheme will protect all the areas that is at the opposite side of the current measurement loop of where the grounding is done.

The IMI device will sense the insulation resistance and trig an alarm output that will be used to stop the Stabiliti conversion and might also open the DC assets circuitry (relevance depending on application and nature of assets).

CT1 and CT2 are optional and depending on the application. It is the responsibility of the system integrator to size the breaking contactors.

In the second case, the Stabiliti is used in topology where the system is seen as a client of a higher-level topology (ASSET 1) in the sketch that provides the grounding connection. This higher-level system can be a DC-Bus for instance.

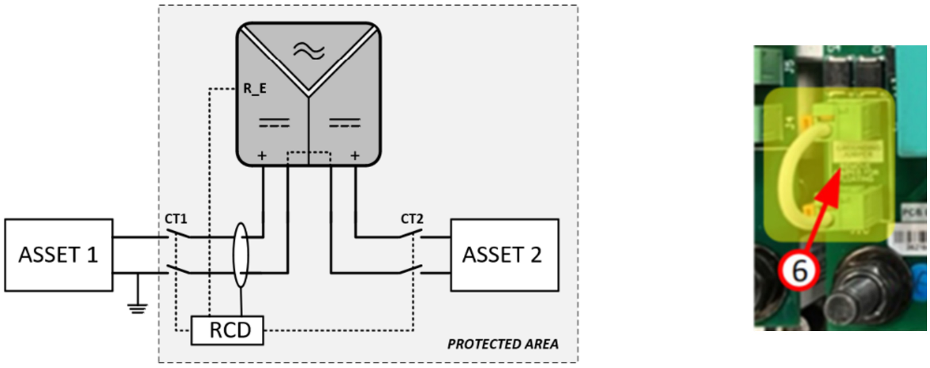


Figure 21: RCD protection of whole Stabiliti perimeter

Jumper in position 6 (Grounding jumper) must be removed.

The scheme will protect everything that is located down the current measurement loop, on the other side of the one where the DC bus is grounded.

CT1 and CT2 are optional and depending on the application. It is the responsibility of the system integrator to size the breaking contactors.

In both cases, the RCD must observe the following criteria:

- Rated for 1000VDC
- B-Type
- Rated for nominal breaking current of 80A per Stabiliti (in case of parallelization).
- Tripping current: 30mA

6.4.1.7 Fuses

The Stabiliti is equipped with some built-in fuses. Their characteristics are provided here below.

Location	Designation	Description
DC Connect board	FH1A/B	Ceramic fuse – 3AB – 1000Vac/dc / 1A
Controller board	F2	Ceramic fuse – 3AB – 500Vac/400Vdc / 6.3A – Fast
Backplane board	F1A	Blade fuse – 32Vac/dc / 7.5A
Aux Power rectifier board	F1/2, F3/4, F5/6	Ceramic fuse – 3AB - 500Vac/500Vdc / 1.25A - Fast

Table 14: Internal Fuses

None of these fuses are intended to be replaced by customer. Only duly trained technicians are allowed to do it since their blow might likely be related to other internal issues.

Important Remark:

The FH1A/B fuse on the DC Connect board provides a loose earth biasing for the COM point in the scope of fault leakage detection and safety perspective. It is implemented as a clamp to maximum 3V voltage drop towards Earth through diodes.

If a strong connection to earth is required, this one should be done directly from power cables outside of Stabiliti.

6.5 Stabiliti system implementation

6.5.1 Typical Stabiliti system

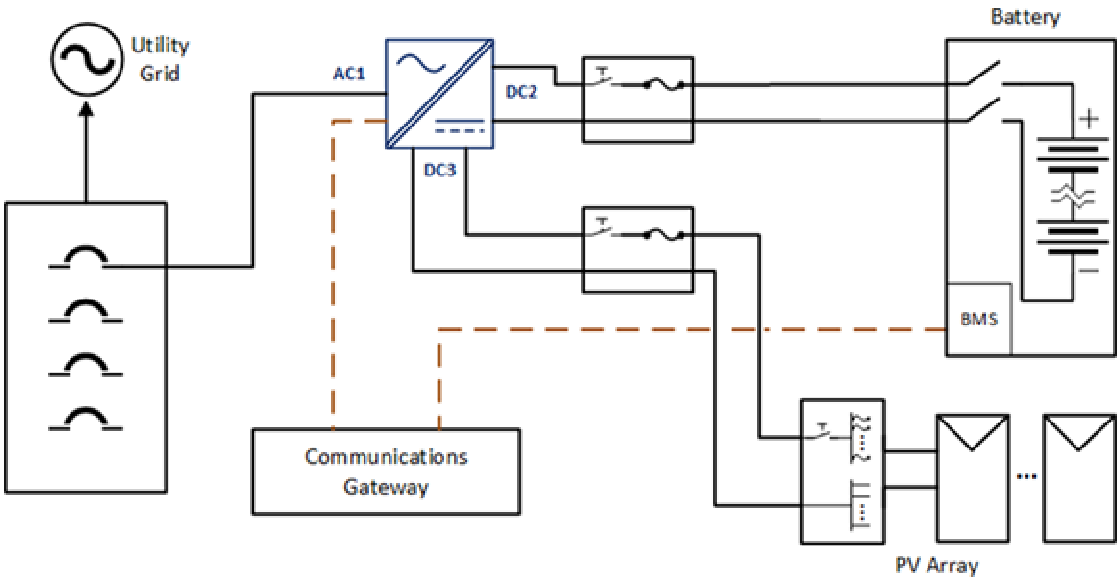


Figure 22: Typical PCS battery and PV system connections

Note! This schematic concentrates on the power topology. Additional required control and safety features are not mentioned in the schematic.

6.5.2 Verification of Electrical connections

Use the following procedure to verify final converter wiring after completing the AC, DC, and Ground wiring as detailed in section “8. Power Flow Control Methods”, page 63. Values specifically related to the Stabiliti 30C3-CE are mentioned between brackets complementary to Stabiliti 25C3-CE wherever applies.

High voltages are present, and only qualified personnel following safety procedures detailed in section “8. Power Flow Control Methods”, page 63 should attempt the following:

1. Open all AC and DC Disconnects.
2. Open the enclosure front door.
3. Close the external AC Disconnect connected to Port AC1.
    - Using a DMM on the AC voltage scale, verify that 400(480) Vac 3-Phase power is present on the AC terminals: measure phase AB voltage, phase BC voltage and phase CA voltage. Measurements from each individual phase-leg to Earth ground should read approximately 230(277) Vac.
    - If observed AC measurements do not meet the above requirements, immediately open the AC Disconnect and remedy AC wiring faults.

4. Close the external DC Disconnect connected to Port DC3.
    - Using a DMM on the DC voltage scale, measure the DC input voltages.
    - If observed DC voltages are higher than 1000 Vdc or outside of PV Array or battery design expectations, open the DC Disconnect and remedy DC wiring faults.
    - Compare Front-Panel Display voltage measurements to DMM observations.
5. Close the external DC Disconnect connected to Port DC2.
    - Using a DMM on the DC voltage scale, measure the DC input voltages.
    - If observed DC voltages are higher than 1000 Vdc or outside of PV Array or battery design expectations, open the DC Disconnect and remedy DC wiring faults.
    - Compare Front-Panel Display voltage measurements to DMM observations.
6. Close and secure the enclosure front door.

6.5.3 Configuration of Grid related settings

Before the PCS can be used to convert power and be controlled externally, it is required to make some settings of AC1 port that are related to the grid code as well as possible local DSO requirements. This must only be done while installing the devices and may likely be subject to approval by appropriate local authorities prior to be able to actually connect the installation to the grid.

Some Grid Interactive regulations states that these parameters setting is only allowed by installation operators and forbidden to system users. For this reason, the process to set and adjust these settings is part of the separate CE+T document **TMP203 – Stabiliti Grid Port Parametrization**.

7. Configuration, Control and Monitoring

7.1 PCS Configuration, Control and Monitoring

7.1.1 Stabiliti configuration scheme

The Stabiliti can be configured thanks to a multilayer scheme, that allows to have a standalone customizable configuration while also providing a full remote control capability.

The basic structure behind the configuration of the device is a parameter table with all significant registers that allows the device to run as expected. Some of these are purely internal registers not accessible to outside the device while others are user oriented and can be reprogrammed at power-up or later. These registers are seen as a Modbus table. Upon power-up, the device successively loads configuration files that update the parameter table by overwriting the previously written or default existing values.

The value of these parameters is fixed either by device locally saved tables, and by remote update using a Modbus link.

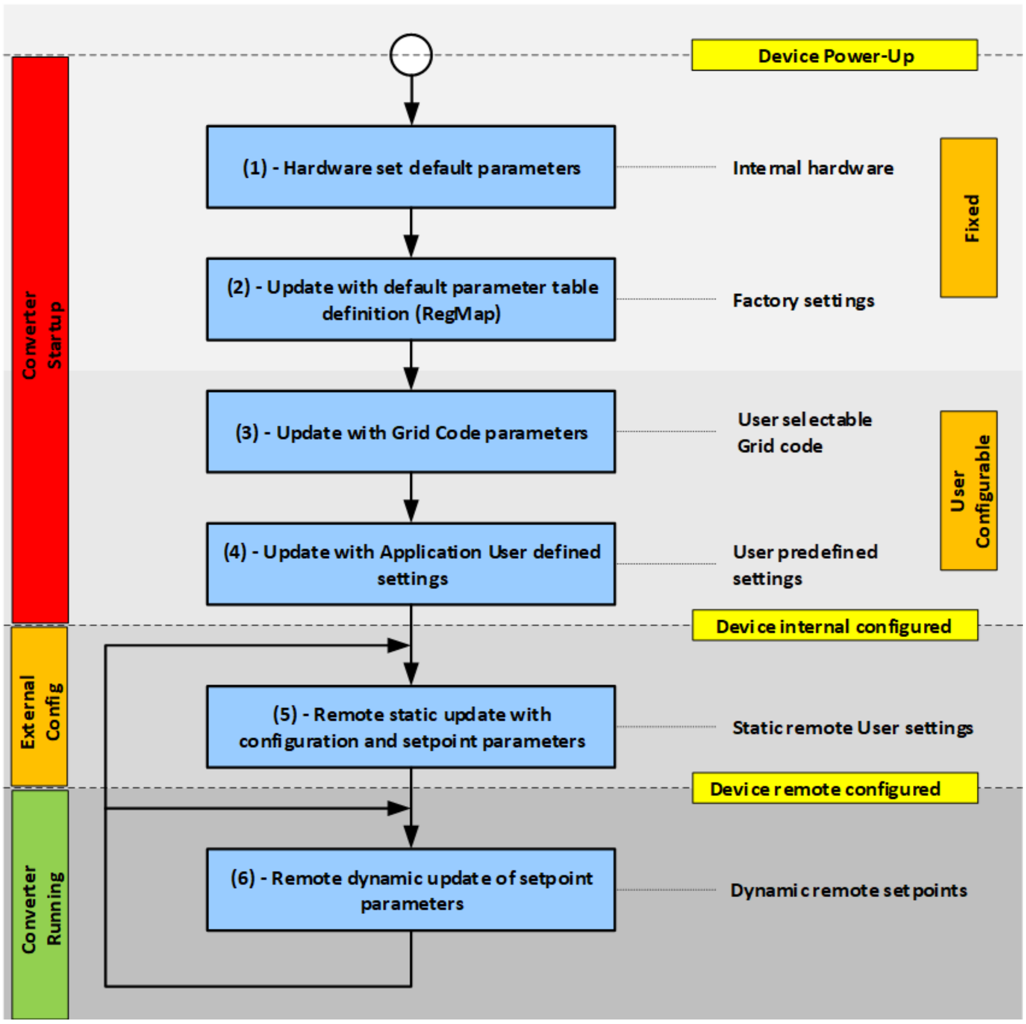


Figure 18: Stabiliti configuration scheme

Let us consider all the different steps:

1. Hardware set default parameters. The internal logic automatically defaults to some settings upon power up. These are typically basic relevant and safe settings.
   - Their values are factory fixed
   - Updatable in the Stabiliti through software package updates
2. Update with default parameter table definition. This table loaded from the non-volatile memory upon startup contains the details and defaults values for exhaustively all parameters of the converter kernel.
   - Parameter values are factory fixed
   - This table is specific to device (25C3-CE or 30C3-CE).
   - The pointer to the right table is saved in the non-volatile memory.
   - Updatable in the Stabiliti through software package updates
3. Update with grid code parameters. This table contains a limited set of parameters that are directly related to the grid interactive behaviour of the device. The content is factory fixed in accordance with various grid interactive local regulations. These tables are also specific to the Stabiliti type (25/30C3-CE) and are present in the non-volatile memory. A specific programmable setting allows to select which table must be loaded upon startup. The current possible settings are:
   - No Grid Code
   - EN50549
   - VDE4105

   These settings have the following characteristics:
   - Content not modifiable at all – factory fixed upon regulations requirements.
   - BUT, possible to overwrite some specific settings related to local DSO requirements.
   - Grid code / voltage setting and saving are done through Modbus command.
   - Access to all grid-code settings is only accessible to authorized persons, through a specific password protected process that is consequently described in a separate document with limited audience.
   - Requires a power-up of the device to be taken into account.
   - New grid code definitions and updates in the Stabiliti through software package updates.
4. Update with application user defined settings. This table is user defined and contains some default settings that the user would like to be set automatically at the end of the startup procedure. This table is present in the non-volatile memory and can be modified by the user by this way.
   - Parameter setting using Modbus commands, even while converter running. Takes immediate effect for most changes.
   - Once modified settings are OK, a save command is issued which will build a user-defined table with all the deviations from the content at output of step (3). This can be done by writing value 3 in register 2000 command.
   - Can contain settings to allow autostart at end of startup process, making it a truly stand-alone converter.
   - From here (4) to upper levels, only a limited application interest oriented selection of parameters is available to the user.

All the registers available at this level are listed by topic with their default values in the chapters here below. A more detailed description of the Modbus Parameter Table and its usage can be found in the CE+T Stabiliti 25/30C3-CE Modbus Programmers Guide.

At the output of this step, the converter is ready to run and receive requests from the user through Modbus.

5. Remote static update with configuration and setpoints. All the user available parameters can be set to their application values prior to start the converter. This operation is performed by a Modbus Master, preferably by the dedicated CE+T InViewX or any PC or PLC. Typically used for setting parameters that will not change once the converter is turned on i.e. but not exhaustively :
   - Methods of ports (only at step (4) or (5)
   - Voltages (plus offsets) and frequency wherever apply.
   - Grid interactive behaviour modes
6. Remote dynamic update with setpoints. Real-time setpoints refreshing while the converter is running, with simultaneous monitoring of working values and status, handled by an upper-level application running on a Modbus Master, preferably by the dedicated CE+T InViewX or any PC or PLC.

7.1.2 Stabiliti factory default configuration

Upon factory, the Stabiliti comes with a default parameter set that mainly defines:

- All ports IDLE
- AC1 port configured for model specific voltage (400VAC for 25C3-CE, 480VAC for 30C3-CE)
- No Grid Code definition
- Autostart disabled
- Modbus device address : 240
- Modbus TCP IP : 192.168.0.240
- Modbus RTU : 19200 bauds, 2 stop bits, 1 parity bit

AC power limits, DC min, max voltage, max current and max power are all set to their maximum extent on all ports.

7.2 Modbus Interface

7.2.1 Communication with Stabiliti

All Stabiliti™ Series Converters are configured, monitored, and controlled via the Modbus TCP (or Modbus RTU) interface. CE+T Power strongly recommends incorporating TCP-based communications into your Energy Storage System (ESS). It is also very highly recommended to handle the Stabiliti and associated TCP connected devices in a closed network, which will much ease implementation of installation cyber protection.

The Modbus interface is used to establish minimum and maximum allowable DC2 and DC3 port voltages, port limits, PV start and PV stop times, non-standard AC over/under voltage limits, non-standard AC over/under frequency limits, and other key system parameters.

The Modbus interface consists of a series of 16-bit holding registers each with its own unique Modbus address. Many registers are enforced as read-only and are dynamically updated by the PCS to present system status, alarm conditions and telemetry values.

The remaining core registers control system configuration including modes of operation and power levels. These registers are both readable and writable. A limited set of registers are read-only and present static values such as firmware version or the unit serial number.

Before applying AC or DC high-voltage to the unit, CE+T highly recommends that parties responsible for initial evaluation first familiarize themselves with the Modbus interface while supplying only 24 Vdc to the Converter's auxiliary power input.

Thoroughly review the Stabiliti User Modbus Register Map to understand all PCS configuration options and ensure safe operation for your situation. This User's Manual only provides a snapshot of most registers for initial evaluation, there are over 250 Modbus registers available to the system operator.

Please refer to **Stabiliti 25/30C3-CE Modbus Programmers Guide** and to CE+T Application Note **TMP103 - Stabiliti Remote Control** for more information about Stabiliti remote control.

Caution

- The concurrent use of Modbus RTU and Modbus TCP is not supported.
- Modbus interface is single thread, which means it does not support multiple simultaneous accesses, by one or multiple masters.

7.2.2 IP Address Setup

As noted above, the Modbus TCP interface is used to monitor and control the PCS. Other TCP services are also provided through the Ethernet link on the PCS Control Board. Detailing these services is beyond the scope of this Document. Out of the factory PCS is configured with a static IP address as follows:

Default IP Address	192.168.0.240
Default Subnet Mask	255.255.255.0
Default IP Gateway	192.168.0.1
Default DNS Server	192.168.0.1

The PCS LCD display will indicate its IP address if the unit is connected and communicating to a wired Ethernet network. If there is no wired Ethernet connection present the display will indicate "No Link". To establish initial communication with the PCS CE+T Power recommends the following procedure via a Windows laptop:

1. Locate the Network Connections Adapter Options window via the control panel
2. Change the properties of TCP/IPv4 component using a wired Ethernet adapter
3. Select the static IP option and set your laptop IP address to 192.168.0.241 with subnet mask 255.255.255.0. No gateway or DNS configuration should be necessary
4. Make a wired Ethernet connection directly between the laptop and PCS. Using the command prompt ping 192.168.0.240 to confirm TCP communications

IP addresses for this product are in IPv4 format represented as a Modbus string of 16 ASCII characters: 8 registers 2030-2037 are concatenated. A single register represents a pair of characters. The string is terminated with one or more null characters or zero bytes to fill the 16 characters. To change the IP address all 8 registers must be written then saved to flash by writing the value 7 to register 2000. New settings will take effect after the next system reset either with a command or by a power cycle. Despite highly not recommended by CE+T, setting the PCS IP to 0.0.0.0 will enable DHCP.

Example IP configuration: 192.168.1.7

Register:	2030	2031	2032	2033	2034	2035	2036	2037
Desired IP:	19	2	16	8	1	7		
Hex Value:	3139	322E	3136	382E	312E	3700	0000	0000

Table 15: Example IP Configuration 192.168.1.7

Refer to the Stabiliti 25/30C3-CE Modbus Programmers Guide for more detail on IP addressing.

7.2.3 Modbus Protocol Parameters

The primary Modbus protocol parameters default as follows and are user configurable.

Register Address	Name	Register Name	Type	Default	Default Value
2026	Modbus RTU Address	mb_adr_rtu	uint16 R/W	240	240
2027	Modbus TCP Address	mb_adr_tcp	uint16 R/W	240	240
2028	Modbus RTU Baud Rate	mb_baud	uint16 R/W	192	19200 bps
2029	Modbus RTU Parity	mb_parity	uint16 R/W	2	Even

Table 16: Modbus protocol parameters

In addition to the configurable Modbus parameters above, the following parameters for Modbus RTU/Modbus TCP are **NOT** configurable:

Modbus RTU Data bits: 8

Modbus RTU Stop bits: 2

Modbus TCP port: 502

Presently, two Modbus function codes are supported: function code 3 to read holding registers and function code 6 to write a single holding register. Refer to the Modbus Programmers Guide for more detail on the Modbus protocol.

7.2.4 Modbus Table Scaling Factors

To represent values in logical Engineering Units, a scaling factor is utilized for many of the Modbus registers noted above. This has been done to limit the values written to and read from the Converter within the 16-bit range of 0-65535 for unsigned and -32768 to 32767 for signed values.

These scaling factors apply to read only telemetry registers, as well as read/write setpoint registers used to set desired output voltage, current, or power levels.

Type	Scaling Factor	Register Read/Write	Actual Value
AC / DC Port Voltage	1 unit = 0.25V	1600	400 Vac / 400 Vdc
Frequency	1 unit = 0.001 Hz	50000	50 Hz
DC Port Current	1 unit = 0.1 A	100	10.0 A
DC Port Power	1 unit = 10 W	1300	13000 W

Type	Scaling Factor	Register Read/Write	Actual Value
AC Port Real Power	1 unit = 10 W	1400	14000 W
AC Port Reactive Power	1 unit = 10 var	700	7000 var
DC Port Current Ramp Rate	1 unit = 0.1 A/sec	2000	200 A/sec
AC/DC Port Power Ramp Rate	1 unit = 10 W/sec	100	1000 W/sec
AC power factor	1 unit = 1/1000th	-400	0.4 leading
Temperature	1 unit = 1/8 K	400	50 °C

Table 17: Modbus register scaling factors & examples

7.3 Modbus Register Assignments

7.3.1 General concepts considerations

7.3.1.1 Prior to write to Stabiliti Modbus registers

At device power-up, the Stabiliti is performing various internal configuration processes and is not advised to make concurrent Modbus register write. For this reason, a two step mechanism must be followed before being allowed to write to Modbus registers of the Stabiliti :

- Wait until the Stabiliti is ready to receive Modbus commands : this means all of its internal configuration processes are completed (get device status from register 2009).
- Enable Modbus Write accesses in Stabiliti (Command 13 in register 2000).

Refer to “10. Power Flow Scenarios”, page 73, for applications in examples.

7.3.1.2 Port Power Flow Sign Convention

The 30C3-CE PCS uses the following sign convention for power flows: positive power represents power being exported from the PCS while negative power represents power being imported into the PCS. This is summarized on a port-by-port basis in Table 4 below.

Port	Power/Current Sign	Meaning
AC1 Real Power	Positive	Exporting to grid
AC1 Real Power	Negative	Importing from grid
DC2 Battery Power	Positive	Exporting to battery (charge)
DC2 Battery Power	Negative	Importing from battery (discharge)
DC3 PV Power	Positive	N/A
DC3 PV Power	Negative	Importing from PV

Table 18: Power flow sign convention

7.3.1.3 Port settings update

Each port has a section in the Modbus Table for its configuration and usage.

All the parameters of the ports can be updated on-the-fly while running, except the port method, that must be set prior to start the conversion process.

For consistancy and deterministic behaviour of the device, it is however recommended to configure all possible settings while the conversion is not started, and keep a live refresh on only those that must be dynamically controlled in relation to the final application.

7.3.1.4 Two or three port usage

The Stabiliti has three usable power ports. In order to make a power transfer relevant, at least two of these are required to be configured, whatever these two. If only two ports are used, it is recommended to leave the third one configured in IDLE mode.

7.3.1.5 NET method

Each port can be configured to have a specific behaviour towards voltage/current/power. The specific setting for this is called the “port method”. All the methods are mostly self-explained. However, one called “NET” method, needs some more explanations.

The basic thing to keep in mind to understand the NET method is the fact that the Stabiliti has no embedded energy storage capability. Hence, the sum of power flows on all ports must always be zero (not taking conversion losses into account).

As the typical Stabiliti usage will need that some ports will have their power fixed either by setpoints, either by external devices, it is mandatory that one port will be slave to the others and always compensate for the sum of the power flows in the others to null the global power sum of the device. That port, that must be selected with the application in mind has to be configured with NET method.

NET method supposes that voltage (and frequency) for AC are fixed from outside the device. Power on this port will be regulated by Stabiliti to ensure null sum of all ports.

Consequently, there should always be one and only one port configured in NET method in the Stabiliti.

7.3.1.6 Throttle concept

The throttle concept is in direct relation with the NET concept. If for any reason, the port selected for NET purpose is not able to compensate for the other ports power, it is required to derate the power behaviour of the other ports to stay within the allowable compensation margin. This will be done through throtting the power on the other ports, with a priority scheme. The port selected for throttling will be derated first. If for any reason, this port does not provide sufficient derating, the third port will be derated too. In particular, if an IDLE port is selected for throttling, this will consequently be handled by the third port.

7.3.1.7 Voltage, Current and Power limits

The DC2 and DC3 maximum voltage limits and maximum current limits should be updated from the factory default and saved to SD-Card to reflect your system (i.e. battery or PV array) safe operating ranges.

- **Voltage limit reached**: the PCS will fault and go offline.
- **Current**: the PCS will attempt to soft limit current flow if a current limit is reached, otherwise it will fault and go offline.
- **Power**: the PCS will attempt to soft limit the power and use alternate ports to fulfill global request, using throttle mechanism (for NET port only).

7.3.2 Port AC1

Register Address	Register Name	Type	Default value	Comments
Control registers				
65	p1_control_method	uint16 RW	0x0000	0x0000 - IDLE0x0001 - NET 0x0402 - GRID POWER (GPWR) 0x0502 - FACILITY POWER (FPWR)
67	p1_throttle_port	uint16 RW	0	Throttle port when configured as NET: 2 : DC2 port throttling priority 3 : DC3 port throttling priority
68	p1_real_pwr_setpt	int16 RW	0	Grid-following real power setpoint
69	p1_reactive_pwr_setpt	int16 RW	0	Grid-following reactive power setpoint
71	p1_voltage_setpt	int16 RW	1600 (400 V)	Facility power line-to-line voltage setpoint
72	p1_frequency_ setpt	int16 RW	50000 (50 Hz)	Facility power line-to-line frequency setpoint
78	p1_voltage_setpt_offset	int16 RW	0	Offset fine adjust of voltage setpoint (-10 V to +10 V capability, 0.25 V unit)
86	p1_static_resistance	uint16 RW	100 (0.1 ohm)	AC1 static resistance in milliohms
88	p1_export_q_pwr_lim	int16 RW	2100 (21 kVAR)	Reactive power limit export on AC1
89	p1_export_p_pwr_lim	int16 RW	2500 (25 kW)	Real power limit export on AC1
90	p1_current_limit	int16 RW	440 (44 A)	Current Limit per AC1 phase
91	p1_apparent_power_lim	uint16 RW	2800 (28 kVA)	Apparent power limit on AC1
92	p1_import_q_pwr_lim	int16 RW	-2100 (21 kVAR)	Reactive power limit import on AC1
93	p1_import_p_pwr_lim	int16 RW	-2500 (25 kW)	Real power limit import on AC1
95	p1_grid_access_control	uint16 RW	0	AC1 grid access control settings: Bit 0 : Enable Grid_Req/Grid_Ack inputs Bit 1 : Revert Grid_Req polarity Bit 2 : Revert Grid_Ack polarity Bit 3 : Enable Grid_Connect input Bit 4 : Revert Grid_Connect polarity Bit 5 : Cease Active Power soft request
Status registers				
100	p1_real_pwr_ramped	int16 RO		Actual AC1 real power control during ramping
101	p1_reactive_pwr _ramped	int16 RO		Actual AC1 reactive power control during ramping

Register Address	Register Name	Type	Default value	Comments
105	p1_frequency	int16 RO		Actual AC1 frequency
109	p1_v_ab_ext_rms	int16 RO		Actual AC1 ab voltage
110	p1_v_bc_ext_rms	int16 RO		Actual AC1 bc voltage
111	p1_v_ac_ext_rms	int16 RO		Actual AC1 ac voltage
112	p1_v_a_ext_rms	int16 RO		Actual AC1 a line voltage
113	p1_v_b_ext_rms	int16 RO		Actual AC1 b line voltage
114	p1_v_c_ext_rms	int16 RO		Actual AC1 c line voltage
118	p1_power_factor	int16 RO		Actual AC1 power factor
119	p1_real_power	int16 RO		Actual AC1 real power
120	p1_reactive_power	int16 RO		Actual AC1 reactive power
121	p1_apparent_power	int16 RO		Actual AC1 apparent power
125	p1_i_a_ext_rms	int16 RO		Actual AC1 a line current
126	p1_i_b_ext_rms	int16 RO		Actual AC1 b line current
127	p1_i_c_ext_rms	int16 RO		Actual AC1 c line current
1002	p1_state	uint16 RO		AC1 port state. *See System Control State & Status* below for port state definitions.
1003	p1_fault_status	uint16 RO		AC1 port fault status. *See System Control State & Status* for fault definitions.
2010	AC_Voltage	uint16 RO		Grid voltage mode : 0 : 400VAC 1 : 480VAC
2011	AC_Grid_Code	uint16 RO		Grid interative code : 0 : No Rule 1 : EN50549 2 : VDE4105

Table 19: Port AC1 modbus table

7.3.2.1 Grid connect

Seemless grid connection is handled by an external interconnection switch, that communicates with the Stabiliti through signals GRID_REQ and GRID_ACK.

7.3.2.2 Grid injection

The AC power injection can be remotely disabled by the ORing of the Cease_Active_Power bit and an active external GRID_CONNECT signal, whose function can be enabled and its polarity programmable. By default, without any polarity revert, the grid injection is allowed when the GRID_CONNECT_IO is supplied with 24V.

7.3.2.3 Grid interactive

When selecting the grid interactive mode in system initial commissionning (authorized operator only), the reactive power will be driven by the grid interactive module algorithms, that make the basic reactive power control registers irrelevant. Consequently, the register p1_reactive_pwr_setpt is ignored. Some default values may be different depending on the default grid code selected.

For support with other grid interconnect standards please contact customer.support@cet-power.com

7.3.2.4 Voltage and code selection

When AC_Voltage or AC_Grid_Code registers are modified, a full power-off/power-up of the Stabilti is required.

See CE+T Application Note **TMP104 – Stabiliti Grid Interactive Behaviour** for more explanations.

7.3.3 Port DC2

Port DC2 being mainly devoted (but not mandatory) to battery handling, explanations are provided about port pre-charge that might be useful if battery is not equipped with such a feature.

Register Address	Register Name	Type	Default value	Comments
Control registers				
129	p2_control_method	uint16 R/W	0	0x0000 - IDLE 0x0001 - NET 0x0002 - MPPT 0x0301 - DC CURRENT 0x0401 - DC POWER 0x0501 – DC VOLT
131	p2_throttle_port_setpt	int16 RW	0	Throttle port when configured as NET: 1 : AC1 port throttling priority 3 : DC3 port throttling priority
132	p2_current_setpt	int16 RW	0	DC2 Current setpoint
133	p2_power_setpt	int16 RW	0	DC2 Power setpoint
134	p2_voltage_setpt	int16 RW	0	DC2 Voltage setpoint. Adjust voltage droop at Reg 157.
137	p2_mppt_restart_setpt	uint16 RW	300	Timeout for restart MPPT conversion after MPPT stop condition encountered
138	p2_mppt_minv_stop_setpt	uint16 RW	400 (100 V)	Low voltage MPPT stop voltage
139	p2_mppt_minv_start_setpt	int16 RW	800 (200 V)	Low voltage MPPT (re)start voltage
141	p2_v_pn_max_limit	int16 RW	4200 (1050 V)	Maximum port DC2 operating voltage
142	p2_v_pn_min_limit	int16 RW	-200 (-50 V)	Minimum port DC2 operating voltage
146	p2_voltage_setpt_offset	int16 RW	0	Offset fine adjust of voltage setpoint (-10V to +10V capability, 0.25V unit)
152	p2_import_pwr_lim	int16 RW	-5000 (-50 kW)	DC2 import power limit
153	p2_export_pwr_lim	int16 RW	5000 (50 kW)	DC2 soft current limit (maximum 60 A, absolute value)

Register Address	Register Name	Type	Default value	Comments
154	p2_current_limit	uint16 RW	620 (62 A)	DC2 current limit
157	p2_static_ resistance	uint16 RW	100 (0.1 ohm)	DC2 static resistance in milliohms
275	precharge_control	uint16 RW	0	DC2 port precharge control (self-cleared): 1 : start precharge 2 : stop precharge
276	precharge_hi_lim	uint16 RW	3200 (800 V)	DC2 precharge regulation top voltage (800V)
277	precharge_lo_lim	uint16 RW	3180 (790 V)	DC2 precharge regulation bottom voltage (790V)
278	precharge_ timeout_lim	uint16 RW	75	Timeout in seconds for precharge regulation within boundaries. Fault generated if not the case.
Status registers				
164	p2_current_ ramped	int16 RO		Actual DC2 current control during current ramping
165	p2_power_ramped	int16 RO		Actual DC2 real power control during power ramping
166	p2_voltage_ ramped	int16 RO		Actual DC2 voltage control during voltage ramping
173	p2_voltage	int16 RO		DC2 actual voltage readout
185	p2_power	int16 RO		DC2 actual power readout
186	p2_current	int16 RO		DC2 actual current readout
1004	p2_state	uint16 RO		DC2 port state. *See System Control State & Status for port state definitions.*
1005	p2_fault_status	uint16 RO		DC2 port fault status. *See System Control State & Status* for fault definitions.

Table 20: DC2 Port Modbus registers

7.3.3.1 P2 with a battery

When Port DC2 is used with a battery, it is advisable to adjust the p2_v_pn_max/min_ limit parameters to safe limits towards battery ratings. Normally, these limits should never been reached, since higher-level battery management algorithms based on BMS input data should keep the battery within even narrower boundary values.

7.3.3.2 Precharge

In order to limit the peak current upon connecting an external low impedance voltage source to the bulky inner capacitors, it is advisable to precharge these to the external source voltage. The precharge should be turned on to charge the capacitors until it allows connection when voltage has significantly levelled with the external one. Once the connection to the external source is done, the precharge circuit should be turned off. The capacity of this precharge circuit devotes it only to the device precharge needs. It can not cope with heavier loaded external circuitry. There are other ways to manage this with the Stabiliti. See CE+T Application Note TMP105 – Stabiliti DC Port Usage.

7.3.3.3 PV

PV panel power transfer can be optimized through built-in MPPT algorithm. The principle is quite simple:

- Power transfer starts when the PV voltage has reached p2_mppt_minv_start_setpt for p2_mppt_restart_setpt seconds.
- Power transfer stops after PV voltage has dropped below p2_mppt_minv_stop_setpt for p2_mppt_restart_setpt seconds.
- If a power derating of the port is required (throttle or soft limitation), the MPPT will lower the current, leading to higher voltage, up to the desired power.

7.3.4 Port DC3

Register Address	Register Name	Type	Default	Comments
Control registers				
193	P3_control_method	uint16 RW	0	0x0000 – IDLE 0x0001 – NET 0x0002 – MPPT 0x0301 – DC CURRENT 0x0401 – DC POWER 0x0501 – DC VOLT
195	P3_throttle_port_setpt	int16 RW	0	Throttle port when configured as NET: 1 : AC1 port throttling priority 2 : DC2 port throttling priority
196	P3_current_setpt	int16 RW	0	DC3 Current setpoint
197	P3_power_setpt	int16 RW	0	DC3 Power setpoint
198	P3_voltage_setpt	int16 RW	0	DC3 Voltage setpoint. Adjust the voltage droop at Reg 221
201	P3_mppt_restart_setpt	uint16 RW	300	Timeout for validating MPPT start/stop conditions in seconds
202	P3_mppt_minv_stop_setpt	uint16 RW	400 (100 V)	Low voltage MPPT stop voltage
203	P3_mppt_minv_start_setpt	int16 RW	800 (200 V)	Low voltage MPPT (re)start voltage
205	P3_v_pn_max_limit	int16 RW	4200 (1050 V)	Maximum port DC operating voltage
206	P3_v_pn_min_limit	int16 RW	-200 (-50 V)	Minimum port DC operating voltage
210	P3_voltage_setpt_offset	int16 RW	0	Offset fine adjust of voltage setpoint (-10 V to +10 V capability, 0.25 V unit)
216	P3_import_pwr_lim	int16 RW	-5000 (-50 kW)	DC3 import power limit
217	P3_export_pwr_lim	int16 RW	5000 (50 kW)	DC3 export power limit
218	P3_current_limit	uint16 RW	620 (62 A)	DC3 current limit
221	P3_static_resistance	uint16 RW	100 (0.1 ohm)	DC3 static resistance in milliohms

Register Address	Register Name	Type	Default	Comments
Status registers				
228	P3_current_ ramped	int16 RO		Actual DC3 current control during current ramping
229	P3_power_ramped	int16 RO		Actual DC3 real power control during power ramping
230	P3_voltage_ ramped	int16 RO		Actual DC3 voltage control during voltage ramping
237	P3_voltage	int16 RO		DC3 actual voltage readout
249	P3_power	int16 RO		DC3 actual power readout
250	P3_current	int16 RO		DC3 actual current readout
1006	P3_state	uint16 RO		DC3 port state. See System Control State & Status for port state definitions.
1007	P3_fault_status	uint16 RO		DC3 port fault status. See System Control State & Status for fault definitions.

Table 21: DC3 Port Modbus registers

7.3.4.1 P3 with a battery

When Port DC3 is used with a battery, it is advisable to adjust the p3_v_pn_max/min_ limit parameters to safe limits towards battery ratings. Normally, these limits should never been reached, since higher-level battery management algorithms based on BMS input data should keep the battery within even narrower boundary values.

7.3.4.2 Precharge

There is no specific precharge circuit on DC3 port. However, this function can be emulated by an external control sequence. See CE+T Application Note TMP105 – DC Port Usage

7.3.4.3 PV

PV panel power transfer can be optimized through built-in MPPT algorithm. The principle is quite simple:

- Power transfer starts when the PV voltage has reached p3_mppt_minv_start_setpt for p3_mppt_restart_setpt seconds.
- Power transfer stops after PV voltage has dropped below p3_mppt_minv_stop_setpt for p3_mppt_restart_setpt seconds.
- If a power derating of the port is required (throttle or soft limitation), the MPPT will lower the current, leading to higher voltage, up to the desired power.

7.3.5 System control

The following registers are used to handle and monitor the global behaviour of the converter.

Register Address	Register Name	Type	Default	Comments
Control registers				
263	user_start	uint16x R/W	0	Manual Mode start, set to 1 to start.
264	user_stop	uint16x R/W	0	Manual Mode stop, set to 1 to stop

Register Address	Register Name	Type	Default	Comments
267	sys_op_mode	uint16x R/W	0	0 = operate in Manual Mode 1 = operate in Automatic Mode
283	watchdog	uint16x R/W	0	0 = watchdog disabled >0 : time in seconds before watchdog activation.
1015	fault_global_reset	uint16x R/W	0	1=reset all faults, including all fault counters and timestamps. Self clearing.
Status registers				
362	pm_temp_max	uint16x RO		Highest internal temperature.
1000	pcs_state	uint16x RO		Converter core state. See state definitions below
1001	pcs_fault_status	uint16x RO		Converter core fault status. See fault definitions below.
1016…1023	fault_active_0..7	uint16x RO		Indicate active faults
1024…1031	fault_occurred_0..7	uint16x RO		Indicate occurred faults
1032…1039	warning_active_0..7	uint16x RO		Indicate active warnings
1040…1047	warning_occurred_0..7	uint16x RO		Indicate occurred warnings

Table 22: System basic Modbus registers

7.3.5.1 sys_op_mode

The manual mode requires the converter to be started using the user_start command, while the automatic mode will automatically restart the converter at startup exit or upon abort recovery.

7.3.5.2 pcs_state

The following table provide the various states notified in pcs_state which reflects the converter kernel state.

Register Value	State	Comments
0	OFF	Converter is off
1	LOCKDOWN	Converter is stopped due to abort. Need external action to restart.
2	ABORT	Converter is in abort mode. Possible automatic resume depending on fault criticality.
3	RESERVED	Intermediate state not meaningful to end user
4	WAITING_RECONNECT	Converter will restart after programmed reconnect time upon abort condition removed.
5	ON	Converter is nominally working

Table 23: PCS_STATE register values description

7.3.5.3 p1..3_state

The following table provides the various faults notified in *p1..3_state*.

Register Value	Fault	Comments
0	STANDBY	Port does not operate because it is not configured or because the PCS is not running.
1	LOCKDOWN	Port does not operate following a lockdown level fault. The only way to restart the port is to restart the PCS.
2	ABORT	An error of ABORT level is present.
3	WAITING_RECONNECT	No error is present but a reconnect timer is counting and a restart is imminent.
5	ON_CURR	Port power conversion running in current control
6	ON_VOLT	Port power conversion running in volt control
7	ON_PWR	Port power conversion running in power control
8	ON_MPPT	Port power conversion running in maximum power point control
10	ON_FPWR_FORMING	Port power conversion running in facility power (forming mode)
12	ON_FPWR_FOLLOWING	Port power conversion running in facility power (following mode)
13	ON_GPWR	Port power conversion running in grid power (following)
14	ON_NET	Port power conversion running in net

Table 24: Px_STATE register values description

7.3.5.4 pcs_fault & p…_fault_status

The following table provides the various faults notified in *pcs_fault_status* and *Px_fault_status*.

Register Value	Fault	Comments
0	OK	Everything is OK to operate normally
1	WARNING	Fully operating but some warning is present (see Warnings pane)
2	DEGRADED	Operating in a degraded state (typically voltage/current/power limitation, (see Warnings pane)
3	WAITING_RECONNECT	Everything is OK to operate normally but a timer is still active, normal operation will be resume as soon as the corresponding timer expires.
4	HOLD_OFF	Specific status when 'PV' port voltage is too low
5	ABORT-0	There is at least a defect present with abort of level 0 (lowest priority)
6	ABORT-1	There is at least a defect present with abort of level 1
7	ABORT-2	There is at least a defect present with abort of level 2
8	LOCKDOWN	There is at least a defect present with abort of lockdown level
9	IDLE	Port not configured

Table 25: PCS_FAULT_STATUS and Px_FAULT_STATUS register values description

7.3.5.5 PCS Faults & Warnings

The faults and warnings are represented in two ways in the table :

- Real-time value in fault_active_x and warning_active_x registers. Cleared by hardware, by fault_global_reset or by user_start commands.
- History values in fault_occured_x and warning_occured_x registers. Cleared by fault_global_reset or by user_ start commands.

CE+T strongly recommends the operator familiarize themselves with the Fault Management sub-system and the extensive list of faults and warnings of the PCS by reading Application Note **TMP101 – Stabiliti Fault Monitoring & Management**, in particular the automatic reconnect feature of Automatic Mode.

7.3.6 Communication control and Status registers

The following registers are used to handle the Stabiliti communication behaviour.

Register Address	Register Name	Comments
Control registers		
2000	command	Comms processor command: - 1=Reset - 3=Save (Reg <2000) - 7=Save Settings (Reg >2000) - 13=Modbus Write Enable
2025	timezone	Device timezone
2026	mb_adr_rtu	Modbus RTU address
2027	mb_adr_tcp	Modbus TCP address
2028	modbus_rtu_baud	Modbus RTU baud rate
2029	mb_parity	Modbus RTU parity
2030..2037	eth_address	Ethernet IP address
2038..2045	eth_mask	Ethernet Mask
2046..2053	eth_gateway	Ethernet Gateway IP address
2054..2061	eth_dns	Ethernet DNS IP address
2062..2069	eth_ntp	Ethernet NTP IP address
Status registers		
2009	pcs_status	Converter global status

Table 26: Communication control and status modbus registers

7.3.6.1 command

This register is related to the load and save of user_cfg registers from/to the SD-Card, or the reset of the device. This register is self-cleared.

7.3.6.2 pcs_status

The pcs_status register provides the device Modbus readyness upon startup & reset.

Register Value	State	Comments
0	UC_INIT	µC initializing and retrieving configuration from SD-Card
1	UC_CONNECT_FPGA	µC initialized and trying to connect to FPGA
2	UC_CONFIG_FPGA	µC configuring FPGA
3	UC_FPGA_READY	µC and FPGA configured and ready
4	UC_MODBUS_READY	Modbus Write enabled, ready to process Modbus commands

Table 27: PCS_ STATUS register values description

7.3.7 General purpose IOs

Register Address	Register Name	Type	Default	Comments
1500	gpio1_cfg	uint16x R/W	0	GPIO1 configuration register
1501	gpio1_filter	uint16x R/W	20 (200msec)	GPIO1 time filter register
1502	gpio1_ctl	uint16x R/W	0	GPIO1 control register
1503	gpio1_sts	uint16x RO		GPIO1 status register
1504	gpio2_cfg	uint16x R/W	0	GPIO2 configuration register
1505	gpio2_filter	uint16x R/W	20 (200msec)	GPIO2 time filter register
1506	gpio2_ctl	uint16x R/W	0	GPIO2 control register
1507	gpio2_sts	uint16x RO		GPIO2 status register
1508	sysio_cfg	uint16x R/W	0	SYS_IO configuration register
1509	sysio_filter	uint16x R/W	20 (200msec)	SYS_IO time filter register
1510	sysio_ctl	uint16x R/W	0x000D	SYS_IO control register
1511	sysio_sts	uint16x RO		SYS_IO status register
1512	sysok_cfg	uint16x R/W	0x0013	SYS_OK configuration register
1514	sysok_ctl	uint16x R/W	0x0001	SYS_OK control register

Table 28: General Purpose I/O Modbus registers

7.3.7.1 xxxIOx_cfg

Register Bit	State	Comments
0	io_mode	IO usage : 0 : input 1 : output
1	io_polarity	IO polarity : 0 : no polarity inversion (1 = in: IO 24V / out: closed contact) 1 : polarity inversion (0 = in: IO 24V / out: closed contact)
2	reserved	

Register Bit	State	Comments
3..5	io_source	IO output source signal : 0 : unused 1 : io_out bit 2 : internal alarm 3 : internal warning 4..7 : reserved
6..7	io_dest	IO input destination signal : 0 : unused 1 : io_in bit 2 : io_alarmx (x =1, 2 for GPIOs, 3 for SYS_IO) 3 : io_warningx (x =1, 2 for GPIOs, 3 for SYS_IO)
8..15	reserved	

Table 29: IO Configuration

7.3.7.2 xxxIOx_ctl

xxx_filter specifies the time the IO must stabilize before assessing the new state.

7.3.7.3 xxxIOx_ctl

Register Bit	State	Comments
0	io_out	IO level : 0 : contact opened 1 : contact closed
1..15	reserved	

Table 30: I/O Control

7.3.7.4 xxxIOx_sts

Register Bit	State	Comments
0	io_in	IO input : 0 : input not energized 1 : input energized
1..15	reserved	

Table 31: I/O Status

Please refer to CE+T Application Note **TMP102 - Stabiliti General Purpose IOs,** for more details on General Purpose I/Os.

7.3.8 System info

The following registers provide information about the programmable items of the device.

Register Address	Register Name	Type	Default	Comments
16	Fpga_Major	uint16 RO		Major FPGA FW version
17	Fpga_Minor	uint16 RO		Minor FPGA FW version
18	Fpga_Patch	uint16 RO		FPGA Patch version

Register Address	Register Name	Type	Default	Comments
19	Fpga_Build	uint16 RO		FPGA Build version
24	Grid_Interactive_ Module_Version	uint16 RO		Version of FPGA grid interactive module
25	Grid_Interactive_ Reserved	uint16 RO		Reserved for Grid Interactive
26	Grid_Interactive_ Module_CRCh	uint16 RO		CRC of FPGA grid interactive module
27	Grid_Interactive_ Module_CRCl	uint16 RO		CRC of FPGA grid interactive module
2001..2005	P_Code	string16 RO		PCS product code : 5 registers concatenated, 2 ASCII characters per register
2006..2008	Serial_Number	string16 RO		PCS serial number: 3 registers concatenated, 2 ASCII characters per register
2010	AC_Voltage	uint16 RO		AC1 port nominal voltage
2011	AC_Grid_Code	uint16 RO		AC_Grid_Code
2086	Comms_Major	uint16 RO		Major Comms FW version
2087	Comms_Minor	uint16 RO		Minor Comms FW version
2088	Comms_Patch	uint16 RO		Patch Comms FW version
2089	Comms_Build	uint16 RO		Build Comms FW version
2090	Regmap_Major	uint16 RO		Major Register Map version
2091	Regmap_Minor	uint16 RO		Minor Register Map version
2092	Regmap_Patch	uint16 RO		Patch Register Map version
2093	Regmap_Build	uint16 RO		Build Register Map version

Table 32: System info Modbus registers

The main sections are:

- FPGA is related to the converter core in hardware programmable logic.
- Grid_Interactive is related to the grid_interactive module firmware (is part of upper FPGA).
- Comms relates to the microcontroller firmware.
- RegMap refers to the global register map definition, that governs all programmable features of the Stabiliti, including variable name, access and min-max and default values.

7.3.9 Fault management

Several types of fault are possible in the Stabiliti:

- Device startup and configuration faults
- Faults during converter operation

7.3.9.1 Device Startup

When the device starts, it will first setup its internal hardware and install a default configuration read from the SD-Card, and updating it with grid-code and user-defined parameters.

The status of these operations can be read from Reg 2009 – pcs_status. When it is successfully completed, it will return 0, otherwise, it mentions either progress, either something abnormal happening during configuration (missing file, …). In this latter case, the device will remain in fault condition, with no possiblity to operate it. This case can only be solved by qualified operator.

7.3.9.2 Converter operation

Once the device has performed a succesful startup (Reg 2009 = 0), the kernel conversion is allowed to operate and the device status to monitor becomes the Reg 2000 pcs_state, which is directly related to the conversion kernel. All the fault management is handled by a collection of functional bloks :

- Fault and warning monitor :
  - A collection of context sensitive possible faults and warnings are sensed and a status is provided for each as a bit in bitfields. The status reflects only the immediate value and is continuously reevaluated.
    - Faults are defined in Reg 1016..1023 fault_active_x with x=1..8
    - Warnings are defined in Reg 1032..1039 warning_active_x with x=1..8.
  - All these events occurrences are stored in a separate twined bitfield area :
    - Occurred faults are defined Reg 1024..1031 fault_occurred_x with x:1..8
    - Occurred warnings are defined in Reg 1040..1047 warning_occured_x with x=1..8

Only a fault_global_reset written to 1 allows to clear the events_occured.

The faults bits are also aggregated in internal conditions filtering to allow operation of the PCS, and each port, individually, or put these in abort or lockdown modes.

PCS State machine that handles the whole power conversion process. May have the following states:

- OFF : idle mode, not converting
- ON : successfully converting
- ABORT : a fault has occurred that has stopped conversion, may eventually restart if fault condition disappears
- WAITING_RECONNECT : timer that is started at fault disappearing end ends with PCS ON State.
- LOCKDOWN : unrecoverable fault that stops the converter. Needs user operation to exit.

Ports state machines: handles the activity of the port. A port may be turned off due to a fault while the other ports and the conversion are still effective.

- STANDBY : state of the port when PCS State is not ON.
- ON : no defect on port, operational
- ABORT : a fault condition detected on this port (i.e. out of range voltage while a PWR method is selected)
- WAITING_RECONNECT : waiting some time before moving to ON after fault disappears
- LOCKDOWN : unrecoverable fault that stops Port activity. Needs user operation to exit.
- Other : various operational modes linked to ON state (PV, NET, …)

Please find additionnal information in the CE+T Application Note TMP101 - Stabiliti Fault Monitoring & Management and in the Stabiliti Modbus Programmer's Guide.

8. Power Flow Control Methods

There are numerous and flexible means to transfer power between PCS power ports using the Modbus interface that are collectively known as "Control Methods" for power flow. These include: MPPT, Grid Power (GPWR), Facility Power (FPWR), DC Power (POWER), DC Current (CURRENT), NET, and IDLE. There is a dedicated Control Method register to configure each individual port of the PCS.

NOTE: The PCS control system does not contain any built-in battery charge profiles or discharge algorithms for any battery types and does not communicate with any batteries directly. An external system controller must dictate battery charge & discharge levels in real-time with current or power commands according to your economic use-case of the overall Energy Storage System.

Each Control Method may have one or two associated setpoint registers to govern the real-time current or power flow within the bounds of the Control Method, as well as ramp rate register which specifies how fast to move from one setpoint level to a new setpoint target. The programmable ramp rate allows the PCS to smoothly ramp up or ramp down port power over a programmable time period ranging from tens of milliseconds to minutes. Power flows will be automatically limited according to the soft power limits and soft current limits.

8.1 AC1 Available Control Methods

Register Value	Name	Description
0x0000	IDLE	Power conversion disabled, factory default
0x0001	NET	Import/export remainder of power flow, grid-tied applications
0x0402	GPWR	Grid-tied power transfer applications
0x0502	FPWR	Interactive grid-forming/grid-following applications (requires external islanding switchgear to support transitions between voltage-following and voltage-forming mode)

Table 33: PCS AC1 control methods

8.2 DC2/DC3 Available Control Methods

Register Value	Name	Description
0x0000	IDLE	Power conversion disabled, factory default
0x0001	NET	Import/export remainder of power flow
0x0002	MPPT	Maximum power point tracking of solar PV array
0x0301	CURR	Constant current import/export
0x0401	PWR	Constant power import/export
0x0501	VOLT	Fixed voltage import/export, with controllable droop

Table 34: PCS DC2/DC3 control methods

8.3 Automatic Mode and Manual Mode

The PCS has two overall operating modes which are selected with register 267 sys_op_mode. In Manual Mode, power flow is only activated by writing 1 to the user_start register 263 as a command after valid Control Methods have been configured. Power flow is stopped either when a fault occurs or by writing a 1 to the user_stop register 264. Manual Mode is intended for a human operator in a laboratory or field service situation. In Automatic Mode, power flow is activated as soon as a valid set of Control Methods are written. Power flow is stopped by sequentially setting Control Methods to IDLE. As discussed below, the NET port is the most critical configuration and should be written first when starting up in Automatic Mode and Idled last when shutting down (Idling) the PCS. Manual Mode is intended for full deployment situations where an automatic controller is supervising the PCS.

8.4 Control Method Uses and Restrictions

The chapters briefly describes the possible methods that can be used on the Stabiliti ports. Please refer to the following applications notes for more detailed explanations:

- TMP104 – Stabiliti Grid Interactive Behaviour
- TMP303 – Stabiliti in Microgrid operation
- TMP105 – Stabiliti DC Port Usage

8.4.1 IDLE Control Method (0x0000)

If a port is not in use it should be set to the IDLE Control Method to disable power flow into our out of that port. All Converters are shipped with IDLE as their factory default for safety purposes.

8.4.2 NET Control Method (0x0001)

To move power between 2 or 3 active ports, one and only one port on the PCS must ALWAYS be set to the NET Control Method. The NET method and port accommodates any remaining power flow necessary, whether import or export, to balance out other fixed or variable power flows on the remaining port(s) which are operating with other Control Methods. This way the power flows in and out of the PCS will always sum nominally to zero (neglecting efficiency losses). Refer to “Figure 19: Three port power flow example with utility grid at AC1 as = NET”, page 65 for an example with AC1 as NET and a variable PV resource. If a power or current limit is reached on a NET port, it will attempt to throttle or push back on another port. The throttling mechanism and configuration is beyond the scope of this document. Refer to the Modbus Programmers Guide for more information.

8.4.3 DC Power Control Method (0x0401)

The DC Power Control Method (POWER) is paired with a power setpoint register which uses a sign to indicate direction of DC2 or DC3 port power flow with a scaling factor of ten (10) Watts. The operator or system controller will write a value to the power setpoint register and the PCS will ramp power flow to that new requested level. The PCS will automatically adjust to changing battery voltage to maintain a constant power flow during extended steady-state operation.

8.4.4 DC Current Control Method (0x0301)

The DC Current Control Method (CURRENT) is paired with a current setpoint register which uses a sign to indicate direction of DC2 or DC3 port current flow with a scaling factor of 0.1 A. The operator or system controller will write a value to the current setpoint register and the PCS will ramp current flow to that new requested level. Current flow is maintained by the PCS independent of battery voltage unless a voltage limit is reached causing a fault.

8.4.5 DC Volt Control Method (0x0501)

The DC Volt Control Method (VOLT) is paired with a voltage setpoint and a static resistance setpoint registers. The operator will write a value to the voltage setpoint register and the output will ramp up or down to this level. The static resistance will have the effect of adding a voltage droop which allows easy parallelization of devices to reach higher power levels. Voltage is always a positive value, ranging from at least 200VDC to 1000VDC. Full power being limited by 60A output is however only available at voltages above 750V. Despite voltage is fixed by Stabiliti, the power may indifferently flow in or out of the device.

8.4.6 MPPT Control Method (0x0002)

The Maximum Power Point Tracking Control Method (MPPT) is used only when a PV array is connected to DC3 (or DC2) to export the maximum available output of the array. Refer to power flow example below for more information on usage.

8.4.7 Grid Power Control Method (0x0402)

The Grid Power Control Method (GPOWER) commands the PCS to follow the utility voltage in a grid-tied mode. This Control Method is paired with real and reactive power setpoint registers which use a sign to indicate direction of DC2 or DC3 port power flow with a scaling factor of 10 Watts or 10 var. The operator or system controller will write a value to the power setpoint register and the PCS will ramp power flow to that new requested level. In this configuration, with factory defaults unchanged, the converter responds to all grid-fault conditions in a manner that is compliant with EN50549-10 regulation.

8.4.8 Facility Power Control Method (0x0502)

The Facility Power Control Method (FPOWER) is used for two (2) possible applications:

1. Interactive grid-following/grid-forming transfer applications: in this use-case external third-party islanding switchgear is incorporated into the system design to facilitate rapid and transfers between grid-following and grid-forming modes while also ensuring the PCS remains safe and never back-feeds the utility grid while in grid-forming mode. While in grid-following mode the PCS may be operated and will behave as with GPOWER.
2. Stand-alone grid-forming mode: this is sometimes described as a "free-standing" microgrid or nanogrid. No interaction with a utility-grid is enabled or allowed.

Refer to Application Notes **TMP201 - Stabiliti Grid Connection** and **TMP303 – Stabiliti in Microgrid operation** for more information on FPOWER microgrid and rapid power transfer applications with the Stabiliti.

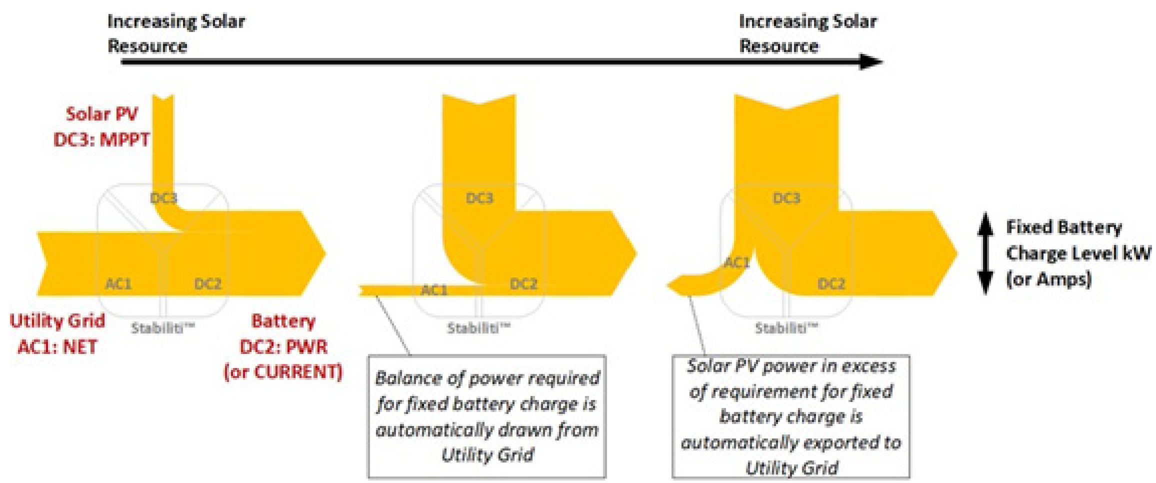


Figure 19: Three port power flow example with utility grid at AC1 as = NET

8.5 Grid interactive behaviour

8.5.1 Grid interactive features

The Stabiliti is by default a power converter that is agnostic versus fields of application. Basic setpoints allow to control voltages, currents, powers, frequency, ramp rates, etc… Most of these parameters are programmable by the user to fit the final application.

When it comes to be connected to the grid and inject power into it, some rules are imposed by the DSOs in order for the equipment to interact within controllable behaviour not to impact normal grid operation. This is know as grid interactive behaviour. It is mostly related to the contribution of the device to grid voltage by the local control of AC phase and reactive power.

In the scope of Stabiliti, this is implemented in the form of an embedded software module that takes control of some usually user controller parameters in order to fit with these regulations. A modbus parameter allows to turn this module on and off.

It must be observed that the Grid connection regulations vary from country to country. Nevertheless, in Europe, most are based on EN50549. The Stabiliti can handle various grid interactive regulations by selecting it through a modbus parameter. This parameter will select a saved parameter list that will overwrite the default startup configuration with the DSOs parameter requirements. The following modes are currently available:

- None: no specific parameter altered, defaults settings kept.
- EN50549: European standard, base for most country specific regulations.
- VDE4105: German standard, derived from EN50549, and widely accepted in other countries as well.

8.5.2 Grid Interactive working modes

The grid interactive features of the Stabiliti that are shortly described here below are just here to list the capabilities of Stabiliti towards these concerns. The Grid Interactive features are normally set once upon installation of the system, should be validated by the DSO and can't be changed anymore. For this reason, the configuration of these features are not accessible to a Stabiliti System User, but only to an authorized operator, using a very specific and password controlled process not described in this manual.

Despite the bottom parameters are not accessible to the Stabiliti System User, they give an overview of the topics handled.

The grid interactive module is turned on and off using parameter mode_voltage_response. Once this parameter is set to 1, the grid interactive module can interact with the grid voltage by means of reactive power controlled by one of the following working modes.

- Q setpoint mode: the reactive power is fixed by the parameter q_setpoint_param
- Q(U): the reactive power is a function of the voltage. In this working mode, the reactive power control at low active power levels can be done by two methods: minimum Cos Phi or Lock In/Loc Out levels, selected by parameter qu_mode_voltage_response
- Cos Phi setpoint mode: the Cos Phi is fixed by the parameter cosphi_setpoint_param
- Cos Phi (P): the Cos Phi is driven as a function of the active power

These working modes are mutually exclusive. Grid voltage interaction using active power limitation control P(U) is not implemented. See CE+T Application Note **TMP104 – Stabiliti Grid Interactive Behaviour** for detailed description of each working mode.

8.5.3 AC interface protection

AC interface protection of an installation with PCS works at two levels:

- Protecting the grid from local generators fault contribution
- Protecting the local generator from various internal or external fault conditions

The protection activation is the same for both purposes: disconnect the AC circuitry between the entity to protect from the external entity. The difference is where it is actually performed, and what is the intelligence that decides about the disconnection as well as reconnection.

This can be modelized in the following scheme.

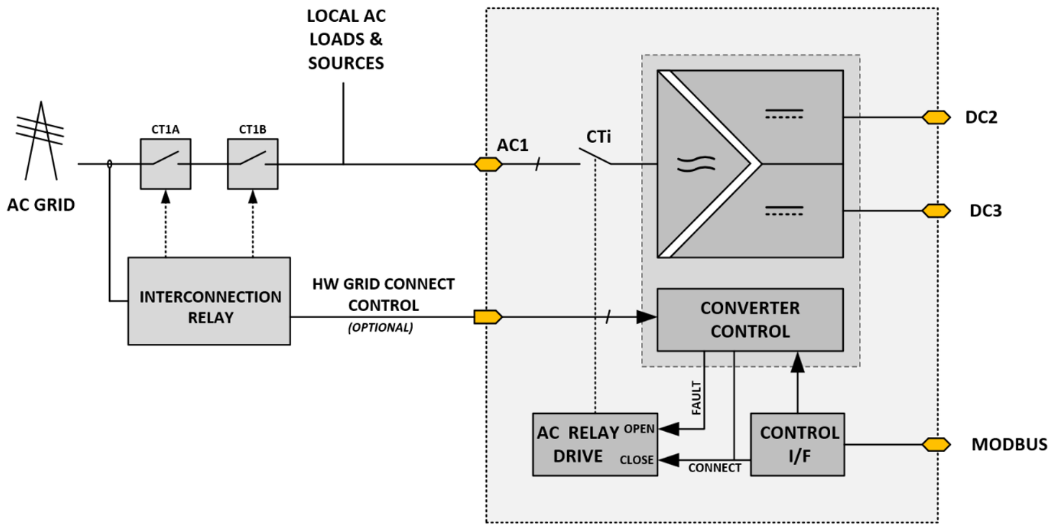


Figure 20: AC protection interface

We can see here:

- The Grid
- A disconnection scheme that protects the AC grid, composed of:
  - One or two contactor in series (CT1A & CT1B)
  - One AC interface Controller unit that senses the Grid and controls the contactors opening/closure (Interconnection relay)
- A local AC grid that can contain loads and sources (like PV inverters)
- The generating entity, namely the Stabiliti composed of:
  - One AC contactor
  - One converter kernel
  - Control units for converter, interface and AC relay connect

The protection of the grid must be performed at system level with contactors and AC interface controller. These must be certified devices and be assembled and configured in accordance with local DSO regulations. Typically, this device will disconnect the generating equipment when the AC Grid shows a specification break in terms of under/over voltage, under/over frequency as well as islanding detection.

The Stabiliti contains a front AC contactor whose aim is to isolate the device from the external AC network in case any internal or external fault condition. Among all the fault conditions, there are also various levels of under/over voltage, under/over frequency with specific window time detection that will disconnect the device. Depending on the criticality of the fault, it will either enter a lockdown condition, that can only be exited with specific action from the system upper control level, either reconnect and restart after a predetermined time after fault condition removal.

It must be noticed that the Stabiliti can be connected to the AC interface protection relay in order to handle an automatic shift to islanding working mode, back and forth when the grid is disconnected. See CE+T Application Note **TMP303 – Stabiliti in Microgrid operation**.

Despite the external disconnection equipment will fix the voltage / frequency limits and related time windows for disconnection, the Stabiliti is also equipped with its own disconnection scheme. Normally, the external equipment should always act in narrower limits as the Stabiliti, so the priority of action is always clear and predictable.

See CE+T Application Note **TMP104 – Stabiliti Grid Interactive Behaviour**.

9. Initial Startup and Basic Commissioning

9.1 Basic checks

CE+T Power recommends the following set of initial commissioning tasks to validate your installation and PCS functionality before attempting to fully exercise the system.

Before energizing the grid, battery or PV connections to the PCS:

- **Torques:** confirm all wiring terminals are properly torqued.
- **Polarity:** confirm the polarity of the battery and PV at their respective disconnect with a multimeter. Confirm wiring polarity through the disconnects to the PCS. Recall that the negative wire will be connected at the terminal labeled COM.
- **Voltage:** confirm with a multimeter that the battery and PV Voc are within the operating range of the PCS (maximum 1000 V) and that all hardware is rated appropriately as well.
- **Run Enable and fault check:** Ensure that the *Run_Enable* connection is made before attempting to start up the PCS. Refer to section 7.2.2, "**#4 – AUX 24V IN / RUN", page 27** for more information. While the PCS is energized but not converting power, open the *Run_Enable* connection (ex., remove the terminal plug) and confirm a fault is displayed. Use the Modbus interface to query the fault's status. Return the connection and reset the fault via Modbus. Refer to CE+T Application Note TMP101 - Stabiliti Fault Monitoring & Management.
- **Communications:** confirm ability to read and write data to the Modbus interface. Preferred with an external 24 Vdc power supply but alternatively with the grid supply.
- **Grid Interactive settings:** using appropriate procedure described in TMP203 – Stabiliti Grid Port Parametrization to adjust Stabiliti nominal working voltage, Grid Code and DSO specific settings.
- **Pre-charge:** Start and stop a pre-charge of the PCS DCx bus capacitors without connecting the battery. After stopping the pre-charge, note the natural discharge time of the PCS capacitors. Refer to the stand-alone battery scenario example in **section 10.3, page 75** for more information on setting up a pre-charge.

After energizing the 400 Vac grid supply but before energizing the battery or PV connections to the PCS:

- Perform an AC-only Power Factor Correction power test as described at the beginning of 10.1, page 73. Confirm that the power, voltage, current telemetry data, and system status information from the Modbus interface matches expectations.
- Check and record the phase rotation of the grid supply to the PCS terminals. Register *1021 fault_active_6 bit 14* will be asserted to 1 if phase rotation is A-C-B, and bit 14 will read 0 if phase rotation is A-B-C. If the application involves FPOWER grid forming, the PCS produces an A-B-C rotation and must observe an A-B-C rotation on the native grid. Swap two phase cables into the PCS if necessary to align rotation.

After pre-charging the DCx bus, energizing the battery and PV connections to the PCS:

- Confirm that the applicable voltage telemetry information from the Modbus interface matches expectation.

9.2 Initial startup

Once the external connections are made and all interfaces are at their nominal level (control & power), the Stabiliti must be configured using the selected methods on each port, related required settings should be programmed and finally, the device can be turned on.

The behaviour of the Stabiliti can be monitored by the Modbus interface. Please see Stabiliti control and fault management sections for more information. On top of this, the on-board LCD display also provide runtime information. Please see below for the applicable content.

9.3 Device display

The Stabiliti is equipped with an on-board display that provides some useful information to help start the device and monitor its usage. This user interface is unidirectional since it does only display.

After some startup steps status that are displayed during device startup, the following window type is displayed (in this case, from a factory blanked configured device)

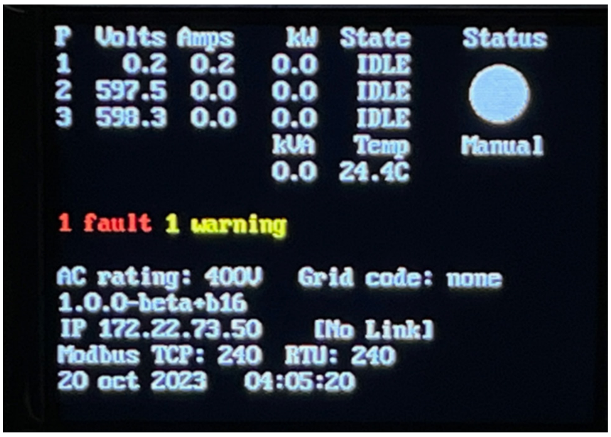


Figure 21: LCD sample display

This display contains the following items.\

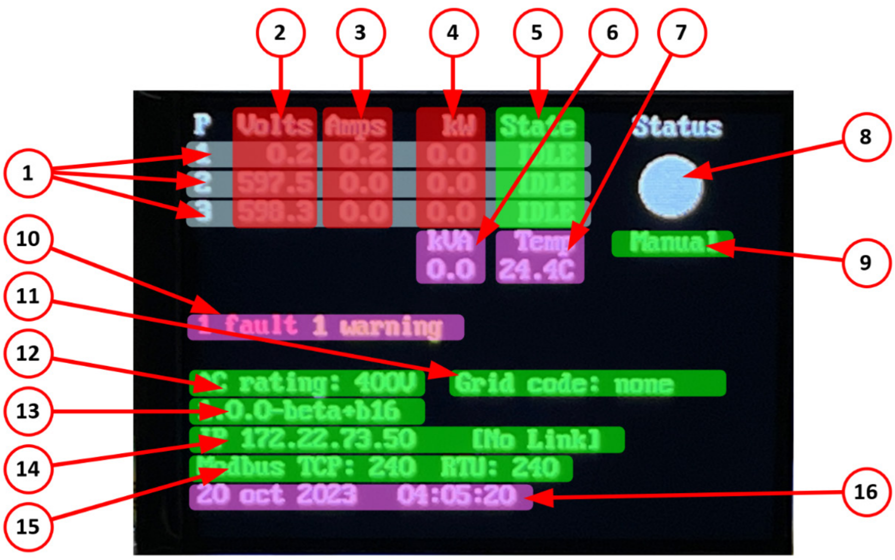


Figure 22: LCD Display contents detail

(1) Ports information : 1=AC1 , 2=DC2 , 3=DC3

(2) Ports voltages (V)

(3) Ports current (A)

(4) Ports (active) power (kW)

(5) Ports method

The ports method display integrates two types of information:

- Method:
  - IDLE: unused port
  - GPWR: Grid following (AC only)
  - FPWR: Grid following (AC only)
  - NET: port used in NET
  - VOLT: port in volt (DC only)
  - CURR: port in current mode (DC only)
  - PWR: port in power mode (DC only)
  - MPPT: port in MPPT mode (DC only)
- Port Status, identified by a colour :
  - White: port unused
  - Green: port used and running in OK state
  - Orange: port in recoverable fault mode
  - Red: port in non recoverable fault mode
  - Yellow: port running with power limitation
  - Blue: port in (re)connection time mode after fault condition

(6) AC Port reactive power (kVA)

(7) Higher internal temperature (°C): the Stabiliti has several internal temperature sensing points on the most critical elements. This one represents the highest of those.

(8) Converter status. The colour of this indicator reflects the kertnel converter status:

- Grey: the Stabiliti is currently not running
- White:
- Blue: the Stabiliti is currently (re)connecting.
- Green: the Stabiliti is converting successfully
- Orange: a recoverable fault has occurred and its state is still pending
- Red: a non-recoverable fault has occurred and the device is in lockdown. Need external action to restart.

(9) Start mode. Manual or Auto

(10) Faults – Warnings status. This line displays the number of faults and or warnings if some are pending.

(11) Grid code selected. Displays the configured grid code selected upon startup:

- none: the Stabiliti uses its defaults settings with grid interactive disabled

- EN50549: uses the EN50549 settings, with grid interctive behaviour turned on by default.
- VDE4105: uses the VDE4105 settings, with grid interctive behaviour turned on by default.

(12) AC1 port nominal working voltage : can be 400VAC or 480VAC.

(13) Firmware revision information. This provides the package information. If the consistency of all programmable items is not verified, an “(!) Unapproved firmware” message will be displayed (!!! Fault message is changed). Such issue must be handled by authorized support operators only.

(14) Stabiliti IP address. Two cases:

- Internal address is programmed with a static address different from 0.0.0.0 : static address.
- internal address has been programmed to 0.0.0.0, considered the Stabiliti works in DHCP mode.

(15) Stabiliti Modbus TCP & RTU Device IDs

(16) Current Date & Time

10. Power Flow Scenarios

The Stabiliti™ Series PCS has numerous options with regards to system configuration and power transfer options. Reviewing the following use cases will demonstrate the flexibility and capabilities of the 30C3-CE Multiport PCS. Note that only Manual Mode is employed in these examples assuming lab operation by the user.

The noted roles of DC2 and DC3 may be reversed in the scenarios below. Both DC power ports have the same Control Method capabilities, although DC2 is intended for battery use due to its integral precharge circuit as noted previously.

10.1 AC-Only Power Factor Correction (Power recycling)

1. After physically installing the PCS as described earlier in this document with the right grid settings, energize the Vac grid supply to the PCS. Please note that by default, if the right Grid control file is used, the grid interactive is activated and a +24V drive of GRID_CONNECT_IO is expected to allow active power injection.
2. Connect to the Modbus interface and check that interface is ready :
    a. Check that pcs_status returns a value >=3
3. Configure the following registers:
    a. R2000 command = 13 (WRITE_ENABLE)
    b. R65 p1_control_method = 0x0001 (NET)
    c. R129 p2_control_method = 0x0501 (VOLT – 2 ports configured mandatory to start)
    d. R193 p3_control_method = 0x0000 (IDLE, factory default)
    e. R134 p2_voltage_setpt = 600 (dummy output)
    f. R74 p1_grid_interactive_enable = 1
    g. R267 system_op_mode = 0 (Manual, factory default)
    h. R524 mode_voltage_response = 3 (Cos Phi setpoint)
    i. R525 cosphi_setpoint_param = 1000 (Cos Phi = 1)
4. Write R263 user_start = 1 to enable power transfer
5. Notice the feedback state indicated by R1000 pcs_state
6. Check the actual power factor, active and reactive power read from registers 118, 119 and 120.
    Notice while power transfer is enabled in this scenario but with a power factor of 1 (R525=1000), the Converter's reactive power is reduced, resulting in a near-unity power factor compared with the default factory idle state. A few hundred watts of real power is drawn from the grid to perform the power factor correction.
7. Vary Cos Phi setpoint to 0.9 leading:
    a. R525 cosphi_setpoint_param = -900 (Cos Phi = 0.9 leading)
8. Notice effect on cos-phi and powers reading changes in R118, R119 and R120
9. Write R264 user_stop = 1 to disable power transfer

NOTE: This is not a normally useful operating scenario except for during initial product evaluation. It serves to demonstrate power conversion activation without a battery connected and system feedback status and telemetry.

10.2 Stand-alone Battery Charge/Discharge on DC2 in PWR

This chapter describes a method to handle a battery which will be controlled in PWR mode, making NET mode available to one of the other ports. This allows to have a real-time strong control of the power/current sent to the battery. This example relates to the Stabiliti 25C3-CE.

After physically installing the PCS as described earlier in this document, energize the VAC grid supply. Do NOT yet close the connection between the battery and the PCS (DC disconnect switch or contactor).

1. Connect to the Modbus interface and check that interface is ready :
   a. Check that pcs_status returns a value >=3
2. Configure the following registers:
   a. R2000 command = 13 (WRITE_ENABLE)
3. Perform the DC2 PCS bus (capacitors) precharge
   a. R276 precharge_hi_lim --> current battery voltage +5 Vdc
   b. R277 precharge_lo_lim --> current battery voltage -5 Vdc
   c. R275 precharge_control = 1 to enable the precharge circuit
   d. Monitor DC2 voltage via R173 p2_v_pn until it is in the range of your battery and within the precharge limits set above
   e. Close external battery contactors or DC disconnect switch to connect the battery and PCS buses with minimal DC voltage difference and minimal current inrush
   f. Write R275 precharge_control = 2 to disable the precharge circuit
4. Configure the following registers:
   g. Configure DC2 voltage limits and current limits according to your battery as described in section 7.3.3. port DC2 Application Specific Register Setup.
   h. R65 p1_control_method = 0x0001 (NET)
   i. R129 p2_control_method = 0x0401 (POWER)
   j. R193 p3_control_method = 0x0000 (IDLE)
   k. R133 p2_power_setpt = 0
5. Enable power conversion and command power flows
   l. Write R263 user_start = 1 to enable power transfer. The internal PPSA conversion link will begin operation but no appreciable power will be transferred since the power setpoint is zero.
   m. Write R133 p2_power_setpt = 100 to command a 1 kW charge into the battery from the grid. The PCS will quickly ramp and maintain a 1 kW charge to the battery, from the grid.
   n. Write R133 p2_power_setpt = -100 to command a 1 kW discharge from the battery to the grid. The PCS will quickly ramp and hold a 1 kW discharge.
   o. As with other setpoints and other Control Methods R133 p2_power_setpt may be changed on-the-fly based on battery or site application requirements.
   p. Observe telemetry feedback during power transfer cases.
      i. R119 p1_real_power
      ii. R185 p2_power
      iii. Write R264 user_stop = 1 to disable power transfer.

10.3 Stand-alone Battery Charge/Discharge on DC2 in NET

This chapter describes an alternate way to handle a battery which will be controlled in NET mode, allowing some configurations where it is not possible to use NET mode on any other ports. By cleverly handling power and current limits, this however proves to be applicable to a very wide range of contexts where the focus can be put on the "utility" ports, the battery being essentially at their service. This example relates to the Stabiliti 25C3-CE.

After physically installing the PCS as described earlier in this document, energize the VAC grid supply. Do NOT yet close the connection between the battery and the PCS (DC disconnect switch or contactor).

1. After physically installing the PCS as described earlier in this document, energize the 400 Vac grid supply. **Do not** close the connection between the battery and the PCS (DC disconnect switch or contactor).
2. Perform the DC2 PCS bus (capacitors) pre-charge.
   a. R276 precharge_hi_lim → current battery voltage +5 Vdc
   b. R277 precharge_lo_lim → current battery voltage -5 Vdc
   c. Write R275 precharge_control = 1 to enable the pre-charge circuit.
   d. Monitor DC2 voltage via R173 p2_v_pn until it is in the range of your battery and within the pre-charge limits set above.
   e. Close external battery contactors or DC disconnect switch to connect the battery and PCS buses with minimal DC voltage difference and minimal current inrush.
   f. Write R275 precharge_control = 2 to disable the pre-charge circuit.
3. Configure the following registers:
   a. Configure DC2 voltage limits and current limits according to your battery as described in **section 7.3, page 48**, Application Specific Register Setup.
   b. R65 p1_control_method = 0x0001 (NET)
   c. R129 p2_control_method = 0x0401 (POWER)
   d. R193 p3_control_method = 0x0000 (IDLE)
   e. R133 p2_power_setpt = 0
4. Enable power conversion and command power flow.
   a. Write R263 user_start = 1 to enable power transfer. The internal PPSA conversion link will begin operation, but no appreciable power will be transferred since the power set point is zero.
   b. Write R133 p2_power_setpt = 100 to command a 1 kW charge into the battery from the grid. The PCS will quickly ramp and maintain a 1 kW charge to the battery from the grid.
   c. Write R133 p2_power_setpt = -100 to command a 1 kW discharge from the battery to the grid. The PCS will quickly ramp and hold a 1 kW discharge.
   d. As with other set points and other Control Methods, R133 p2_power_setpt may be changed on-the-fly based on battery or site application requirements.
   e. Observe telemetry feedback during power transfer cases.
      i. R119 p1_real_power
      ii. R185 p2_power
   f. Write R264 user_stop = 1 to disable power transfer.

10.4 Stand-alone Solar PV export on DC3

This example relates to the Stabiliti 25C3-CE connected between PV panels and AC grid in stand-alone operation mode.

1. After physically installing the PCS as described earlier in this document, energize the 400 Vac grid supply to the PCS and also energize the PV connection to the PCS.
2. Connect to the Modbus interface and configure the following registers:
    a. Configure DC3 voltage limits and current limits according to your PV array as described in **section 7.3, page 48**, Application Specific Register Setup.
    b. R65 p1_control_method = 0x0001 (NET)
    c. R129 p2_control_method = 0x0000 (IDLE)
    d. R193 p3_control_method = 0x0002 (MPPT)
    e. R203 p3_mppt_minv_start_setpt = minimum (re)start voltage
    f. R202 p3_mppt_minv_stop_setpt = minimum stop voltage
    g. R201 p3_mppt_restart_setpt = period of validation of conditions for stop/restart.
3. Enable power conversion.
    a. Write R263 user_start = 1 to enable power transfer. The internal PPSA conversion link will begin operation, and PV export to the grid will ramp up to the maximum power point of the array.
    b. Observe telemetry feedback during power transfer cases
        i. R119 p1_real_power
        ii. R249 p3_power
        iii. R1001 pcs_fault_status (holdoff if PV too low)
    c. Write R264 user_stop = 1 to disable power transfer.

A minimum operating PV voltage can be set at register 203 p3_mppt_minv_start_which will set the threshold for MPPT activation. Conversely, register 202 p3_mppt_minv_stop_setpt will set the level below which the MPPT algorithm will stop working and turn the PV power conversion off, putting the PCS fault status to HOLD_OFF, still working on other ports if the configuration allows for it (which is not the case in the upper one). The validation for mode change can be adjusted by register 201 p3_mppt_restart_setpt.

10.5 PV + Battery Sum for Grid Export

This is an example of PV plus battery energy management within the Stabiliti. The export to the grid will be held firm irrespective of the available PV resource, the battery in NET mode compensating the available PV to obey the requested AC power setpoint.

1. After physically installing the PCS as described earlier in this document, energize the 400 Vac grid supply to the PCS and also energize the PV connection to the PCS.
2. Connect to the Modbus interface and perform the DC2 PCS bus pre-charge sequence as described above in the stand-alone battery example, then electrically connect the battery to the PCS.
3. Connect to the Modbus interface and configure DC2 and DC3 voltage limits and current limits according to your battery and PV array as described in **section 7, page 43**, Application Specific Register Setup.
4. Connect to the Modbus interface and configure the following registers.
    a. R129 p2_control_method = 0x0001 (NET)
    b. R65 p1_control_method = 0x0402 (GPWR)

c. R193 p3_control_method = 0x0002 (MPPT)

d. R68 p1_real_pwr_setpt = 0

e. R203 p3_mppt_minv_start_setpt = minimum (re)start voltage

f. R202 p3_mppt_minv_stop_setpt = minimum stop voltage

g. R201 p3_mppt_restart_setpt = period of validation of conditions for stop/restart

5. Enable power conversion

    a. Write R263 user_start = 1 to enable power transfer. The internal PPSA conversion link will begin operation, and PV export to the battery will ramp up to the maximum power point of the array.

    b. Write R68 p1_real_pwr_setpt = 500 to ramp to a fixed 5kW AC export to the utility grid. Note that this scenario is most illustrative if the AC power export level is fixed and the PV power varies around the AC power level.

    c. Observe telemetry feedback during power transfer cases. Observe that while the PV power varies, the AC power exported is constant, and the power flow to/from the battery varies as the difference between the PV and the grid export. The battery will charge if PV > p1_real_pwr_setpt, and the battery will discharge if PV < p1_real_pwr_setpt, always making up the difference in the power flow.

        i. R119 p1_real_power

        ii. R185 p2_power

        iii. R249 p3_power

        iv. R1001 pcs_fault_status (holdoff if PV too low)

    d. As with other set points and other Control Methods R68 p1_real_pwr_setpt may be changed on-the-fly based on battery or site application requirements.

    e. Write R264 user_stop = 1 to disable power transfer.

10.6 Battery (Dis)charging from PV and/or Grid

This is a variant of the previous one, where the master request is put on the battery charge/discharge setpoint, while the AC port in NET will compensate the varying available PV to obey the requested battery power setpoint. This example relates to the Stabiliti 25C3-CE.

1. After physically installing the PCS as described earlier in this document, energize the 400 Vac grid supply to the PCS and also energize the PV connection to the PCS.

2. Connect to the Modbus interface and perform the DC2 PCS bus pre-charge sequence as described above in the stand-alone battery example, then connect the battery to the PCS.

3. Connect to the Modbus interface and configure DC2 and DC3 voltage limits and current limits according to your battery and PV array as described in **section 7, page 43**, Application Specific Register Setup.

4. Connect to the Modbus interface and configure the following registers:

    a. R65 p1_control_method = 0x0001 (NET)

    b. R129 p2_control_method = 0x0401 (POWER)

    c. R193 p3_control_method = 0x0002 (MPPT)

    d. R133 p2_power_setpt = 0

    e. R203 p3_mppt_minv_start_setpt = minimum (re)start voltage

    f. R202 p3_mppt_minv_stop_setpt = minimum stop voltage

    g. R201 p3_mppt_restart_setpt = period of validation of conditions for stop/restart

5. Enable power conversion.
    a. Write R263 user_start = 1 to enable power transfer. The internal PPSA conversion link will begin operation, and PV export to the grid will ramp up to the maximum power point of the array.
    b. Write R133 p2_power_setpt = 300 to ramp to a fixed 3 kW battery charge (PCS export). Note that this scenario is most illustrative if the battery charge power level is fixed and the PV power varies around the charge power level.
    c. Observe telemetry feedback during power transfer cases. Observe that while the PV power varies, the battery charge power is constant, and the power flow to/from the grid varies as the difference between the PV and the battery charge. There will be grid export if PV > p2_power_setpt and there will be grid import if PV < p2_power_setpt; the grid will always make up the difference in the power flow.
        i. R119 p1_real_power
        ii. R185 p2_power
        iii. R249 p3_power
        iv. R1001 pcs_fault_status (holdoff if PV too low)
    d. Write R264 user_stop = 1 to disable power transfer

NOTE: The DC Constant Current Control Method (CURRENT) along with R132 p2_current_setpt may be an appropriate substitute for the POWER Method when applied to the DC2 Port.

10.7 AC Standalone Battery-Supported Microgrid

This is an example of a battery supplying power as demanded in real time to support and hold an AC microgrid output at 400 Vac, despite variations in load. This example relates to the Stabiliti 25C3-CE.

1. After physically installing the PCS as described earlier in this document disconnect and isolate the PCS from the 400 Vac grid supply.
2. Connect a variable AC load bank to AC1 either directly or via a distribution panel. Set to a low initial power level.
3. Use a 500 Vdc (or higher) battery connected to DC2 with sufficient capacity to support the load bank.
4. Supply 24 Vdc external power to the PCS to enable communications and setup.
5. Connect to the Modbus interface and perform the DC2 PCS bus pre-charge sequence as described above in the stand-alone battery example, then electrically connect the battery to the PCS.
6. Connect to the Modbus interface and configure DC2 voltage limits and current limits according to your battery as described in **section 7, page 43**, Application Specific Register Setup.
7. Connect to the Modbus interface and configure the following registers
    a. R193 p3_control_method = 0x0000 (IDLE)
    b. R129 p2_control_method = 0x0001 (NET)
    c. R65 p1_control_method = 0x0502 (FPWR)
    d. R71 p1_voltage_setpt = 480 (480 Vac line-to-line)
    e. R72 p1_frequency_setpt = 60000 (60 Hz)
    f. R95 p1_fpwr_island_detection = 0 (stand-alone microgrid without grid transfers)
8. Enable power conversion. Use caution when forming a microgrid!
    a. Write R263 user_start = 1 to enable power transfer. The internal PPSA conversion link will begin operation and rapidly ramp up the AC voltage on its AC1 output terminals thereby performing a blackstart of the microgrid with the load bank. It will immediately support the initial load and draw down on the battery accordingly.

b. Vary the AC load bank level and observe telemetry feedback during power transfer cases.
    i. R119 p1_real_power
    ii. R109 p1_v_ab_ext_rms
    iii. R110 p1_v_bc_ext_rms
    iv. R111 p1_v_ca_ext_rms
    v. R185 p2_power

c. Write R264 user_stop = 1 to disable power transfer and shut down the microgrid.