Leading Conversion Technology for Power Resilience

STABILITI 30C3-CE

Quick Start Guide V1.0

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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Leading Conversion Technology for Power Resilience

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Revision History

Version	Release date (DD/MM/YYYY)	Modified page number	Modifications
1.0	03/07/2023	-	Draft release of the manual

Leading Conversion Technology for Power Resilience

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1. Introduction to CE+T

CE+T Power designs, manufactures, and markets a range of products for industrial operators, with mission critical applications, who are not satisfied with existing AC backup system performances and related maintenance costs.

Our product is an innovative AC backup solution that unlike most UPS's available.

- Maximizes the operator's applications uptime;
- Operates with lowest OPEX;
- Provides best protection to disturbances;
- Optimizes footprint.

Our systems are:

- Modular
- Truly redundant
- Highly efficient
- Maintenance free
- Battery friendly

CE+T power puts 60+ years expertise in power conversion together with worldwide presence to provide customized solutions and extended service 24/7 - 365 days per year.

2. Glossary of Terms

Acronym or Term	Full Expression
AWG	American Wire Gauge
CEC	California Energy Commission
CPU	Central Processing Unit
Converter	CE+T Power Converter: Stabiliti 30C, Stabiliti 30C3
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. References

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

- Stabiliti 30C3-CE 30kW Installation and Operations Manual
- Application Note 504: Rapid Backup Power Solution Guide with Stabiliti PCS
- Application Note 102: Stabiliti 30C3-CE Grid Interconnection and Transformer Design Requirements
- Application Note for Islanding modes with Stabiliti
- Application Note 303: Fault Monitoring & Management with Stabiliti Series PCS
- Stabiliti 30C3-CE Modbus Programmers Guide

4. Introduction

4.1 Purpose, Scope, and Audience

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

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 30C3-CE 30kW Installation and Operations Manual** should 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.

4.2 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 9, page 21** 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 12, page 37** for more information.
- Ensure the run enable connection is made before attempting to start-up the PCS. Refer to **section 7, page 11** 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 30C3-CE have opposite terminal layouts. Refer to **section 8, page 17** for more information.

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 30 kW max for the AC port and up to 45 kW 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 Stabiliti 30C3-CE Multiport

The 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 pre-charge circuit is the preferred port for easy battery connection.

	Wiring	Voltage	Current	Power
AC Port 1	3-wire, 3-phase	400 Vac, 50 Hz	37 Aac	25 kW (30 kW*)
DC Port 2	2-wire	100-1000 Vdc	60 Adc	45 kW
DC Port 3	2-wire	100-1000 Vdc	60 Adc	45 kW

*: Since the circuitry is dimensioned to handle US triphased 480 Vac, a 400/480V autotransformer should be added between the grid and Stabiliti to take benefit of the full 30 kW range.

Refer to the latest Stabiliti PCS Specification Sheet for complete product specifications.

6. PCS Installation

6.1 Unpacking and Inspecting the PCS

The Stabiliti is pallet shipped and is enclosed in a purpose-built heavy-duty cardboard box. Once unpacked, inspect the PCS for any obvious shipping damage. Immediately contact your shipper and CE+T Power regarding any damage noted. You may also save the box with foam in the event it is needed to transport the converter.

6.2 Mounting the PCS

The PCS, when installed on its wall mounting bracket weighs approximately 63 kg. External dimensions are 52 x 102 x 41 cm (WxHxD). The PCS must always be installed in a vertical upright position to ensure proper thermal management, this includes for any testing and evaluation 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.

Clearance requirements to meet requirements:

- 45 cm underneath the intake filter for airflow and splash resistance
- One metre in front

The PCS is hung on an included wall-mount bracket. The bracket has four (4) 13mm holes for fastening to a wall (fasteners not included). After hanging, the PCS is fastened to the bracket underneath with two (2) M6 socket cap screws.

Complete the mounting and installation following instructions in the **Stabiliti Series 30 kW Installation and Operations Manual**.

The bottom of the device is fitted with an air filter that has parts outside the basic Stabiliti volume. Pay attention while handling it during installation. In no circumstances can the Stabiliti be placed on its bottom face in order not to damage this filter.

7. Low Voltage Comms and Control Wiring

7.1 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 of 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. Refer to Stabiliti 30C3-CE - Installation and Operations Manual for additional information regarding low-voltage wiring.

In all Stabiliti 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 interfaces shown in Figure 1.

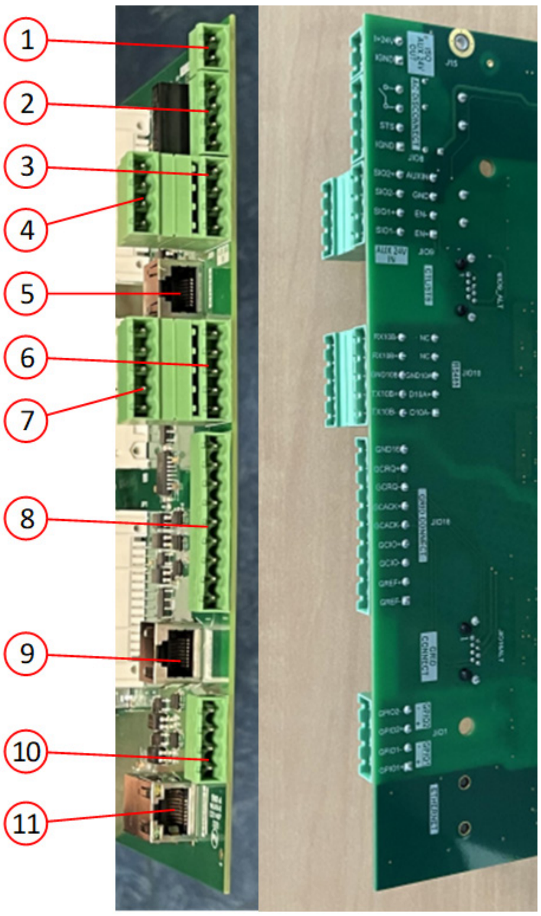


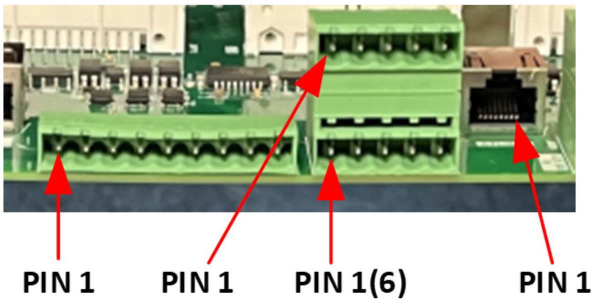
Figure 1: Control Board Low-Voltage Connectors

Shown in Figure 1, there are nine (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)

7.2 Low-Voltage Interface Overview



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

#1 – ISO AUX 24V OUT

This 2-Pin terminal block connector provides an isolated +24V supply for various +24 Vdc usage that might be required in the direct vicinity of the Stabiliti. Maximum current is 1 A 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

#2 – AC Disconnect

Not applicable, reserved for future use.

#3 – CTL / STS

4-Pin terminal block connector that provides System Control and Status signals. It can be programmed for various usage as an additional device remote control or specific status output to the outside. Floating contacts and inputs suitable for 24 Vdc signals.

By default, the following usage is programmed:

- SYSIO1 as output. Floating contact closes when the system is not in warning or fault condition.
- SYSIO2 as output. Floating contact closes when the system is not in fault condition.

Pin	Signal Name	Description
1 (5)	SYSIO1-	SYSIO1 IO – NEG
2 (6)	SYSIO1+	SYSIO1 IO – POS
3 (7)	SYSIO2-	SYSIO2 IO – NEG
4 (8)	SYSIO2+	SYSIO2 IO – POS

#4 – AUX 24V IN / RUN

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

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

#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	SYSIO1+	SYSIO1 IO – POS
2	SYSIO1-	SYSIO1 IO – 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	SYSIO2+	SYSIO1 IO – POS
8	SYSIO2-	SYSIO1 IO – NEG

#6 – FPGA RS422

5-Pin terminal block connector. It is used as a 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

Pin	Signal Name	Description
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

#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 CE+T Power offers this interface support for backwards compatibility. CE+T highly recommend that operators employ Ethernet TCP communications for enhanced reliability, speed and functionality.

The RS-485 media layer employs 2-wire differential signalling 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 devices 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	-	

#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 the inner of the device and are intended to be used with +24 Vdc logic, except GRID_REF, which is a RS485 physical layer.

For usage, please refer to CE+T Power **Application Note 504: Rapid Backup Power Solution Guide with Stabiliti PCS.**

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	Reserved for future use
4	GRID_CONNECT_IO_P	Reserved for future use
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

#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	Reserved for future use
4	GRID_REF_P	Reserved for future use
5	GRID_REF_N	Reserved for future use
6	GRID_CONNECT_IO_N	Reserved for future use
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

#10 – GPIO

4-Pin terminal block connector. This connector provides two fully programmable general-purpose I/Os for various usage in the vicinity of the Stabiliti (i.e. checking status of fuses).

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

#11 – Ethernet

Standard 8-pin RJ45 Connector

Provides support for multiple TCP-based communications service:

- 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 web server 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 9, page 21** of this document for more information on TCP Ethernet communications.

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

8. High-voltage Wiring

During the 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.

8.1 Wiring AC1 port

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 (20.5" x 40") hinged front door. Punch-outs have been marked on the underside wiring access panel for conduit mounting.

- 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 enclosure.

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 shown below.

8.2 AC1 Interconnect Board

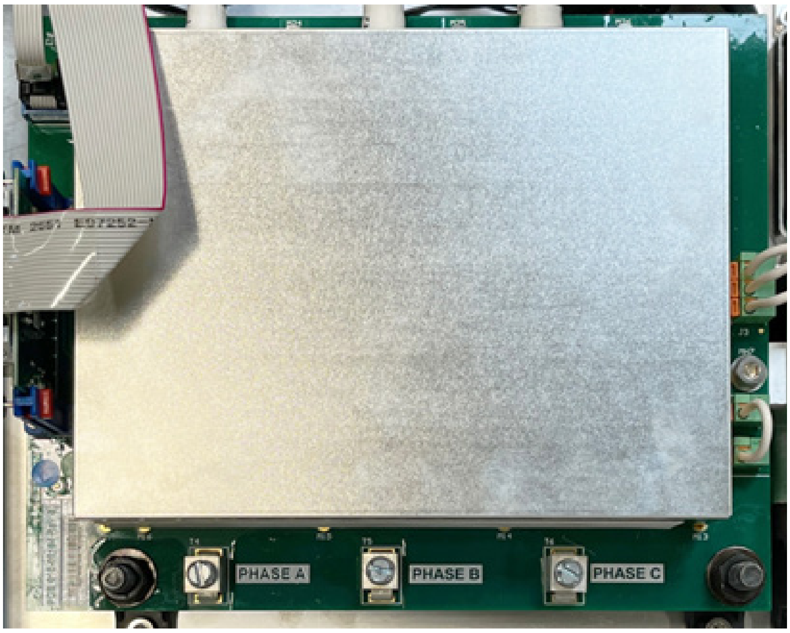


Figure 2: 30C3-CE AC1 Connect Board

The bi-directional AC1 port shown in Figure 2 is configured as a 3-wire delta interface without neutral. Factory defaults are set to allow full available power to be used, with an operating frequency of 50 Hz and line-to-line operating voltage is 480 Vac.

For service voltages other than 480 Vac, a transformer will be necessary. Please refer to CE+T Power Application Note 102: Stabiliti 30C3-CE Grid Interconnection and Transformer Design Requirements. Contact CE+T Power regarding any questions you may have regarding available AC voltage and frequency options.

AC connections are made to the bottom terminals designated as PHASE A, PHASE B, and PHASE C; refer to Figure 3. Torque these terminals to 45 in·lbf (5 Nm). Note that the right phase rotation must be ensured by the wiring. Otherwise, this will prevent Stabiliti to start, signalling a phase rotation fault.

An earth chassis grounding lug is located just below the PHASE C terminal; refer to Figure 3. Ensure that the chassis/ enclosure is correctly grounded by utilizing this connector for earth ground from the AC service.

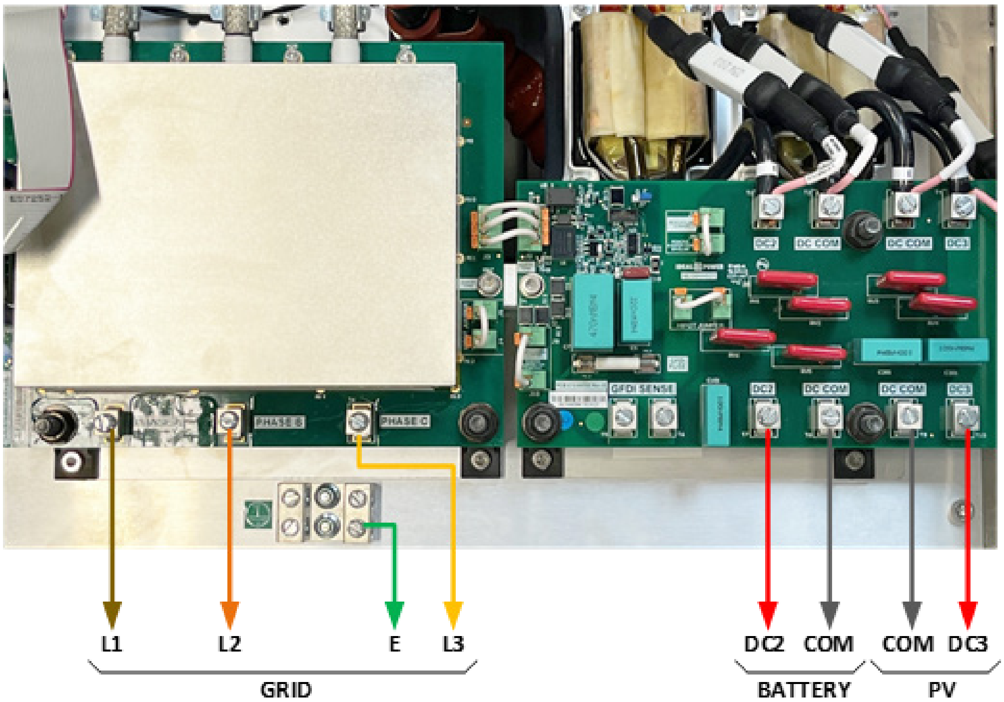


Figure 3: AC1, DC2 and DC3 power connection terminals

8.2.1 AC External Circuit Protection and Disconnect

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. Refer to Figure 5. In some jurisdictions, this circuit breaker may also be approved for use as a safety disconnect. However, CE+T Power recommends that you confirm specific AC disconnect requirements with your local Authority Having Jurisdiction (AHJ). Some jurisdictions may require an external “red handle” visible, lockable disconnect in additional to the protection breaker.

8.3 DC2/DC3 Connect Board

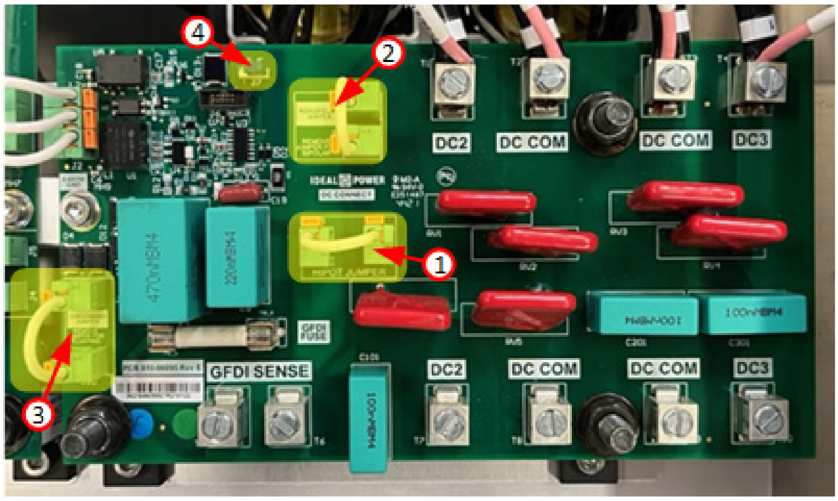


Figure 4: 30C3-CE DC2 and DC3 Connect Board

8.3.1 DC Grounding

The battery and PV array connections share a common negative connection via DC COM. They are not electrically isolated from each other. In the factory default configuration, this common negative DC connection is grounded within the PCS via a 1 A fuse. This is the recommended configuration for a solar plus storage multiport application.

8.3.2 DC Grounding fault 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 30C3-CE device. Nevertheless, some configuration of the DC board must be done to ensure proper functioning:

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

(2) Unipolar/bipolar jumper must be set. Bipolar is only intended for the rare cases where bipolar batteries are to be used (See "**Stabiliti Series 30C3-CE - Installation and Operation Manual**").

(3) Grounding jumper must be set if DC COM must be grounded.

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

8.3.3 Battery Wiring

The DC wiring interconnects board shown in Figure 3 reflects a 30C3-CE PCS with DC2 and DC3 components installed. DC cables are landed on the bottom terminals. The battery positive is connected to DC2 (T7, fourth from right) and the battery negative to the DC COM (T8, third from right). Torque these terminals to 45 in·lbf (5 Nm). Note that the two DC ports of the 30C3-CE have opposite terminal polarity layouts.

8.3.4 PV Wiring

Typically, a PV array installation for the 30C3-CE will employ a 3rd-party combiner box with a single MPPT output wire pair. The negative connection is made to DC COM (T9, second from right) and the positive PV array connection to DC3 (T10, right-most). Torque these terminals to 45 in·lbf (5 Nm). Note that the two DC ports of the 30C3-CE have opposite terminal layouts.

Important notes:

- The Stabiliti PCS does not include arc-fault detection or rapid shut down 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.

8.3.5 Alternate DC Wiring

There are numerous DC wiring options available on the 30C3-CE. Refer to **Stabiliti Series 30 kW Installation and Operations Manual** to determine what configurations best fits your application.

8.3.6 DC External Circuit Protection and Disconnect

The 30C3-CE must be installed with external fused circuit protection on their DC power ports. Refer to Figure 5. 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 Authority Having Jurisdiction (“AHJ”).

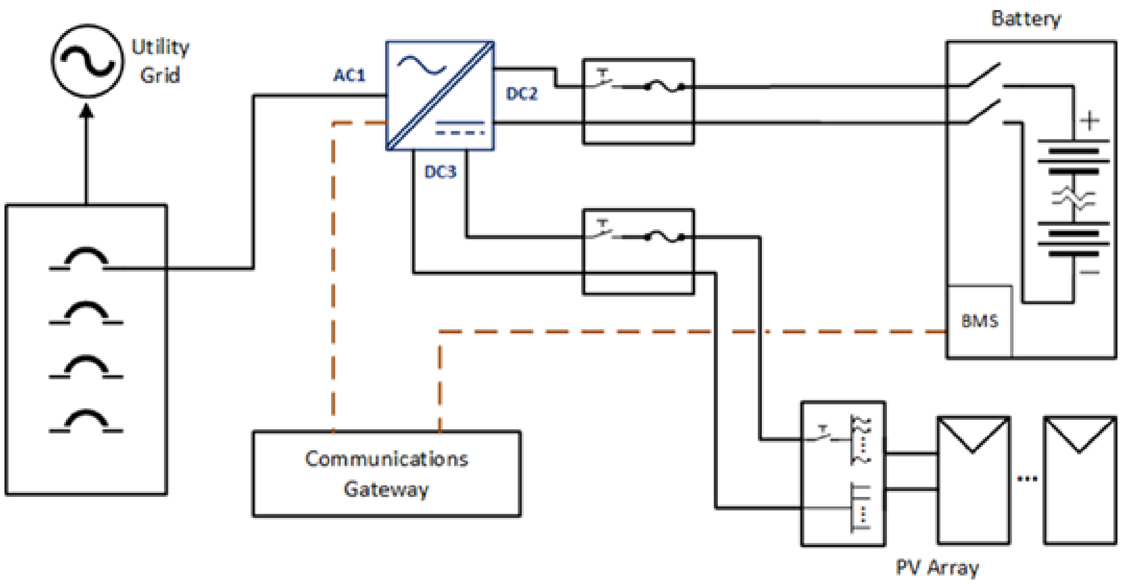


Figure 5: Typical PCS battery and PV system connections

9. Communications and Modbus Interface

9.1 PCS Configuration, Control and Monitoring

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).

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, IPWR 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.

9.2 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 Quick Start Guide. 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. Via the wired Ethernet adapter change properties of the TCP/IPv4 component.
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

Refer to the Modbus Programmers Guide for more detail on IP addressing.

9.3 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

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.

9.4 Application Specific Register Setup

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.

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

All converters shipped from CE+T Power have AC1, DC2, and DC3 set to the IDLE Control Method (ports asleep) for safety purposes. They cannot transfer power until configured and/or commanded to do so via the Modbus interface. Such configurations are detailed later in this document.

The DC2 and DC3 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 safe operating voltage ranges. The PCS will fault and go offline if a voltage limit is reached. The PCS will attempt to soft limit current flow if a current limit is reached, otherwise it will fault and go offline.

Register Address	Name	Register Name	Type	Default	Default Value
141	DC2 max voltage	p2_v_pn_max_limit	int16 R/W	1050	1050 Vdc
142	DC2 min voltage	p2_v_pn_min_limit	int16 R/W	-50	-50V Vdc
154	DC2 max current	p2_current_limit	int16 R/W	620	62 Adc
205	DC3 max voltage	p3_v_pn_max_limit	int16 R/W	1050	1050 Vdc
206	DC3 min voltage	p3_v_pn_min_limit	int16 R/W	-50	-50 Vdc
218	DC3 max current	p3_current_limit	int16 R/W	620	62 Adc

Table 1: Operational safety configuration Modbus registers

Once changed from factory defaults, your application-specific configuration options are not automatically saved to Flash and will not persist after a system power cycle. CE+T suggests that they be saved to flash by writing the value 3 to register 2000 to ensure that your revised operating limits remain intact if power is cycled or lost.

Caution: Be very conscious of all registers that are saved to flash different from their defaults. Registers, such as those dedicated to port Control Methods and their related set points, will be dynamically controlled by your external system controller. These registers should typically not be saved to Flash. This ensures that if AC power is disrupted, or a hard system reset occurs, the Converter will safely revert to its default IDLE operating state, ensuring no unplanned power transfer occurs.

The Converter's default AC over/under voltage limits, AC over/under frequency limits, AC Surge, and fault reconnect timers are overwritten at startup by a specific data set related to the regulatory applicable to the location of use. Default values are set to workable values but in no case represent a valid setup versus regulations. The specific grid setups are defined in separate register files that are pointed to by the configuration file Settings.INI in the System folder in the SD-Card and should in no case be modified without the express approval of your local utility responsible for approving your grid interconnection.

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

9.5 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 set point 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 = 1.0 V	480	480 Vac / 480 Vdc
Frequency	1 unit = 0.001 Hz	60000	60 Hz
DC Port Current	1 unit = 0.1 A	100	10.0 A

Type	Scaling Factor	Register Read/Write	Actual Value
DC Port Power	1 unit = 10 W	1300	13000 W
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 per second	2000	200 A/second
AC/DC Port Power Ramp Rate	1 unit = 10 W per second	100	1000 W/second
AC power factor	1 unit = 1/1000th	-400	0.4 leading

Table 2: Modbus register scaling factors & examples

9.6 Power Flow Sign Convention

The 30C3-CE PCS uses the following sign convention for power flows: positive power represents power exported from the PCS, while negative power represents power imported into the PCS. This is summarized on a port-by-port basis in Table 3 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 3: Power flow sign convention

9.7 Modbus Ports Register Assignments

9.7.1 Port AC1

Register Address	Register Name	Type	Default	Comments
65	p1_control_method	uint16x R/W	0x0000	0x0000 - IDLE 0x0001 - NET 0x0402 - GRID POWER (GPWR) 0x0502 - FACILITY POWER (FPWR)
68	p1_real_pwr_setpt	uint16 R/W	0	If p1_control_method = 0x0402 or 0x502: real power setpoint while voltage-following

Register Address	Register Name	Type	Default	Comments
71	p1_voltage_setpt	int16 RW	480 (480 V)	If p1_control_method = 0x502: line-to-line voltage setpoint for voltage-forming mode, otherwise unused.
72	p1_frequency_setpt	int16 RW	60000 (60 Hz)	If p1_control_method = 0x502: output frequency setpoint for voltage-forming mode, otherwise unused.
74	p1_grid_interactive_enable	uint16 RW	0	AC1 Grid Interactive behaviour enabled when set to 1
86	p1_static_resistance	uint16 RW	100	AC1 static resistance in milliohms.
90	p1_current_limit	int16 RW	440	Soft Current Limit (port maximum is 44 A)
95	p1_grid_access_control	uint16x R/W	0	AC1 grid access control settings
118	p1_power_factor	int16 RO		Actual AC1 power factor
119	p1_real_power	int16 RO		Actual AC1 real power (in 10W)
120	p1_reactive_power	int16 RO		Actual AC1 reactive power (in 10VAR)
121	p1_apparent_power	int16 RO		Actual AC1 apparent power (in 10VA)
1002	p1_state	uint16 RO		AC1 port state. See *State & Status* below for port state definitions.
1003	p1_fault_status	uint16 RO		AC1 port fault status. See *State & Status* for fault definitions.

Table 4: AC1 basic Modbus registers

See more information about specific Grid Interactive registers in a separate chapter below.

9.7.2 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	Comments
129	p2_control_method	uint16x R/W	0	0x0000 - IDLE 0x0001 - NET 0x0002 - MPPT 0x0301 - DC CURRENT 0x0401 - DC POWER 0x0501 – DC VOLT
132	p2_current_setpt	int16 R/W	0	If p2_control_method = 0x0301: DC Current set point
133	p2_power_setpt	int16 R/W	0	If p2_control_method = 0x0401: DC Power set point

Register Address	Register Name	Type	Default	Comments
134	p2_voltage_setpt	int16 R/W	0	If p2_control_method = 0x0501: DC Voltage set point. Adjust voltage droop at reg 157.
137	p2_mppt_restart_ setpt	uint16 R/W	300	Timeout for validating start/stop conditions in seconds
138	p2_mppt_minv_ stop_setpt	uint16 RW	400	Low voltage MPPT stop voltage
139	p2_mppt_minv_ start_setpt	int16 RW	800	Low voltage MPPT (re)start voltage
141	p2_v_pn_max_ limit	int16 RW	1050	Maximum port DC operating voltage: for safety, set according to expected battery Vdc maximum
142	p2_v_pn_min_limit	int16 RW	-50	Minimum port operating voltage: for safety, set to expected battery Vdc minimum on battery port.
152	p2_import_ pwr_lim	int16 RW	-3200	DC2 discharge (import) soft power limit (maximum -32 kW)
153	p2_export_pwr_lim	int16 RW	3200	DC2 charge (export) soft power limit (maximum 32 kW)
154	p2_current_limit	uint16 RW	620	DC2 soft current limit (maximum 60 A, absolute value)
157	p2_static_ resistance	uint16 RW	100	DC2 static resistance in milliohms
173	p2_voltage	int16 RO	3200	DC2 actual voltage readout
185	p2_power	int16 RO	3200	DC2 actual power readout
186	p2_current	int16 RO	620	DC2 actual current readout
275	precharge_control	uint16x R/W	0	DC2 port pre-charge started when 1 is written in this register
276	precharge_hi_lim	uint16 RW	3200	DC2 pre-charge regulation top voltage (800V)
277	precharge_lo_lim	uint16 RW	3180	DC2 pre-charge regulation bottom voltage (790V)
278	precharge_ timeout_lim	uint16 RW	75	Timeout in seconds for pre-charge regulation within boundaries. Fault generated if not the case.
1004	p2_state	uint16 RO		DC2 port state. See State & Status for port state definitions.
1005	p2_fault_status	uint16 RO		DC2 port fault status. See State & Status for fault definitions.

Table 5: DC2 basic Modbus registers, used with a battery

9.7.3 Port DC3

As DC2 is mainly devoted to battery handling, PV are preferably connected to DC3, despite exactly the same functionality being present on DC2 to perform the same. So the focus on PV handling is only present here.

Register Address	Register Name	Type	Default	Comments
193	p3_control_method	uint16x R/W	0	0x0000 - IDLE 0x0001 - NET 0x0002 - MPPT 0x0301 - DC CURRENT 0x0401 - DC POWER 0x0501 – DC VOLT
196	p3_current_setpt	int16 R/W	0	If p2_control_method = 0x0301: DC Current set point
197	p3_power_setpt	int16 R/W	0	If p2_control_method = 0x0401: DC Power set point
198	p3_voltage_setpt	int16 R/W	0	If p2_control_method = 0x0501: DC Voltage set point. Adjust voltage droop at reg 157.
201	p3_mppt_restart_setpt	uint16 R/W	300	Timeout for validating start/stop conditions in seconds
202	p3_mppt_minv_stop_setpt	uint16 RW	400	Low voltage MPPT stop voltage
203	p3_mppt_minv_start_setpt	int16 RW	800	Low voltage MPPT (re)start voltage
205	p3_v_pn_max_limit	int16 RW	1050	Maximum port DC operating voltage: set according to expected PV Vdc maximum
206	p3_v_pn_min_limit	int16 RW	-50	Minimum port operating voltage: set to -50 Vdc to eliminate nuisance under-voltage faults for port configured to support PV
216	p3_import_pwr_lim	int16 RW	-3200	DC3 discharge (import) soft power limit (maximum -32 kW)
217	p3_export_pwr_lim	int16 RW	3200	DC3 charge (export) soft power limit (maximum 32 kW)
218	p3_current_limit	uint16 RW	620	DC3 soft current limit (maximum 60 A, absolute value)
221	p3_static_resistance	uint16 RW	100	DC2 static resistance in milliohms
237	p3_voltage	int16 RO		DC3 voltage, positive to negative
249	p3_power	int16 RO		DC3 power
250	p3_current	int16 RO		DC3 current
1006	p3_state	uint16 RO		DC3 port state. See State & Status for port state definitions.

Register Address	Register Name	Type	Default	Comments
1007	p3_fault_status	uint16 RO		DC3 port fault status. See State & Status for fault definitions.

Table 6: DC3 basic Modbus registers, as used for a PV array

9.7.4 Grid control

The following registers are used to handle the grid connection parameters.

Register Address	Register Name	Type	Default	Comments
74	p1_grid_ interactive_enable	uint16 RW	1	0 = No Grid Interactive behaviour 1 = Grid interactive behaviour enabled
95	p1_grid_access_ control	uint16x R/W	0	Configure grid access control: - Bit 0: enable active grid connect - Bit 1: invert GRID_REQ - Bit 2: invert GRID_ACK - Bit 3: enable Grid Cease I/O - Bit 4: invert GRID_CONNECT_IO in - Bit 5: Soft Grid_Cease_Active_ Power
118	p1_power_factor	int16 RO		Actual power factor
259	connect_timer_set	uint16 RW	0	Startup connect delay in sec
524	mode_voltage_ response	uint16 RW	1	Voltage response mode select: - 1: Q setpoint - 2: Q function of U - 3: COS_PHI setpoint - 4: COS_PHI function of P
525	cosphi_setpoint_ param	int16 RW	1	Cos Phi setpoint in ratio 1/1000th units. 0 to -1000 for capacitive reactance 0 to +1000 for inductive reactance
526	q_setpoint_param	int16 RW	0	Reactive setpoint parameter in 10 VAR units.

Table 7: Grid Control Modbus registers

The grid interactive behaviour may require to be turned off, i.e. when connecting to other local sources (genset, other Stabiliti in forming, …), even when programmed in GPWR. That is the purpose of Register 74.

When the active islanding management is used, some signal interfacing settings are required. This is done through Register 95. Please see the specific Application Note for Islanding modes with Stabilti.

The GRID_CONNECT_IO is a general-purpose I/O that can be programmed to an alternate behaviour, providing for hardware Active Power Injection Cease. The polarity of the pin is programmable. By default, with no polarity inversion, 24V should be present at the pin to allow injection. The Power Active Injection cease can also be activated by writing 1 in bit 5 of register 95. Both hardware and software Active Power Injection Cease sources are Red.

The GRID_CONNECT_IO Power cease functionality is disabled in the device default settings but forced to be set in the Grid definition file if required for a particular Grid Regulation.

9.7.5 System

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

Register Address	Register Name	Type	Default	Comments
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
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.
1000	pcs_state	uint16x RO		Stabiliti global state. See state definitions below
1001	pcs_fault_status	uint16x RO		Stabiliti global fault status. See fault definitions below.
1015	fault_global_reset	uint16x R/W	0	1=reset all faults, including all fault counters and timestamps. Self clearing.
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 8: System basic Modbus registers

9.7.6 High-Level info and control

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

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
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

Register Address	Register Name	Type	Default	Comments
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
2000	Command	uint16 RW	0	1=Reset 3=Save (Reg <2000) 7=Save Settings (Reg >2000)
2001-2008	Serial_Number	string16 RO		PCS serial number: 8 registers concatenated, 2 ASCII characters per register
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 9: Basic system operation Modbus registers

9.7.7 States and Status

The following table provides the various states notified in *pcs_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 10: PCS_STATE register values description

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 11: Px_STATE register values description

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

Register Value	State	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 12: PCS_FAULT_STATUS and Px_FAULT_STATUS register values description

9.8 Fault Management & Watchdog Timer

CE+T strongly recommends that the operator familiarize themselves with the Fault Management sub-system on the PCS by reading **Application Note 303: Fault Monitoring & Management with Stabiliti Series PCS**, particularly the automatic reconnect feature of Automatic Mode. CE+T also recommends that the watchdog timer function be utilized in all production converters deployed by your company and also during lab evaluation, if possible. The watchdog function at register 283 operates as follows: after a user writes a value in seconds to the register, the timer will count down and upon reaching zero, the converter will be automatically set to a faulted, offline state. This ensures that if a system controller or operator fault occurs or a communications failure occurs between your system controller and the converter, the system will automatically idle itself after the watchdog countdown. The converter is shipped with the watchdog feature disabled.

It must also be noted that the pcs_start command (R263) also clears all pending statuses (faults and warning, active and occurred).

10. 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 set point registers to govern the real-time current or power flow within the bounds of the Control Method, as well as a ramp rate register which specifies how fast to move from one set point level to a new set point 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.

10.1 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 13: PCS AC1 control methods

10.2 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 14: PCS DC2/DC3 control methods

10.3 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 has 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 good 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 supervises the PCS.

10.4 Control Method Uses and Restrictions

10.4.1 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 or out of that port. All Converters are shipped with IDLE as their factory default for safety purposes.

10.4.2 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 accommodate 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 6 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 are beyond the scope of this document. Refer to the Modbus Programmers Guide for more information.

10.4.3 DC Power Control Method (0x0401)

The DC Power Control Method (POWER) is paired with a power set point register which uses a sign to indicate the 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 set point 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.

10.4.4 DC Current Control Method (0x0301)

The DC Current Control Method (CURRENT) is paired with a current set point register which uses a sign to indicate the 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 set point register, and the PCS will ramp the 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.

10.4.5 DC Volt Control Method (0x0501)

The DC Volt Control Method (VOLT) is paired with a voltage set point and static resistance set point register. The operator will write a value to the voltage set point 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 100 to 1000 Vdc. Full power being limited by 60 A output is, however only available at voltages above **650 V**. Despite the voltage being fixed by Stabiliti, the power may indifferently flow in or out of the device.

10.4.6 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. **This Control Method is paired with PV start and stop time configuration registers to enable operation on a time basis or a minimum voltage configuration register to enable operation on that basis. Refer to the power flow example below for more usage information.**

10.4.7 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 set point registers, which use a sign to indicate the 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 set point 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**.

10.4.8 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 behave as with GPOWER.
2. Stand-alone grid-forming mode: this is sometimes described as a "free-standing" microgrid or nano grid. No interaction with a utility grid is enabled or allowed.

Refer to Application Notes 503 and 504 for more information on FPOWER microgrid and rapid transfer applications with the Stabiliti PCS.

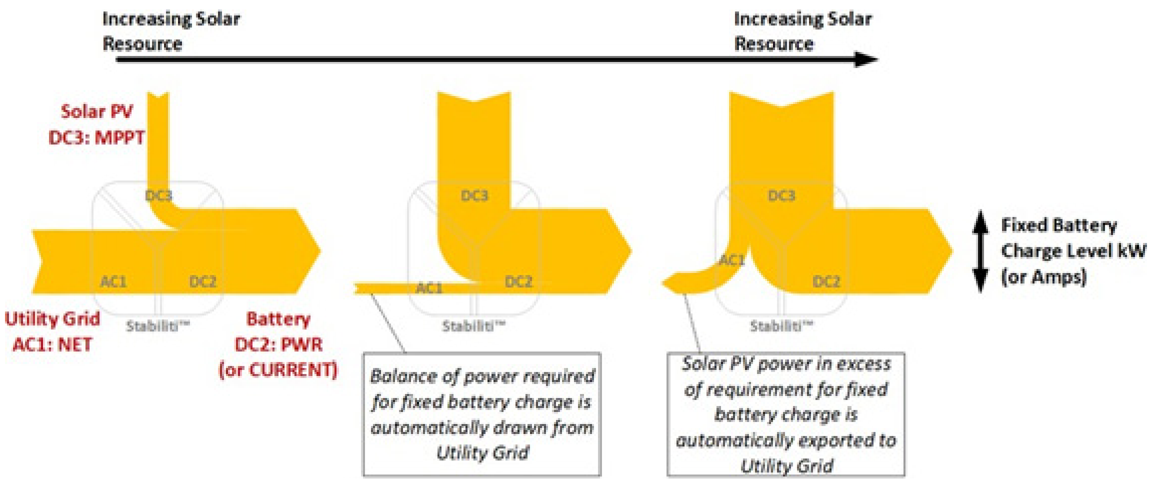


Figure 6: Three port power flow example with utility grid at AC1 as = NET

11. Initial Startup and Basic Commissioning

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 labelled 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.
- **Communications:** confirm the ability to read and write data to the Modbus interface. Preferred with an external 24 Vdc power supply but alternatively with the grid supply.
- **Run Enable and fault check:** Ensure the *Run_Enable* connection is made before attempting to start up the PCS. Refer to section "**#4 – AUX 24V IN / RUN", page 13** 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 Application Note 303: Fault Monitoring & Management with Stabiliti™ Series PCS.
- **Pre-charge:** Start and stop a pre-charge of the PCS DC2 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 12.2, page 37** for more information on setting up a pre-charge.

After energizing the 480 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 **section 12.1, page 37**. Confirm 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 DC2 bus, energizing the battery and PV connections to the PCS:

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

12. 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 pre-charge circuit, as noted previously..

12.1 AC-Only Power Factor Correction (Power recycling)

1. After physically installing the PCS as described earlier in this document, energize the 480 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 configure the following registers:
   a. R65 p1_control_method = 0x0001 (NET)
   b. R129 p2_control_method = 0x0501 (VOLT – 2 ports configured mandatory to start)
   c. R193 p3_control_method = 0x0000 (IDLE, factory default)
   d. R134 p2_voltage_setpt = 600 (dummy output)
   e. R276 system_op_mode = 0 (Manual, factory default)
   f. R524 mode_voltage_response = 3 (Cos Phi setpoint)
   g. R525 cosphi_setpoint_param = 1000 (Cos Phi = 1)
3. Write R263 user_start = 1 to enable power transfer
4. Notice the feedback state indicated by R1000 pcs_state
5. 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.
6. Vary Cos Phi setpoint to 0.9 leading:
   a. R525 cosphi_setpoint_param = -900 (Cos Phi = 0.9 leading)
7. Notice effect on cos-phi and powers reading changes in R118, R119 and R120
8. 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.

12.2 Stand-alone Battery Charge/Discharge on DC2

1. After physically installing the PCS as described earlier in this document, energize the 480 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 9.7.2, page 25**, 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.

12.3 Stand-alone Solar PV export on DC3

1. After physically installing the PCS as described earlier in this document, energize the 480 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 9.7.3, page 27**, 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.

12.4 PV + Battery Sum for Grid Export: Battery on DC2, PV Array on DC3

This is an example of PV firming and demand charge management battery discharging. The export to the grid will be held firm irrespective of the available PV resource.

1. After physically installing the PCS as described earlier in this document, energize the 480 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 9, page 21**, 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.

12.5 Battery Charging from PV and/or Grid: Battery on DC2, PV Array on DC3

This is an example of "battery-friendly" steady-rate charging. Refer to Figure 6.

1. After physically installing the PCS as described earlier in this document, energize the 480 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 9, page 21**, 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.

12.6 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 480 Vac, despite variations in load.

1. After physically installing the PCS as described earlier in this document disconnect and isolate the PCS from the 480 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 9, page 21**, 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.