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Quick Start Guide
Stabiliti™ Series
30 kW Power Conversion System (PCS)
Model Numbers: 30C, 30C3

MAN-00114, Rev D

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SECTION 1.0 INTRODUCTION

Purpose, Scope, and Audience
This Quick Start Guide describes the features and capabilities of the Stabiliti™ 30C3 Multiport Power Conversion System ("PCS" or "Converter"), as well as the Stabiliti™ 30C Dual Port PCS. It should be used in conjunction with other product documentation provided by Ideal Power ("IPWR"), 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™ Series Installation and Operations Manual (MAN-00115) should be used to ensure safe installation and operation of this Converter. Please review this entire document prior to starting your system evaluation. Contact support@idealpower.com for technical support as needed.

SECTION 2.0 SYSTEM SPECIFICATIONS

Hardware Description
The 30C3 PCS uses IPWR's proprietary Power Packet Switching Architecture™ ("PPSA") to efficiently transfer and manage power flows amoung three power ports: AC1, DC2, and DC3:

- AC1 is a 3-Wire, 3-Phase AC power port.
- DC2 is a DC power port typically dedicated to battery-based energy storage systems.
- DC3 is an auxiliary DC power port for use with a second battery system, or a PV Array.

The 30C is a Dual Port PCS based on the 30C3 platform. The primary difference is that the Port DC3 power electronics are depopulated and disabled at the factory. Other than the noted depopulation of power electronics on DC3, the Stabiliti™ Series PCS share a common Firmware and Hardware platform.

The 30C has the following power port configuration:

- AC1 is a 3-Wire, 3-Phase AC power port.
- DC2 is a DC power port typically dedicated to battery-based energy storage systems.

The remainder of this document is dedicated to the 30C3, which can be configured to emulate the 30C by setting port DC3 to the IDLE Control Method.

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Unlike previous PCS offerings from IPWR, the Stabiliti™ Series PCS uses a novel Link Transformer coupled with 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: floating; grounded-unipolar; as well as bipolar battery types are all supported (minor wiring changes are required to their DC power board connections).

All ports support bi-directional power flows (up to 30 kW max per port). Their highly flexible operating modes are managed via Modbus RTU over an RS485 serial, control, and monitoring interface. Modbus TCP is also supported. Future versions of the Stabiliti™ Series PCS will support wireless connectivity options.

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 Ideal Power regarding any damage noted.

Mounting the PCS
The PCS, when installed on its wall mounting bracket weighs approximately 135 pounds. External dimensions are 20.5" W x 40" H x 16" D. The PCS MUST always be installed in a vertical upright position, this includes 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. Complete the mounting and installation following instructions in the Stabiliti™ Series Installations and Operations Manual (MAN-00115).

SECTION 3.0 LOW VOLTAGE WIRING

Wiring Access
The PCS wiring compartments are accessed by three screws which open the full-sized (20.5" x 40") hinged front door. All low-voltage wiring is directly terminated to connectors located on the system's Control Board, located on the upper left side of the enclosure.

- *Other than Ethernet and USB connections, low-voltage terminations are bare wire type. Sourcing appropriate 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 sources and a grounding strap should be worn by the equipment installer. Refer to MAN-00115, Stabiliti™ Series Installation and Operations Manual for additional information regarding low-voltage wiring.*

In all Stabiliti™ Series applications, an outside system controller is required to configure, control, and monitor the PCS in real-time via the serial Modbus RTU, or 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 (9) low-voltage interfaces on the Control Board. From top to bottom in ascending order:

1. AC Disconnect (J8)
2. E-Stop / Aux 24 V In (J9)
3. RS485 (J10)
4. Sync/CAN (J11)
5. Transfer Switch (J16)
6. Ethernet (J7)
7. USB (J13)
8. Aux 24 V out (J15)
9. Arc Fault Interface (J12)

Interface Overview

<u>#1 - AC Disconnect</u>
2-Pin Phoenix-style connector
- Pin 1 is relay "in"
- Pin 2 is relay "out"

This low-power relay driver output will open whenever the PCS senses a grid-fault condition. It is intended to drive an external 24 Vdc relay which in turn drives an external AC contactor/disconnect, to open the connection between the PCS and the grid. 2.5 A is the maximum load current.

<u>#2 - E-Stop / Aux 24 V In</u>
4-Pin Phoenix-style connector
- Pin 1 is Ground
- Pin 2 is Emergency Stop
- Pin 3 is Ground
- Pin 4 is Auxiliary 24 V in

For normal PCS operation, the E-Stop input (pin 2) must be connected to ground. If left open or tied to 24 Vdc, the E-Stop feature is activated and the PCS will cease exporting power and move to an idle state. For voltage-forming applications, connect a 150 W 24 Vdc power supply between Ground (pin 3) and Aux 24 V in (pin 4).

This external power supply is required to keep the control board awake when the PCS is black-started in voltage-forming mode. The power supply also keeps the control board awake when transitioning between voltage-following and voltage-forming modes.

For applications that support only voltage-following operation (grid-tied), the supply is not required.

NOTE: For initial Modbus configuration and read/write verification, use of the external supply is useful, otherwise a 480 Vac grid connection is required to power the Control Board.

<u>#3 - RS485</u>
3-Pin Phoenix-style connector
- Pin 1 is RS485 D0 (also known as A/A', positive half of differential pair)
- Pin 2 is RS485 D1 (also known as B/B', negative half of differential pair)
- Pin 3 is isolated ground (Common, also known as C/C', signal/power)

2-Wire Serial Modbus interface. Factory default: 240 / 19,000 / 8 / even / 2. The media layer protocol uses 2-wire Modbus RTU. This protocol relies on RS485 differential signaling. The need for external termination resistors is determined by a number of factors including Modbus

run length, number of devices on the Modbus run, type of interconnection cable, and baud rate selected.

A maximum of one terminating resistor should be used when the Modbus interface of multiple units are daisy chained together and connected to one master Modbus device. The optional 120 ohm Modbus terminating resistor is frequently not necessary, and may in fact interfere with proper communications operation under some circumstances. Shorter connections typically perform quite well without a termination resistor.

#4 - Sync/CAN
8-Pin Phoenix-style connector
- Pin 1 is CAN_L
- Pin 2 is CAN_H
- Pin 3 is CAN isolated ground
- Pin 4 is Sync RX_N
- Pin 5 is Sync RX_P
- Pin 6 is Sync TX_N
- Pin 7 is Sync TX_P
- Pin 8 is Sync isolated ground

NOTE: The CAN interface is reserved for future use.

#5 - Transfer Switch
8-Pin Phoenix-style connector
- J16 pin 1 Island (24 Vdc)
- J16 pin 2 Island Return (24 Vdc Return)
- J16 pin 3 Island Acknowledge Return (24 Vdc Return)
- J16 pin 4 Island Acknowledge (24 Vdc)

To enable voltage-forming (islanded operation), both pin 2 and pin 3 on J16 must be connected ground, or left open. Connect to 24 Vdc to ensure the system never attemps to island while the Facility Power Control Method is enabled.

These inputs are designed to interface with external third-party Islanding Switchgear which allows the PCS to move between grid-following and grid-forming modes in a seamless, blinkfree fashion to support critical loads. Detailing the Islanding Switchgear application is beyond the scope of this initial Quick Start Guide. If not using third-party Islanding Switchgear, leave J16 pins open.

#6 - Ethernet
8-pin RJ45 Connector

- **Ethernet Services**
The Stabiliti™ Series PCS supports wired Ethernet connectivity. This Ethernet connectivity

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will eventually support a range of services at a particular Ethernet IP address, each service accessed through one or more ports. Detailing all of these services is beyond the scope of this preliminary Quick Start Guide.

NOTE: The 30C3 supports Modbus TCP on port 502, slave ID 255. Presently, two functions are supported: Function 3, Read Holding Registers; and Function 6, Write Holding Register.

- **Determining the Ethernet IP Address.**
Once the PCS boots, it will request an IP address via DHCP (Dynamic Host Configuration Protocol). Once an IP address is assigned by the local network, the PCS will display the assigned IP address on its front panel display. If no IP address is assigned (e.g. if DHCP is not available), the PCS will display 0.0.0.0 for the IP address (no address assigned). The prototype PCS does not, presently, provide for retry of DHCP, so a power cycle of the PCS is required if the 0.0.0.0 IP address is shown on the display. To ensure correct address assignment, connect the network to the PCS prior to applying power to the unit's Control Board.

NOTE: Static IP addresses are not supported. DHCP address assignment by the local network is required. If DHCP is not available, communicate with the PCS via Modbus RTU.

- **FTP (File Transfer Protocol)**
Ideal Power use only. Supports remote file transfers to/from the PCS. This provides support for collection of data and fault logs, and also for remote firmware updates. FTP uses ports 20 and 21.

- **Telnet**
Ideal Power use only. Supports interactive application development, diagnostic troubleshooting, and factory configuration. Telnet uses port 23.

#7 – USB Connector

Standard Mini-B USB connector.

NOTE: Not for customer use.

#8 - Aux 24 V Out
8-Pin Phoenix-style connector
- Pin 1 is Isolated 24 V return (ground)
- Pin 2 is Aux 24 V out

NOTE: Not for customer use.

#9 - Arc Fault Interface
8-Pin Phoenix-style connector.

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NOTE: Not for customer use.

SECTION 4.0 HIGH-VOLTAGE WIRING

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 access to the Control Board and the various configuration, control, and monitoring features supported by the Stabiliti™ Series PCS and detailed later in this document.

Wiring Access
IPWR recommends that all product evaluations begin with a low-voltage systems analysis first as described in the paragraph above. Once the systems analysis is completed, connect AC and DC power sources. The Converter wiring compartments are accessed by eight hex screws which open the full-sized (20.5" x 40") hinged front door.

- High-voltage AC1 connection points are located on the left bottom section of the Converter enclosure.
- High-voltage DC2 and DC3 connections are located on the right bottom 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..

AC1 Interconnect Board

Figure 2: 30C3 AC1 Wiring Interconnect Board

The bi-directional AC1 port shown in Figure 2 is configured as a 3-wire delta interface. Factory defaults are set to support North American grid standards: operating frequency is 60 Hz; operating voltage is 480 Vac. **Detailing 50 Hz operation is beyond the scope of this document**.

AC Connections are made to the bottom terminals designated as PHASE A, PHASE B, and PHASE C. Note that the PCS will automatically adapt to phase rotation.

An earth grounding lug shown in the image is located just below the Phase A connector. Ensure that the chassis/enclosure is correctly grounded by utilizing this connector for earth ground. Contact support@idealpower.com regarding any questions you may have regarding available AC voltage and frequency options.

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 commonly used for such purposes. In some jurisdictions, this circuit breaker may also be approved for use as a safety disconnect. However, Ideal Power recommends that you confirm specific AC disconnect requirements with your local Authority Having Jurisdiction ("AHJ"). Some utilities may require an external "red-handle" lockable disconnect, in additional to the protection breaker.

DC2/DC3 Interconnect Board

Figure 3: 30C3 DC2 and DC3 Wiring Interconnect Board
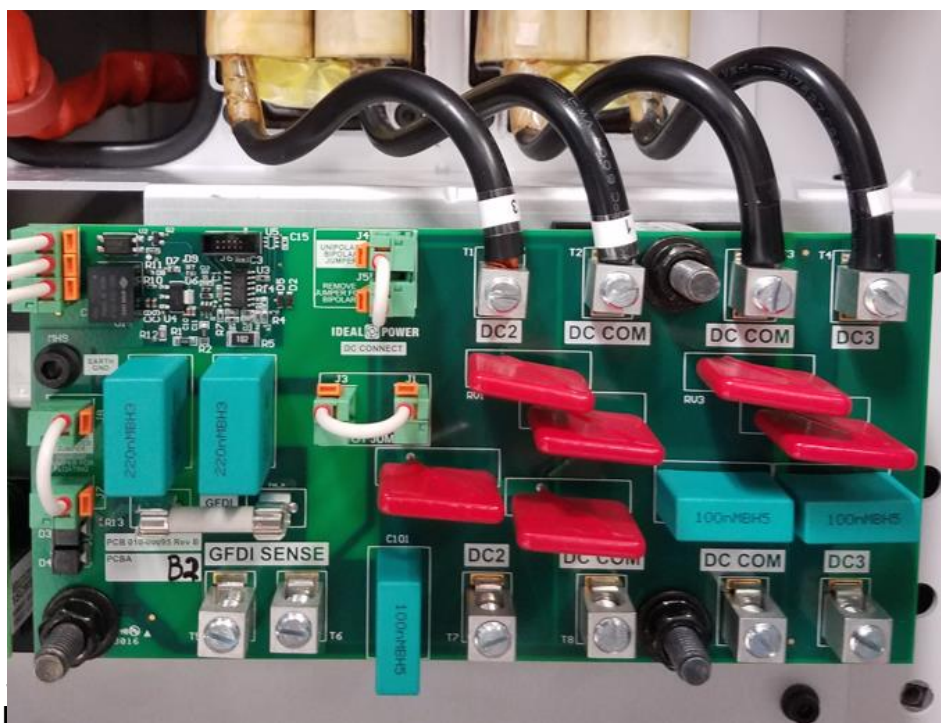
The DC Wiring Interconnect Board shown in Figure 3 reflects a 30C3 PCS with DC3 components installed. The battery positive is connected to DC2 (T7) and the battery negative to the right most DC COM (T8).

Typically, an external PV array negative connection is made to the bottom and left-most DC COM (T9) and positive PV array connection to DC3 (T10). Note that the battery and PV Array connections share a common negative connection: DC COM. They are NOT isolated from one-another.

There are numerous DC wiring options available on the 30C3, including support for floating, grounded unipolar and bipolar battery configurations. Refer to Stabiliti™ Series Installations and Operations Manual (MAN-00115) to determine what configurations best fits your application.

Contact support@idealpower.com for questionsregarding DC2 and/or DC3 wiring options.

DC2 and DC3 External Circuit Protection and Disconnect
The 30C (DC2 only) and 30C3 (DC2 and DC3) must be installed with external fused circuit protection on their DC power ports. A 1000 Vdc rated, 100 A fused PV Disconnect is commonly used for such purposes. However, Ideal Power recommends that you confirm specific DC disconnect and safety requirements with your local Authority Having Jurisdiction ("AHJ").

SECTION 5.0 MODBUS INTERFACE

PCS Configuration, Control, and Monitoring
All Stabiliti™ Series Converters are configured, monitored, and controlled via the Modbus RTU or Modbus TCP Interfaces. The interface consists of a series of signed or unsigned 16-bit registers, each with its own unique hexadecimal Modbus address.

Several of these registers are read-only that present static values such as model number and serial number. Other read-only registers are dynamically updated presenting system status, alarm conditions, port voltage, current, and power levels. The remaining registers control system configuration, modes of operation, output power levels, and other parameters of the Converter. These registers are both readable and writable.

Before applying AC or DC Power 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 aux power input.

Application Specific Register Settings

The Modbus interface is used to establish minimum and maximum allowable DC2 and DC3 (30C3 model only*)* port voltages, port soft-power 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.

For example, DC3 maximum voltage (default = 1000 Vdc) should be updated from the factory default and saved to flash to reflect your PV Array operating voltage range (30C3 only). DC2 minimum should be set from its factory default of 200; to -20 Vdc. This will eliminate nuisance under-voltage faults from occurring. A separate register "p2_min_v_setpt1" should be programmed to reflect the desired PV Array minimum starting voltage.

DC2 minimum voltage (default = 100 Vdc) and DC2 maximum voltage (default = 1000 Vdc) should be updated from the factory default to reflect your battery voltage operating range (30c and 30C3).

Once changed from factory defaults, your application-specific configuration options **are not automatically** updated and saved to flash. IPWR suggests that they be saved to flash using Converter's internal memory to ensure that your revised defaults remain intact if power is lost.

Other registers, such as those dedicated to port Control Methods and their related setpoints will be dynamically controlled by your external system controller. These registers should **NEVER** 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 occur.

The Stabiliti™ Series PCS factory defaults support the North American grid interconnection standard of 60 Hz, 480 Vac, 3-phase. The physical connection is 3-wire Delta.

The Converter's default AC over/under voltage limits, AC over/under frequency limits, AC Surge, and fault reconnect timers all comply with applicable UL 1741 and IEEE 1547a standards. To retain full compliance with these grid safety standards, these registers SHOULD NOT be updated, without the review and approval of the local utility responsible for approving your grid interconnection.

All Converters are shipped from Ideal 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 RTU or Modbus TCP interface. Such configurations are detailed later in this document.

For ease of presentation in this document, register addresses shown below are in decimal.

All register addresses must be converted to their hexadecimal equivalent by your system controller. Also note that the Control Method register utilizes a hexadecimal data format "0x….", where 0x0000 indicates the Port Control Method is IDLE, as defined in Table 1.

Modbus Register Assignments

Table 1: AC1 Registers

Addr	Register Name	Format	Factory Default	Comments
64	p1_port_type	uint16x R/W	0x0103	0x0103 – AC1 DELTA 3-Wire
65	p1_control_method	uint16x R/W	0x0000	0x0000 - IDLE 0x0001 - NET 0x0402 - GRID POWER (GPWR) 0x0502 – FACILITY POWER (FPWR)
66	p1_ramp_rate	int16 R/W	500	If p1_control_method = 0x0402 or 0x502: real power and reactive power ramp rate while voltage-following
67	p1_throttle_port	int16x R/W	0x0000	If p1_control_method = 0x0001: throttle port DC3 = 0; throttle port DC2 = 1
68	p1_real_pwr_setpt	uint16 R/W	0	If p1_control_method = 0x0402 or 0x502: real power setpoint while voltage-following
69	p1_reactive_pwr_setpt	uint16 R/W	0	If p1_control_method = 0x0402 or 0x502: reactive power setpoint while voltage-following
70	p1_power_factor_setpt	uint16 R/W	0	If p1_control_method = 0x0001: power factor setpoint, otherwise unused – need to define scaling factor
71	p1_voltage_setpt	int16 RW	0	If p1_control_method = 0x502: line-to-neutral voltage setpoint for voltage-forming mode, otherwise unused
72	p1_frequency_setpt	int16 RW	0	If p1_control_method = 0x502: output frequency setpoint for voltage-forming mode, otherwise unused
74	p1_reactive_disable	int16x RW	0x0000	If p1_control_method = 0x0001 (NET): 1 = automatic power factor correction is disabled, defaut is enabled
89	p1_apparent_power_limit	uint16 RW	3200	Soft VA Limit (port maximum is 32 kVA)
90	p1_current_limit	int16 RW	4400	Soft Current Limit (port maximum is 44 A)
96	p1_port_status	int16x RO		b0 = 1: AC1 power limiting b1 = 1: AC1 current limiting b2 = 1: Throttling DC2 b3 = 1: Throttling DC3

109	p1_v_ab_rms	int16 RO		AC1 A-B RMS voltage
110	p1_v_bc_rms	int16 RO		AC1 B-C RMS voltage
111	p1_v_ca_rms	int16 RO		AC1 C-A RMS voltage
115	p1_i_a_ext_adc	int16 RO		AC1 phase A RMS current
116	p1_i_b_ext_adc	int16 RO		AC1 phase B RMS current
117	p1_i_c_ext_adc	int16 RO		AC1 phase C RMS current
118	p1_power_factor	int16 RO		AC1 power factor
119	p1_real_power	int16 RO		AC1 real power
120	p1_reactive_power	int16 RO		AC1 reactive power
121	p1_apparent_power	int16 RO		AC1 apparent power

Table 2: DC2/DC3 Registers

Addr	Register Name	Format	Factory Default	Comments
128 /192	p2/p3_port_type	uint16x R/W	0x0002	DC port
129 /193	p2/3_control_method	uint16x R/W	0	0x0000 - IDLE 0x0001 - NET 0x0002 - MPPT 0x0301 - DC CURRENT 0x0401 - DC POWER
130 /194	p2/p3_ramp_rate	uint16 R/W	50	IDLE – not applicable NET – not applicable DC CURRENT – factory default current ramp rate = 5 A per second DC POWER – factory default power ramp rate = 500 W per second
131 /195	p2/p3_throttle_port_setpt	int16x R/W	0x0000	If p2 or p3_control_method = 0x0001: throttle port AC1 = 0; throttle port DC3 (or DC2) = 1
132 /196	p2/p3_current_setpt	int16 R/W	0	If p2/p3_control_method = 0x0301: DC Current setpoint
133 /197	p2/p3_power_setpt	int16 R/W	0	If p2/p3_control_method = 0x0401: DC Power setpoint

135 /199	p2/p3_pv_start_tod_ setpt	uint16 R/W	0	If p2 or p3_control_method = 0x0002: PV/MPPT start time in minutes from midnight (1 to 1440)
136 /200	p2/p3_pv_stop_tod_ setpt	uint16 R/W	0	If p2 or p3_control_method = 0x0002: PV/MPPT stop time in minutes from midnight (1 to 1440)
138 /202	p2/p3_pv_min_v_ setpt	uint16 RW	100	If p2 or p3_control_method = 0x0002: PV Array Voc must exceed this minimum DC voltage to enable MPPT morning start
141 /205	p2/p3_v_pn_max_ limit	int16 RW	1000	maximum port DC operating voltage – for safety, lower to expected battery or PV Vdc maximum
142 /206	p2_v_pn_min_limit	int16 RW	200	minimum port operating voltage – for safety, set to expected battery Vdc minimum on battery port; set to -20 Vdc to eliminate nuisance under-voltage faults for port configured to support PV
153 /217	p2/p3_power_limit	uint16 RW	3200	DC2/DC3 Soft Power Limit (maximum 32 kW)
154 /218	p2/p3_current_limit	uint16 RW	600	DC2/DC3 Soft Current Limit (maximum 60 A)
160 /224	p2/3_port_status	int16x RO		b0 = 1: DC2/DC3 power limiting b1 = 1: DC2/DC3 current limiting b2 = 1: Throttling AC1 b3 = 1: Throttling DC3/DC2
173 /237	p2/3_v_pn	int16 RO		DC2/3 voltage, positive to negative (common)
176 /240	p2/3_v_pg	int16 RO		DC2/3 voltage, positive to ground (earth)
177 /241	p2/3_v_ng	int16 RO		DC2/3 voltage, negative to ground (earth)
185 /249	p2/3_power	int16 RO		DC2/3 power
186 /250	p2/3_current	int16 RO		DC2/3 current

Table 3: Other Pertinent Registers

Addr	Register Name	Format	Factory Default	Comments
258	reconnect_timer_set_ 0	uint16 R/W	320	Reconnect timer_2 setpoint (320 seconds)
263	user_start	uint16x R/W	0	Manual mode start, set to 1 to start
264	user_stop	uint16x	0	Manual mode stop, set to 1 to stop

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		R/W		
266	remote_reset	uint16x R/W	0x0000	Set b15 =1 to reset converter
267	sys_op_mode	uint16x R/W	0x0000	0 = operate in manual mode; 1 = automatic mode
296	firmware_version	uint16 RO		Major build FW version (8-bit)
297	build_version	uint16 RO		Incremental build FW version (16-bit)
298	system_status	uint16x R0		b0 = 1 = self-test mode b1 = 1 = RTO countdown b2 = 1 = RT1 countdown b3 = 1 = RT2 countdown b4 = 1 = RT3 countdown b5 = 1 = product not verified b6 = 1 = lockdown active b7 = 1 = link A starting b8 = 1 = link B starting b9 = 1 = link A exporting b10 = 1 = link B exporting ? = abort active (need to define)
0 to 63	Fault Management	various	various	The use of fault monitoring and management registers is detailed in a separate Applications Note.
576 to 703				IEEE 1547a over/under voltage and over/under frequency setpoint registers

All of the registers' decimal addresses noted above are exposed to the user via the Modbus RTU or TCP interface and must be converted to hexadecimal by your system controller. Additional registers are reserved for future support of SunSpec (www.sunspec.org) Smart Inverter features, starting at address 40000.

NOTE: This document details only the pertinent registers of interest for initial evaluation. Request the "IPC_Modbus_Register.xls" for the complete Modbus register list and data format by contacting support@idealpower.com.

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 "measurement registers", as well as read/write "setpoint registers" used to set desired output voltage, current, or power levels. The setpoint registers are generally not utilized in 30C stand-alone applications.

Table 4: Register Scaling Factors

Type	Scaling Factor	Register Read/Write	Actual Value
AC / DC Port Voltage	1 unit = 1.0 V	100	100 Vac / 100 Vdc
DC Port Current	1 unit = 0.1 A	100	10.0 A
DC Port Power	1 unit = 10 W	100	1000 W
AC Port Real Power	1 unit = 10 W	100	1000 W
AC Port Reactive Power	1 unit = 10 Var	100	1000 Var (1 kVar)
AC Port Voltage Ramp Rate	1 unit = Volts per second	100	100 V/second
DC Port Current Ramp Rate	1 unit = 0.1 A per second	100	10 A/second
AC/DC Port Power Ramp Rate	1 unit = 10 W per second	100	1000 W/second
Frequency	1 unit = 0.001 Hz	6000	60 Hz

In 30C3 applications, a DC power command of +1500 on DC3 will deliver 15 kW of "export power" (charging a battery). Conversely, a DC power command of -1000 on DC3 will deliver 10 kW of "import power" (discharging a battery).

The ramp rate command is a modifier of the power command defined above. It limits the port ramp rate (power, current, or voltage depending on selected Control Method). A power ramp rate setting of 300 limits the ramp up or ramp down of the commanded port to a 3 kW/second rate.

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Watchdog Timer

IPWR recommends that our watchdog timer function be utilized in all production Converters deployed by your Company. This ensures that if a system controller fault occurs, or a communications failure occurs between your system controller and the Converter, the system will idle itself after watchdog countdown. After a user writes an update to the watchdog timer register, the timer will count down and upon reaching zero the Converter will be automatically set to an idle state. The Converter is shipped with the watchdog feature disabled.

SECTION 6.0 CONTROL METHODS

Via the Modbus RTU or Modbus TCP interface, there are numerous and flexible means to transfer power amoung Converter power ports. These port-specific operating modes are collectively known as "Control Methods" and include MPPT, GRID POWER (GPWR), FACILITY POWER (FPWR), DC Power (PWR), DC CURRENT (DCA), NET, and IDLE. There is a dedicated Control Method register for each port of your PCS.

Each Control Method may also have one or two associated setpoint registers (target output power, output current, and/or output voltage), as well as a separate ramp rate register which specifies how fast to move from an existing output power or current 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.

The Control Methods supported in the Stabiliti™ Series PCS are listed below.

AC1 Control Methods
- IDLE (0x0000) – factory default
- NET (0x0001) – grid-tied applications only
- GPWR (0x0402) – grid-tied applications only
- FPWR (0x0502) – interactive voltage-following/voltage-forming applications (requires external islanding switchgear or voltage-forming applications)

DC2/DC3 Control Methods
- IDLE (0x0000) – factory default
- NET (0x0001)
- MPPT (0x0002)
- DCA (0x0301)
- DC POWER (0x0401)

Control Method Uses and Restrictions

IDLE Control Method (0x0000)
If a port is not in use, it should be set to the IDLE Control Method. All Converters are shipped with IDLE as their factory default for safety purposes.

NET Control Method (0x0001)

To move power amoung active ports, one and only one port on the PCS MUST ALWAYS be set to the NET Control Method, allowing that NET port to satisfy all bi-directional power flows demanded by the remaining port(s), which will typically be assigned a power, current, or MPPT Control Method.

DC POWER Control Method (0x0401)

The POWER Control Method ("PWR") uses a sign to indicate direction of DC2 and DC3 port power flow, with a scaling factor of 10 Watts. For example, a kW setpoint of -500 on DC3 commands the port to import into the Converter at a 5 kW level (discharge a battery connected to DC3); 1500 on DC3 exports out of the Converter at a 15 kW rate (charges the DC3 battery).

DC CURRENT Control Method (0x0301)

The DC CURRENT ("DCA") Control Method uses a sign to indicate direction of DC port current flow, with a scaling factor of 100 mA. For example: a current setpoint of -500, on DC3 commands the port to import a fixed 50 A (discharge the battery); 300 will export (charge the DC3 battery) at a fixed 30 A.

Note that these constant current flows are maintained by the Converter, independent of battery voltage, with a DC port maximum current of 60 A.

MPPT Control Method (0x0002)

The Maximum Power Point Tracking ("MPPT") Control Method is used only when a PV array is connected to DC2 or DC3. Note that the pv_start_time registers and pv_stop_time registers define when the MPPT Control Method is enabled. Start/stop values in the range of 0 to 1440 reflect the use of an internal "minute clock", where 0 corresponds to midnight. For example: programming 450 in the start register reflects a start time of 7:30 AM.

GPWR Control Method (0x0402)

The GRID POWER ("GPWR") Control Method commands the Converter to voltage-follow. In this configuration, with factory defaults unchanged, the converter responds to all grid-fault conditions in a manner that is compliant with UL 1741 and IEEE 1547A.

FPWR Control Method (0x0502)

The FACILITY POWER ("FPWR") Control Method is used for two unique types of applications:

1. Interactive voltage-following / voltage forming applications, where external third-party islanding switchgear is incorporated into the system design to facilitate rapid and blink-less transfers between voltage-following and voltage-forming mode (and back again), while ensuring while in voltage-forming mode, the PCS remains safe and never back-feeds the grid.

OR,

2. Stand-alone voltage-forming mode. This is otherwise described as a "free-standing" microgrid or nanogrid. No interaction with a utility-grid is enabled or allowed.

Detailing #1 above ("blink-less" grid interactive voltage-following / voltage-forming) is beyond the scope of this document, and will be detailed in a separate Application Note.

SECTION 7.0 POWER FLOW SCENARIOS

Initial System Configuration: Battery on DC2; PV Array on DC3
1. Connect an external 24 Vdc power supply, and/or a 480 Vac grid connection.
2. Connect to the Modbus interface and observe the following:
    a. Confirm that Port 1 (AC1), Port 2 (DC2), and Port 3 (DC3) Control Methods are IDLE (0).
    b. Set p3_v_ll_min_limit = – 20 Vdc to minimize nuisance trips of the Converter due to low PV voltage.
    c. Set p3_pv_min v_setpt = minimum PV Array startup voltge – system will not attempt MPPT start until this voltage is sensed
    d. Set p3_v_ll_max_limit = maximum maximum PV Array voltage – system will shutdown automatically if this voltage is sensed.
    e. Set p2_v_ll_min_limit = minimum battery voltage at lowest SoC – system will shutdown automatically if this voltage is sensed.
    f. Set p2_v_ll_max_limit = maximum battery voltage at lowest SoC – system will shutdown automatically if this voltage is sensed.
3. Power down external 24 Vdc power supply and/or open AC disconnect.
4. Connect Battery to DC2 and PV array to DC3 as detailed in the Installation and Operations Manual.
5. Apply power to all ports (close external AC and DC Disconnects).

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 Multiport PCS.

We begin with a sequence of DC-only test cases, followed by voltage-forming (microgrid), and lastly voltage-following (grid-tied) applications. Note that a few of these use cases have detailed Control Method configuration instructions. Use these examples as guidance for other use cases.

Lastly, the noted roles of DC2 and DC3 may be reversed. Both of these DC power ports have the same Control Method capabilities.

Single Battery Power Exchange

AC1 = IDLE / DC2 = PWR / DC3 = NET

- A novel example of DC-to-DC power conversion. This use case uses a single battery wired identically and shared between the DC2 and DC3 ports. The net current measured and multiplied by stack voltage reflects the efficiency of the Converter's DC-to-DC conversion.
- The PWR Control Method scaling factor is 10 Watts. Writing a DC2 power setpoint value of 500 will yield an output power level of 5 kW on DC2. This power is provided by DC3, which is actively discharging DC2, while DC3 is actively charging the battery at approximately the same rate, net of converter efficiency loses . Writing a DC2 power setpoint value of -500 reverses power flow direction on both ports yielding an output power level of 5 kW on DC3 net of efficiency losses.

NOTE: IPWR's name for this single-battery DC-to-DC power flow example is "net @ battery".

Dual Battery Power Exchange

AC1 = IDLE / DC2 = PWR / DC3 = NET

- This DC-to DC power conversion example uses two independent batteries connected to DC2 and DC3. Battery stack voltages may be dramatically different. However, note that battery voltages <500 V will not allow full 30 kW transfers due to system DC current constraints.
- The PWR Control Method works identically to the single battery example above.

AC Microgrid – Using Single Battery

AC1 = FPWR / DC2 = IDLE / DC3 = NET

- This power flow example uses a 500 Vdc (or higher) battery connected to DC3.
- DC3's battery will supply power as demanded in real time to support and hold the AC microgrid output at 480 Vac, despite variations in load.
- Connect a variable AC load bank to AC1 and use an external DC current probe to observe DC3 current responding rapidly to support the AC microgrid's changing load demand.
- Configure the 30C3 as follows:
    1. Disconnect from external AC grid, and provide 24 Vdc external power to unit.
    2. Update Port 1 (AC1) registers.
        a. Update register 'p1_control_method' to 0x0502 (FPWR).
        b. Update register 'p1_voltage_setpt' to desired microgrid line-to-neutral voltage.
            i. 277 = 277 Vac line-to-neutral (480 V line-to-line), or
            ii. 230 = 230 Vac line-to-neutral (400 V line-to-line)
        c. Update register 'p1_frequency_setpt' to microgrid frequency.
            i. 6000 = 60 Hz, or
            ii. 5000 = 50 Hz
    3. Update Port 3 (DC3) registers.
        a. Update register 'p3_control_method' to 0x0001.
    4. Start power flow by updating register 'user_start' to 1.

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5. Run for desired time and shut down the AC1 microgrid output by updating register 'user_stop' to 1.

AC Microgrid – Using Dual Batteries
AC1 = FPWR / DC2 = PWR / DC3 = NET

- This energy flow example uses two batteries. Depending upon DC2's PWR sign and setpoint, and microgrid load, one or both of the batteries will support the microgrid.
- "Summing" of the batteries to the AC1 voltage-forming output occurs when DC2's negative power setpoint is below the microgrid load. Because DC3 is set to NET, it will make up the shortfall to ensure the microgrid load is supported.
- "Splitting" of DC2 occurs when DC2's negative power setpoint is above the microgrid load. In this flow case, DC2 services the microgrid entirely and excess power available from DC2 is netted to DC3 (DC2 battery charging the DC3 battery).

NOTE: Dual battery systems could use smaller capacity lithium-ion '"power" batteries on DC3 to support rapidly changing microgrid load demands and larger capacity lead-acid "energy" batteries on DC2 to support average microgrid demand.

Solar + Storage Microgrid
AC1 = FPWR / DC2 = MPPT / DC3 = NET:

- This energy flow example uses a PV Array or PV simulator on DC2 with a 500 Vdc+ battery on DC3. Note that these DC port assignments are easily swapped.
- "Summing" of PV and battery to support the AC1 microgrid load occurs when the available solar resource cannot support the microgrid alone (due to low or highly-variable irradiance).
- "Splitting" occurs when the available solar resource exceeds the microgrid's load. The PV Array connected to DC2 completely supports the microgrid and any excess power available from DC2 is diverted to DC3 (charging the DC3 battery).

NOTE: During periods of high-irradiance and modest microgrid load, your system controller must proactively manage the DC3 battery State of Charge (SoC). This is accomplished by setting a lower soft-power limit on the DC2 port, curtailing PV power, and preventing battery overcharging. Adjust the soft power limit higher once batteries are below max SoC.

Solar + Storage Microgrid, with Genset Backup
AC1 = FPWR / DC2 = PWR / DC3 = NET

- At night, or during periods of low-irradiance and high microgrid load, the Solar microgrid use case detailed above may be dynamically re-configured to allow an external AC genset equipped with a rectifier (rectifier connected to DC2 and shared with the PV Array) to support the microgrid while also charging the battery on DC3.
- In this use case, the external system controller will set an import power level on DC2 that is higher than the microgrid load. The generator seamlessly supports the microgrid and excess

power is diverted to DC3, charging the battery. Moving from PV to genset and back again is blink-less because the DC3 battery will completely support the microgrid during these Control Method transitions.

NOTE: This use case requires additional hardware and related control mechanisms to disconnect the PV array and connect the genset into DC2, notably external DC contactors and an external 3-phase rectifier. This genset integration scheme offers higher quality microgrid power, compared to traditional AC-coupled solutions.

PV Firming / Demand Management
<u>AC1= GPWR / DC3 = MPPT / DC2 = NET:</u>
- This energy flow example uses a PV Array or PV simulator on DC3 with a high-voltage battery on DC2.
- Setting the AC1 GPWR power setpoint to 1500 will export a constant 15 kW to the grid.
- "Summing" of PV and battery power occurs when the available solar resource alone cannot support the commanded AC1 power level (low or highly-variable irradiance).
- "Splitting" occurs when the available solar resource exceeds 15 kW. The PV Array connected to DC2 exports 15 kW to the grid and any excess power available from DC2 is shunted to DC3 (charging the DC3 battery).
- *Considerations: During periods of high-irradiance and modest export demand, your system controller must proactively manage the DC3 battery State of Charge (SoC). This is accomplished by setting a lower soft-power limit on the DC2 port, curtailing PV power, and preventing battery overcharging. Adjust the soft power limit higher once batteries are below max SoC.*
- Changing the FPWR setpoint to -500 reverses power flow and will charge the battery at a fixed 5 kW rate. This is a typical overnight charging application with charging power sourced from the grid.
- During the day, if the -500 setpoint remains active, the available solar energy and the 5 kW charge rate will sum to charge the DC3 battery.
- Configure the 30C3 as follows:
  1. Update Port 1 (AC1) registers.
     a. Update register 'p1_control_method' to 0x0402 for GPWR method.
     b. Update register 'p1_ power_setpt' to desired real power level for grid export.
        - 1500 = 15 kW of real power exported to AC1
        - Update register 'p1__reactive_pwr_setpt' to desired reactive power level for grid export
        - 0 = 0 kVar of reactive power exported to AC1, or
        - 200 = 2 kVar of reactive power exported to AC1
  2. Update Port 2 (DC2) registers.
     a. Update register 'p2_control_method' to 0x0002 for MPPT method.
     b. Update register 'pv_start_time' to appropriate start time window (in minutes).

c. Update register 'pv_stop_time' to appropriate stop time window (in minutes).
3. Update Port 3 (DC3) registers.
   a. Update register 'p2_control_method' to 0x0001 for NET method.
4. Start power flow by updating register 'user_start' to 1.
   a. Note if available PV resource is < 15kW, the battery will contribute as necessary to ensure that 15kW is exported to the grid.
   b. Note if available PV resource is > 15kW, 15kW is exported to the grid and any excess power from the PV will be directed to port DC3, charging the battery.
5. Run for desired time and stop power flow by updating register 'user_stop' to 1.

PV + Battery Sum to Grid
AC1 = NET / DC2 = MPPT / DC3 = - PWR

- Changing the sign on the above example results in a constant discharge of the battery to the grid summed with whatever energy is available from the PV array.
- If DC2 is set to the IDLE Control Method or its target setpoint is programmed to "0", available PV energy is exported to the grid, and the system behaves as a PV Inverter.
- Alternatively, setting DC3 to the IDLE Control Method disables the PV power effectively creating a two-port Battery Converter.

NOTE: The DC Constant Current Control Method (DCA) may be an appropriate substitute for the Power Method when applied to the DC3 Port.

Battery Charging from PV and/or Grid
AC1 = NET / DC2 = MPPT / DC3 = PWR

- Unlike the Demand Management/PV Firming flow example, which often subjects the battery to highly variable and bidirectional power flows, this "battery friendly" configuration always charges the battery at a fixed rate: +300 setpoint on DC3 = 3 kW charge.
- When available PV energy exceeds the commanded charge level, DC2 satisfies the DC3 charge requirement and excess power is exported to the grid.

NOTE: If available PV energy cannot satisfy the DC2 charge level, AC1 will import the power necessary to satisfy DC3's 3 kW charge requirement by charging the battery from PV and grid at the same time.

Use the use cases described above as a starting reference for other desired applications of the 30C and 30C3. Contact support@idealpower.com, should you have any questions about the use of Control Methods.

SECTION 8.0 LABVIEW MODBUS TOOL

Upon request, IPWR will provide a simple Modbus LabView application ("Modbus Tool") for evaluating. The application runs on all modern versions of Windows and is delivered as a software executable via a Dropbox account that IPWR will set up on your behalf.

The Modbus Tool allows the evaluator the ability to manually set default system configurations, program operating modes, and monitor Converter voltage, current, and power settings. Comprehensive fault status and fault management is also supported.

The factory default settings for the RS485 Modbus RTU serial interface are set identically for all IPWR products: bus protocol = RTU; baud rate = 19200 bps; word size bits = 8; parity = even; stop bits = 2. The default slave address is 240. The Modbus Tool DOES NOT support Modbus TCP.

Figure 4: IPWR Modbus Tool Screenshot
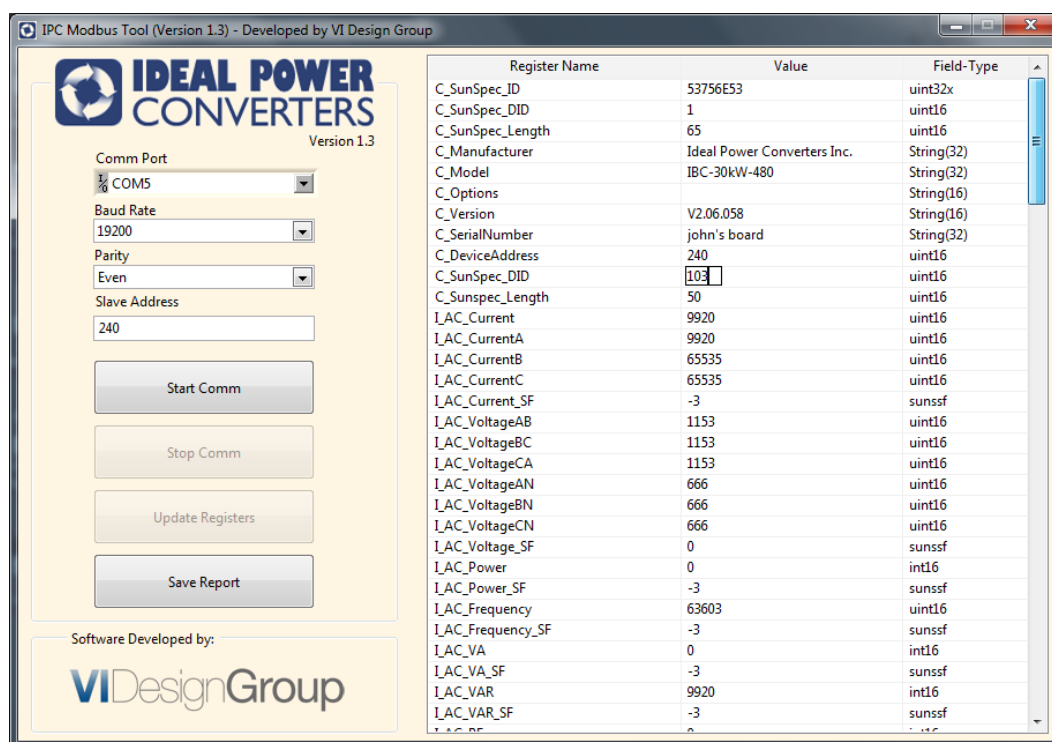
The Modbus Tool should be installed on your lab PC. Installation instructions are provided with the Modbus Tool executable. A Modbus Quick Start Kit, which includes a USB to RS485 Modbus Adapter is also available for purchase. Contact Ideal Power for Quick Start Kit pricing and availability. This Tool does not work with the Modbus TCP is RTU only.

Three additional files are included in the Dropbox:
1) USB driver which should self-install on compatible Windows operating systems

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2) "IPC_Modbus_Register_Map.csv"
3) "IPC_Modbus_Register_Map.xls"

The "IPC_Modbus_Register_Map.csv" file provides the Modbus Tool with register names and formats compatible with your Converter's firmware release. Copy this file into the IPC Modbus Tool config folder, replacing the previous version with a 2013 date stamp. The Modbus Tool WILL NOT run correctly until this update is complete.

The "IPC_Modbus_Register_Map.xls" file further details the Converter's register structure, including factory defaults, register names, register type and location. Copy this file into the IPC Modbus Tool config folder, replacing the previous version with a 2013 date stamp. Use this file as a reference resource as necessary to better understand register structures and system capabilities beyond those detailed in this Quick Start Guide.

End of Document.