IDEAL ⊙ POWER

Quick Start Guide
SunDial™ Series
30 kW Commercial PV String Inverter
Model Numbers: 30PV, 30PVF, 30PV+S, 30PVF+S

MAN-00116, Rev C

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SECTION 1.0 INTRODUCTION

Purpose, Scope and Audience
This Quick Start Guide describes the features and capabilities of the the Ideal Power (IPWR) SunDial™ Series 30PV Commercial PV String Inverter product (30PV, 30PV+S or Inverter).   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 SunDial™ Series Installation and Operations Manual (MAN-00117) should be used to ensure safe installation and operation of the Inverter. 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 SunDial™ Series includes an integrated PV Combiner and DC Disconnect, and is available in the following product configurations:

- **30PV:**   30kW 3-Phase PV String Inverter with Ground-referenced 6-String Combiner, field upgradable to support energy storage (requires +S upgrade kit)

- **30PVF:**   30kW 3-Phase PV String Inverter with Floating 6-String Combiner, field upgradable to support energy storage (requires +S upgrade kit)

- **30PV+S**:   30kW 3-Phase PV String Inverter with Grounded 6-String Combiner, factory installed energy storage port

- **30PVF+S:**   30kW 3-Phase PV String Inverter with Floating 6-String Combiner, factory installed energy storage port

- **+S Kit:** Energy Storage field upgrade kit

Unlike previous PCS offerings from IPWR, the SunDial™ Series utilizes a novel Link Transformer coupled with IPWR's Power Packet Switching Architecture ("PPSA") to deliver full galvanic isolation between the AC grid and the PV Array. This isolation also delivers greater flexibility with regards to PV Array wiring options: both floating and grounded-unipolar PV Array are supported. Select the appropriate Combiner model (floating or grounded), to support your

application. Other than noted Combiner type (floating or ground-referenced), all of the 30PV Inverters share a common Firmware and Hardware platform.

The 30PV and 30PVF are Commercial 3-Phase (480 Vac) 30kW PV String Inverters. With the addition of the +S kit, these Inverters become multiport power systems. We refer to these power ports as noted below:

- AC1: AC power port
- DC2: PV input port
- DC3: (+S upgrade) "battery-ready" bidirectional power port

Inverters equipped with the +S Kit unleash a new suite of features and capabilities, unique to the SunDial™ Series when PV is directly integrated with energy storage. These novel features, enabled by the 30PV+S flexible operating modes (collectively know as "Control Methods"), and are managed via an R485 (Modbus RTU protocol) serial, control and monitoring interface. Modbus TCP is also supported. Future versions of the SunDial™ Series will also support wireless connectivity options.

Unpacking and Inspecting the Inverter
The 30PV and 30PV+ S are pallet shipped in enclosed in a purpose-built heavy-duty cardboard box. Once unpacked, inspect the Inverter for any obvious shipping damage. Immediately contact your shipper and Ideal Power regarding any damage noted.

Mounting the Inverter
The Inverter, when installed on its wall mounting bracket weighs approximately 145 pounds. External dimensions are approximately 20.5" W x 52" H x 16" D. The Inverter MUST always be installed in a vertical upright position for testing and evaluation purposes. Do not block cooling airflow to the 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 SunDial™ Series Installations and Operations Manual (document number MAN-00117).

SECTION 3.0 LOW VOLTAGE WIRING

Wiring Access
The Inverter's wiring compartments are accessed by three hex 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, which is located on the upper left side of the enclosure.

- *Other than Ethernet and USB, note that remaining 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 Inverter should be disconnected from AC and DC power sources and a grounding strap should be worn by the equipment installer. Refer to MAN-00117: SunDial™ Series*

Installations and Operations Manual for additional information regarding low-voltage wiring.

Figure 1: Control Board Low-Voltage Interfaces
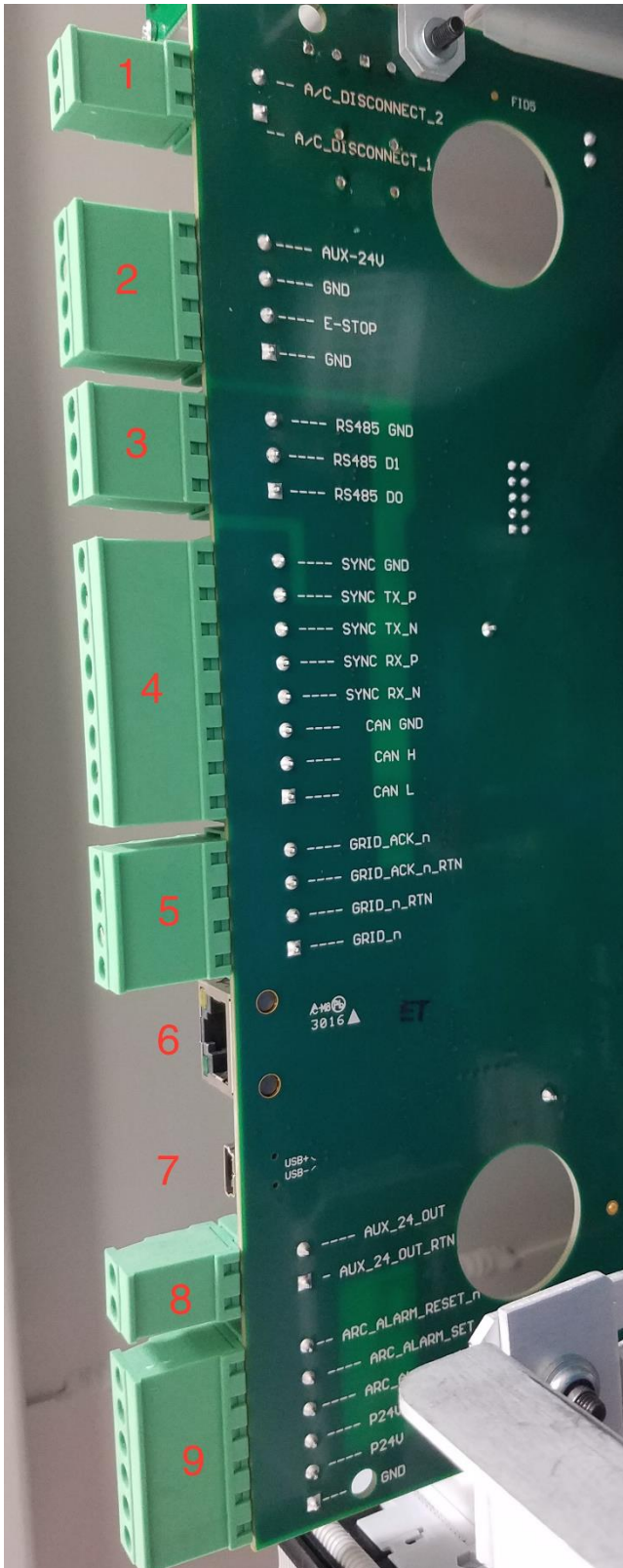
Shown in Figure 1,
there are nine (9) low-voltage interfaces
on the Control Board. From top to
bottom in ascending order:

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)

In 30PV+S, 30PVF+S applications, an outside system controller is required to configure, control and monitor the Inverter in real-time via the serial Modbus RTU, or Modbus TCP interface. These +S systems may also utilize other low-voltage interfaces as described in Section 3.0.

For PV-only applications (30PV and 30PVF); the Modbus RTU interface is typically used for initial Inverter configuration during initial system commissioned and test.   This same interface is also used by third-party providers of PV system remote monitoring equipment, to monitor Inverter health and performance. Alternatively, the Modbus TCP interface could be used in lieu of the Modbus RTU interface for commissioning and monitoring purposes.

Interface Overview
#1 - AC Disconnect
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 Inverter senses a grid-fault condition. It Is intended to support a series interlock of an external 24 Vdc relay coil circuit of an external AC contactor/disconnect, which will open the connection between the PCS and the grid. The driver supports a maximum load current of 2.5A.

#2 - E-Stop / Aux 24V In
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 Inverter 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 Inverter will cease exporting power and move to an idle state.

For production applications the aux supply is not required. The Inverter will power its control board from the 480 Vac grid connection.

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

#3 - RS485
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. 2-Wire Serial Modbus interface. Factory default: address = 240 / baud rate = 19,000 / word length = 8 / parity = even / stop bits = 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 from pin 1)
- J16 pin 3 Island Acknowledge Return (24 Vdc return from pin 4)
- J16 pin 4 Island Acknowledge (24 Vdc)

NOTE: The Transfer Switch Interface is not utilized by the SunDial™ Series.

#6 - Ethernet
8-pin RJ45 Connector

Ethernet Services on the SunDial™ Series
- The 30PV supports wired Ethernet connectivity. This Ethernet connectivity will eventually support a range of services at a particular Ethernet IP address, each service accessed through 1 or more ports. Detailing all of these services is beyond the scope of this

preliminary Quick Start Guide.

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

Determining the Ethernet IP Address.

- Once the 30PV boots, it will request an IP address via DHCP (Dynamic Host Configuration Protocol). Once an IP address is assigned by the local network, the 30PV 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 30PV will display 0.0.0.0 for the IP address (no address assigned). The prototype 30PV does not, presently, provide for retry of DHCP, so a power cycle of the 30PV 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 30PV, 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 you do not have DHCP available, communicate with the Inverter via Modbus RTU (RS-485 Serial).

FTP (File Transfer Protocol)

- Ideal Power use only. Supports remote file transfers to/from the 30PV. 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
Standard Mini-B USB connector.

NOTE: The USB interface is reserved for future use.

#8 - Aux 24V 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.

NOTE: Connects to arc-fault sense circuitry located in the Combiner, 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 Inverter 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 SunDial™ Series 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 Inverter 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 Inverter enclosure.
- High-voltage DC3 connections (for connection to an external battery) are located on the right bottom section of the Inverter enclosure: *(+S only).*
- The Combiner is a separate enclosure, bolted and mounted to the bottom of the power electronics Inverter enclosure. The Combiner output is wired to DC2 at the factory.

NOTE: Do not disturb or change this factory wiring. Terminate each PV string at the Combiner as detailed in MAN-00117: SunDial™ Series Installations and Operations Manual.

AC External Circuit Protection and Disconnect
The SunDial™ must be installed with external circuit protection. A 50A 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.

AC1 Interconnect Board

Figure 2: 30PV AC1 Wiring Interconnect Board
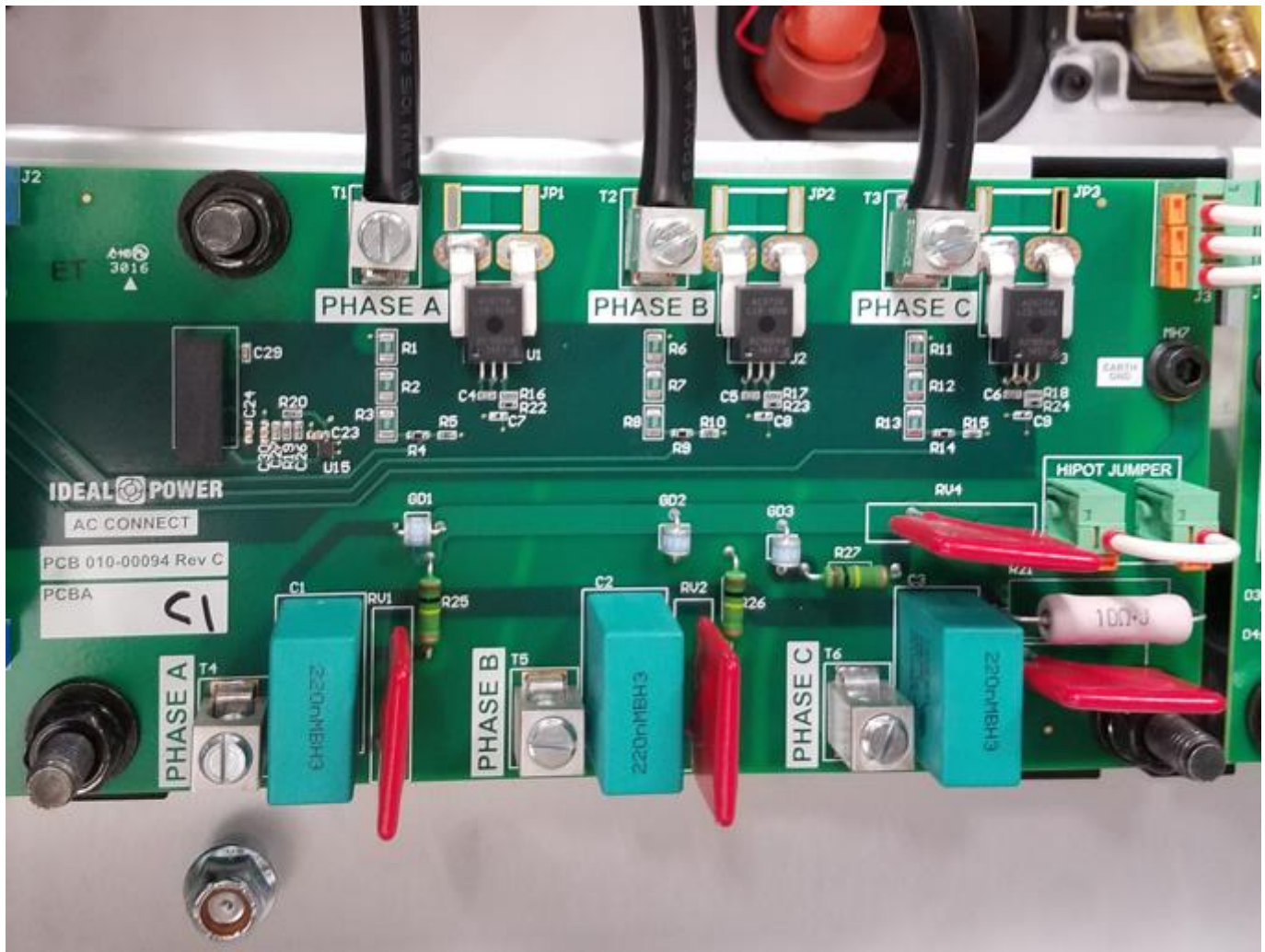
The AC1 port shown in Figure 2 is configured as a 3-wire delta interface, with factory defaults set to support North American grid standards: operating frequency is 60 Hz; line-to-line voltage is 480 Vac, voltage following. **50 Hz operation is not supported.**

AC Connections are made to the bottom terminals designated as PHASE A, PHASE B, and PHASE C. Note that the SunDial™ 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.

DC2/DC3 Interconnect Board

Figure 3: 30PV+S DC Wiring Interconnect Board
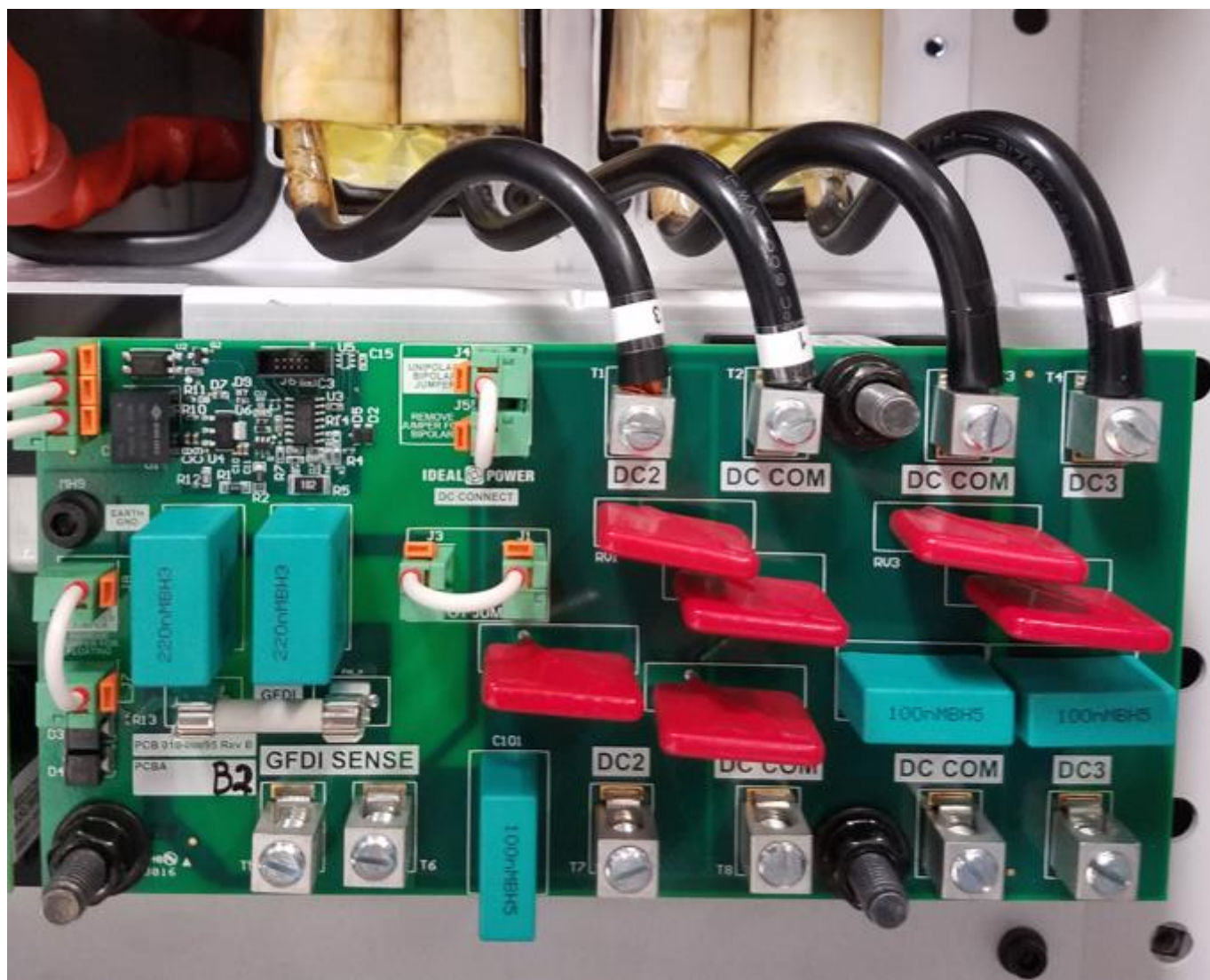
Although not shown in the figure above, note that the Combiner output is terminated to DC2 (T7) and DC COM (T8) at the factory. Do not disturb or change this factory-provided power interconnection between the Combiner output and the Inverter's DC Wiring Interconnect Board.

NOTE: A standalone 30PV has different/missing components on the DC3 port, compared to those shown above. The image above includes the +S option installed on DC3.

DC3 (Battery) External Circuit Protection and Disconnect

The 30PV+S must be installed with external fused circuit protection on its DC3 (battery) power port. 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").

The DC Wiring Interconnect Board show above reflects a 30PV Inverter with the +S kit installed. The external battery negative connection is made to the bottom and left-most DC COM (T9) and positive battery 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 PV Array wiring options available on the 30PV, including support for floating, or ground-referenced PV Arrays. Select the appropriate Combiner option (floating or grounded) to fit your application. The Combiner selected will also determine the default battery configuration for your energy storage system (floating or ground-referenced, + S option only).

Please consult MAN-00117: SunDial™ Series Installation and Operations Manual to determine what Combiner type and DC3 wiring (+S option only) configuration best fit your target application. Contact support@idealpower.com regarding any questions you may have regarding available DC3 wiring options.

Combiner Access

The Combiner enclosure is externally mounted on the bottom of the 30PV power module enclosure. The Combiner wiring compartment is accessed by two hex screws, located on the right side which open the 20.5" x 9.5" hinged front door. Once the hex screws are removed, the DC Disconnect must be rotated to the off position (facing right) before the door can be opened.

Figure 4: Combiner Access Door

Figure 5: Bottom View of Combiner
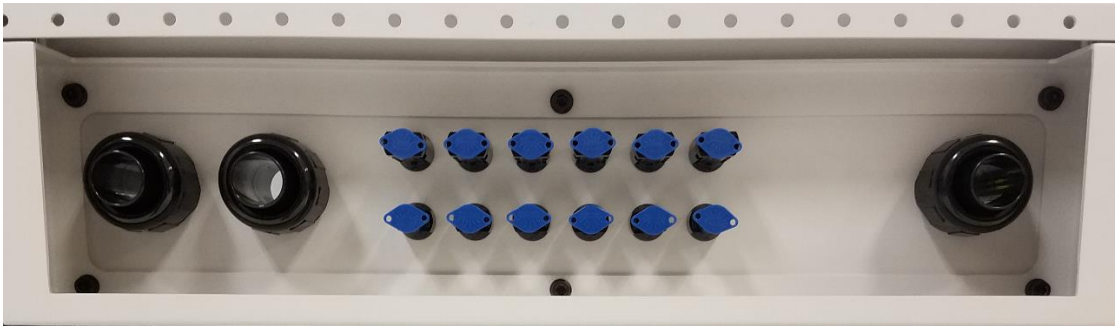
Figure 5 provides a bottom view of the Combiner.   Both the floating and ground-referenced versions of the Combiner share this common set of connectors.

PV String Wiring
Up to 6 PV strings are terminated to the 12 Amphenol MC4 bulkhead connectors located in the middle of Figure 5 above. The blue plugs shown are removed and discarded prior to termination.   6-female and 6-male 10 gauge Amphenol MC4 crimp connectors are provided by Ideal Power (bubble-packed in the Combiner), for field wiring and termination of the PV Strings.

Control and Grid Wiring
The 1-inch conduit fittings located to the left of the MC4 connectors support low-voltage and AC1 (AC power) connections to the Inverter. Both low-voltage control and AC power wiring pass thru the Combiner for termination on the Control Board, and the AC1 Interconnect Board.

Battery Wiring
The 1-inch conduit fittings located to the right of the MC4 connectors support the DC3 battery wiring connection for 30PV+S systems. This wiring passes thru the Combiner for termination on the DC3 (T10), and DC COM (T9) terminals located on the D2/DC3 Interconnect Board.   The conduit fitting may be field replaced as necessary to support other conduit types. It is not utilized in PV-only applications.

Ground-Referenced Combiner
The 30PV and 30PV+S Inverters utilize a circuit that references the negative leg of the combined PV Strings to earth ground, via Ground Fault Detection Interface (GFDI) circuit that senses DC fault currents. A 1A fault fuse located on the DC2/DC3 Interconnect Board will open whenever a ground fault on DC COM of > 1A is encountered. The fuse must be replaced; the fault condition must be cleared; and the Inverter AC power must be cycled, to clear the Inverter's internal GFDI fault. This is known as a "lock-down" fault, requiring a site visit to clear.

Figure 6: Internal View of Ground-Referenced Combiner
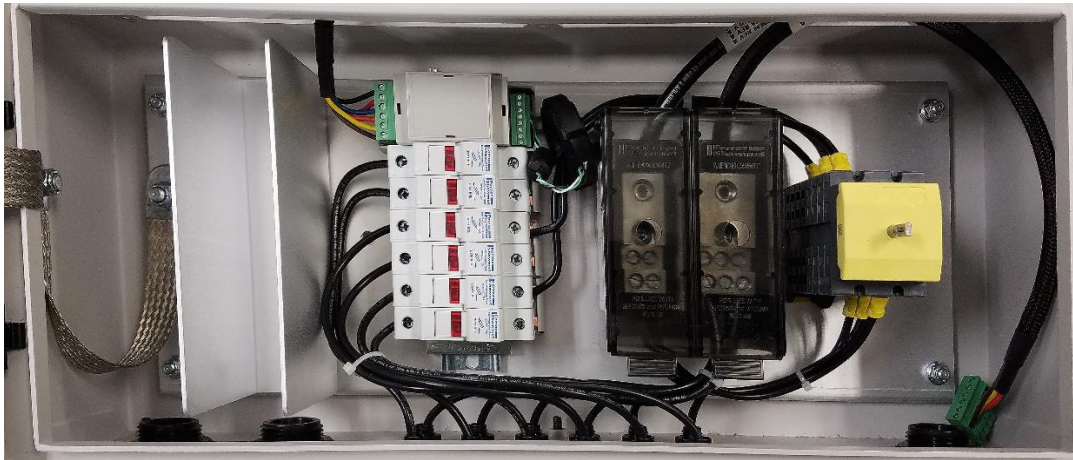
The ground-referenced Combiner utilizes 6 "touch-safe" string fuses on the positive leg of each string, the 6 negative String legs are not fused. The combined positive legs are connected internally to DC2 (T7) on the DC2/DC3 interconnection board. The combined negative legs are connected internally to DC COM (T8) on the DC2/DC3 Interconnection Board.

Floating Combiner
The 30PVF and 30PVF+S Inverters utilize an IMI circuit for the detection of ground faults. Describing the operation of this fault detection circuit is beyond the scope of this quick start guide, however, like the GFDI circuit described above, an IMI-detected ground fault on DC COM is a lock-down fault requiring a site visit to clear.

Figure 7: Internal View of Floating Combiner

The floating Combiner utilizes 6 "touch-safe" string fuses on the positive leg of each string, and six (6) additional touch-safe fuse for each negative string leg. The combined positive legs are connected internally to DC2 (T7) on the DC2/DC3 interconnection board. The combined negative legs are connected internally to DC COM (T8) on the DC2/DC3 Interconnection Board.

Arc-Fault Detection
A PV arc-fault detection circuit is is utilized on both the ground-referenced and floating Combiners. A detected arc-fault is a lock-down fault condition, requiring a site visit to clear.

SECTION 5.0 MODBUS INTERFACE

Inverter Configuration, Control and Monitoring
All 30PV / 30PV+S Inverters 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 and/or port voltage, current and power levels. The remaining registers control system configuration, modes of operation, output power levels, and other parameters of the Inverter. These registers are both readable and writable.

As noted above: 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 Inverter's aux power input.

Application Specific Register Settings
The Modbus interface is used to establish minimum and maximum allowable DC2 and DC3 (+S option 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, DC2 maximum voltage (default = 1000 Vdc) should be updated from the factory default and saved to flash to reflect your PV Array operating voltage range. 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.

DC3 minimum voltage (default = 200 Vdc) and DC3 maximum voltage (default = 1000 Vdc) should be updated from the factory default to reflect your battery voltage operating range: (+S option only).

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 the Inverter'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 Inverter will safely revert to its default IDLE operating state, ensuring no unplanned power transfer occur.

The 30PV factory defaults support the North American grid interconnection standard of 60 Hz, 480 Vac, 3-Phase. The physical connection is 3-wire Delta. **50 Hz grid standards are NOT supported.**

The Inverter'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 Inverters shipped from Ideal Power have AC1, DC2 and DC3 (+S only) 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 below.

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 – GPWR (+S only)
66	p1_ramp_rate	int16 R/W	500	If p1_control_method = 0x0402: real power and reactive power ramp rate (+S only)

67	p1_throttle_port	int16x R/W	0x0000	If p1_control_method = 0x0001: throttle port DC3 = 0; throttle port DC2 = 1 (+S only)
68	p1_real_pwr_setpt	uint16 R/W	0	If p1_control_method = 0x0402: real output power setpoint (+S only)
69	p1_reactive_pwr_set pt	uint16 R/W	0	If p1_control_method = 0x0402: reactive power setpoint while voltage-following (+S only)
70	p1_power_factor_set pt	uint16 R/W	0	If p1_control_method = 0x0001: power factor setpoint, otherwise unused
74	p1_reactive_disable	int16x RW	0x0000	If p1_control_method = 0x0001 (NET): 1 = automatic power factor correction is disabled
89	p1_apparent_power_ limit	uint16 RW	3200	Soft VA Limit (port maximum is 32 kVA) (+S only)
90	p1_current_limit	uint16 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 (+S only)
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 (+S, DC3 only) 0x0002 - MPPT 0x0301 - DC CURRENT (+S, DC3 only) 0x0401 - DC POWER (+S, DC3 only)
194	p3_ramp_rate	uint16 R/W	50	IDLE – not applicable NET – not applicable DC CURRENT – factory default current ramp rate = 5 A per second (+S only) DC POWER – factory default power ramp rate = 500 W per second (+S only)
195	p3_throttle_port_ setpt	int16x R/W	0x0000	When p3_control_method = 0x0001: throttle port AC1 = 0; throttle port DC3 (or DC2) = 1 (+S only)
196	p3_current_setpt	int16 R/W	0	If p3_control_method = 0x0301: DC Current setpoint (+S only)
197	p3_power_setpt	int16 R/W	0	If p3_control_method = 0x0401: DC Power setpoint (+S only)
135	p2_pv_start_tod_set pt	uint16 R/W	0	PV/MPPT start time in minutes from midnight (1 to 1440)
136	p2_pv_stop_tod_ setpt	uint16 R/W	1440	PV/MPPT stop time in minutes from midnight (1 to 1440)
137	p2_pv_restart_ setpt	uint16 R/W	300	PV restart timer (in seconds)
138	p2_pv_min_v_ setpt	uint16 RW	100	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 DC2 (+S, DC3) operating voltage – for safety, set to expected PV or battery Vdc maximum
142 /206	p2_v_pn_min_limit	int16 RW	100	minimum port DC2 (+S, DC3) operating voltage – for safety, set to expected battery Vdc minimum on DC3, set to -20 on DC2 to eliminate nuisance under-voltage faults during PV startup
153 /217	p2/p3_power_limit	uint16 RW	3200	DC2 (+S, DC3) Soft Power Limit (maximum 32 kW)
154 /218	p2/p3_current_limit	uint16 RW	600	DC2 (+S, DC3) Soft Current Limit (maximum 60 A)

160 /224	p2/3_port_status	int16x RO		b0 = 1: DC2/DC3 power limiting (+S only) b1 = 1: DC2/DC3 current limiting (+S only) b2 = 1: Throttling AC1 (+S only) b3 = 1: Throttling DC3/DC2 (+S only)
173 /237	p2/3_v_pn	int16 RO		DC2 (+S, DC3) voltage, positive to negative (common)
176 /240	p2/3_v_pg	int16 RO		DC2 (+S, DC3) voltage, positive to ground (earth)
177 /241	p2/3_v_ng	int16 RO		DC2 (+S, DC3) voltage, negative to ground (earth)
185 /249	p2/3_power	int16 RO		DC2 (+S, DC3) power, negative sign indicates power flow sinking/into port; unsigned indicates power flow sourcing/out of port (+S, DC3 only)
186 /250	p2/3_current	int16 RO		DC2 (+S, DC3) current, negative sign indicates current flow sinking/into port; unsigned indicates current flow sourcing/out of port (+S, DC3 only)

All of the registers' decimal addresses noted 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 30PV+ S "IPC_Modbus_Register.xls" for the complete Modbus register list and data formats.

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 Inverter 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 not utilized in 30PV stand-alone applications.

Table 3: Other Pertinent Registers

Addr	Register Name	Format	Factory Default	Comments
258	reconnect_timer_set_0	uint16 R/W	320	Reconnect timer_0 setpoint (320 seconds)
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
266	remote_reset	uint16x R/W	0x0000	Set b15 =1 to reset Inverter
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				IEEE1547a over/under voltage and over/under frequency setpoint registers

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

For example, in +S 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.

Watchdog Timer
IPWR recommends that our watchdog timer function be utilized in all production 30PV+S systems deployed by your Company. This ensures that if a system controller fault occurs, or a communications failure occurs between your system controller and the 30PV+S Inverter, 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 Inverter will be automatically set to an idle state. The Inverter 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 between Inverter power ports. These port-specific operating modes are collectively known as "Control Methods" and include MPPT, GRID POWER (GPWR), NET, and IDLE. There is a dedicated Control Method register for each port of your Inverter.

Note that the 30PV supports a limited number of Control Methods: MPPT (DC2), NET (AC1), and IDLE (DC2 and AC1). Once the +S option is installed, additional Control Methods are enabled. The Control Methods supported in the 30PV+S are summarized below.

AC1 Control Methods
- IDLE (0x0000) – factory default
- NET (0x0001)
- GPWR (0x0402) (+S only)

DC2 Control Methods
- IDLE (0x0000) – factory default
- MPPT (0x0002)

DC3 Control Methods (+S only)
- IDLE (0x0000) – factory default
- NET (0x0001)
- DC Current (0x0301)
- DC Power (0x0401)

Control Method Restrictions

IDLE Control Method (0x0000)
If a port is not in use, it should be set to the IDLE Control Method. As noted above, all 30PV Inverters are shipped with IDLE as their factory default for safety purposes.

NET Control Method (0x0001)
To move power between the PV array on DC2 and the grid (30PV only) AC1 must always be set to the NET Control Method.   When AC1 = NET, the desired output power factor is defined via a separate Modbus setpoint register.

Note that all 30PV+ S Inverter configurations require that one and only one port MUST always be configured to NET.

MPPT Control Method (0x0002)

The Maximum Power Point Tracking ("MPPT") Control Method is utilized on port DC2. Note that DC2's pv_start_time register 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): (+S, AC1 only)
The GRID POWER Control Method enables the integration of Solar + Storage, and is primarily utilized for PV smoothing and firming applications. The GPWR Control Method requires that DC3's Control Method be NET, while DC2 is set to MPPT.

In this configuration, the Inverter responds to all grid-fault conditions in a manner that is compliant with UL 1741 and IEEE 1547A. Output real (kW) and reactive power (kVar) setpoints enable fixed power export to the grid.

DC POWER Control Method (0x0401): (+S, DC3 only)
The DC POWER Control Method enables constant power charging of the battery from the PV Array, and is primarily utilized for PV shifting, and/or firming applications.   The DC Power Control Method requires that DC2's Control Method be MPPT, while AC1 must be set to NET. Any excess power available from the PV Array (available PV Power is greater than the DC3 power setpoint) will be exported to the grid.

The desired DC3 power setpoint must be negative to enable charging from the PV array. Changing the DC3 power setpoint to positive (un-signed) enables the summed export of PV power + fixed battery power; to the grid.

In this configuration, the Inverter responds to all grid-fault conditions in a manner that is compliant with UL 1741 and IEEE 1547A.

DC CURRENT Control Method (0x0301): (+S, DC3 only)
The DC CURRENT Control Method enables constant current charging of the battery from the PV Array, and is primarily utilized for PV shifting, and/or firming applications.   The DC Current Control Method requires that DC2's Control Method be MPPT, while AC1 must be set to NET. Any excess power available from the PV Array (available PV Power is greater than the DC3 current setpoint) will be exported to the grid.

The desired DC3 current setpoint must be negative to enable charging from the PV array. Changing the DC3 current setpoint to positive (un-signed) enables the summed export of PV power + fixed battery current; to the grid.

In this configuration, the Inverter responds to all grid-fault conditions in a manner that is compliant with UL 1741 and IEEE 1547A.

SECTION 7.0 POWER FLOW SCENARIOS

Initial System Configuration: PV on DC2 (30PV / 30PV+S); Battery on DC3 (30PV+S)
1. Connect external 24 Vdc power supply, and/or 480 Vac grid connection.
2. Connect to 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 p2_v_ll_min_limit = – 20 Vdc to minimize nuisance trips of the Inverter due to low PV voltage
   c. Set p2_pv_min v_setpt = minimum PV Array startup voltge – system will not attempt MPPT start until this voltage is sensed
   d. Set p2_v_ll_max_limit = maximum PV Array open-circuit voltage (Voc) – system will shutdown automatically if this voltage is sensed
   e. Set p3_v_ll_min_limit = minimum battery voltage at lowest SoC – system will shutdown automatically if this voltage is sensed (+S only)
   f. Set p3_v_ll_max_limit = maximum battery voltage at lowest SoC – system will shutdown automatically if this voltage is sensed (+S only)
3. Power down external 24 Vdc power supply and/or open AC disconnect.
4. Connect Battery to DC3 *(+S only)* and PV array to DC2 as detailed in the Installation and Operations Manual.
5. Apply power to all ports (close external AC and DC Disconnects).

Autonomous PV Mode (30PV)
Once configured as detailed below, the 30PV will behave as a traditional PV String Inverter and will operate autonomously: requiring no external system controller supervision. Autonomous configurations require that 30PV Control Methods be set to MPPT (DC2) and NET (AC1). PV start and PV stop times must also be set, along with minimum and maximum PV Array working voltages. Lastly, an autostart feature must be enabled to ensure that the 30PV will run autonomously.

<u>AC1 = NET / DC2 = MPPT / DC3 = NA (30PV) or IDLE (30PV+S)</u>
- This scenario supports autonomous PV operation, and closely resembles PV String Inverter functionality.
- Configure the Inverter as follows:
  1. Update Port 1 (AC1) registers.
     a. Update register 'p1_control_method' to 0x0001 (NET).
  2. Update Port 2 (DC2) registers.
     a. Update register 'p3_control_method' to 0x0002 (MPPT).
  3. Set the pv_start and pv_stop registers to desired times (minutes after midnight), and set sys_op_mode = 1. The Inverter will now start and stop autonomously.

PV Firming / Demand Management (+S only)
AC1= GPWR / DC2 = MPPT / DC3 = NET

- This energy flow example utilizes a PV Array or PV simulator on DC2 with a high-power battery on DC3.
- 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).
- Changing the GPWR 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 Inverter 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.
        i.   1500 = 15 kW of real power exported to AC1
        ii.   Update register 'p1__reactive_pwr_setpt' to desired reactive power level for grid export.
        iii. 0 = 0 kVar of reactive power exported to AC1, or
        iv.   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_start_time' to appropriate start time window (in minutes)
  3. Update Port 3 (DC3) registers.
     a. Update register 'p3_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.

NOTE: 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. Set the DC2 soft power limit higher, once batteries are below max SoC.

Constant Battery Charging by PV

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, The PV Array satisfies the DC3 charge requirement and excess PV power is exported to the grid.
- If the available PV resource is < charging setpoint, the battery will be charged at the rate = available power from PV

NOTE: The DC Current Control Method may be utilized in lieu of the DC Power Control Method.

Constant Battery Discharging + PV 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 DC3 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.
- Modify the PV Firming/Demand Management configuration example above to suit this use case.

NOTE: Setting DC2 to the IDLE Control Method disables the PV Array, effectively creating a two Port Battery Converter.

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 your 30PV or 30PV+S. 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 Inverter 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 8: IPWR Modbus Tool Screenshot
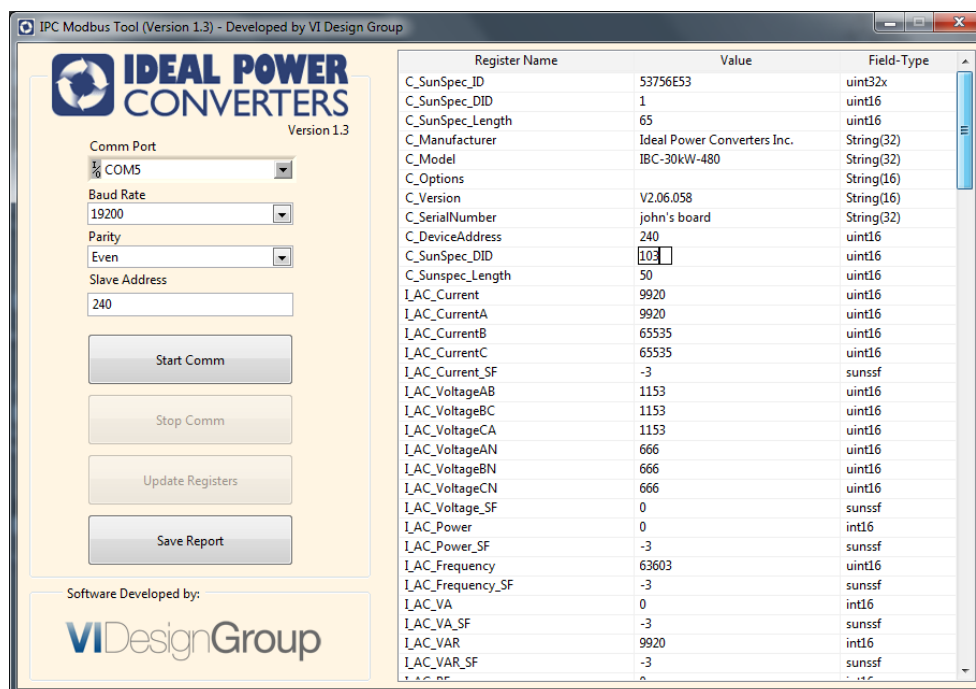
The Modbus Tool should be installed on your lab PC. Installation instructions are provided with the Modbus Tool executable. A 30PV / 30PV+S Modbus Quick Start Kit, which includes a USB to RS485 Modbus Adapter is also available. Contact Ideal Power for Quick Start Kit pricing and availability. This Tool does not work with the Modbus TCP interface, it is RTU only.

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