APPLICATION NOTE 502

Providing Backup Power with 30B3 and 125B2 Power Conversion Systems

1.0 PURPOSE AND SCOPE

The 30B3 and 125B2 Power Conversion Systems (PCS) by Ideal Power (IPWR) support both voltage-following (grid-tied), as well as voltage-forming (microgrid/off-grid) operation. When used in standalone microgrid applications, the AC1 power port will form a nominal 60 Hz / 480 Vac 3-phase output, supporting real, as well as reactive microgrid loads up to their nominal nameplate ratings of 30 kVar or 125 kVar. In voltage-following applications, the AC1 port will source or sink power into a utility interconnection, with the same AC characteristics as described above.

Supporting both modes of operation at a customer site delivers greater value than traditional grid-tied only systems. Typically, the PCS operates in voltage-following mode, sourcing or sinking power to and from the grid, utilizing a large battery as a DC energy source. Collectively, such systems, comprised of PCS, batteries and controllers, are known as Energy Storage Systems (ESS). If the utility grid fails, the ESS is dynamically re-configured to voltage-following mode, enabling backup support of facility critical loads, a new customer value-stream. This application note provides hardware, control recommendations and utility interconnection considerations for using a 30B3 or 125B2 PCS for backup power applications.

2.0 SAFETY CONSIDERATIONS

This application note should be used in conjunction with other product and safety documentation provided by Ideal Power. The intended audience is engineering and lab personnel familiar with high-voltage/high-power systems and the general safety issues related to the wiring and use of 3-phase AC electricity, battery systems, and PV energy sources.

Additionally, this document does not purport to make recommendations regarding conformance with applicable electrical codes. A qualified electrical engineer should be engaged to do detailed system design and ensure conformance with applicable codes. Refer to the product datasheet for detailed specifications upon which to base any detailed designs. Lastly, this document assumes that the reader is already familiar with the 30B3 and/or 125B2 Modbus Interface, and is comfortable using that serial interface to configure, monitor and command PCS operation.

3.0 PCS CAPABILITIES

- After a utility grid is lost, the PCS may be commanded to form a 3-phase grid at the standard AC voltages of 480 Vac, 400 Vac, 380 Vac at either 60 Hz or 50 Hz.
- Although the PCS does operate in both voltage-following, and voltage-forming modes at all voltages and grid frequencies noted above, it is only certified to the North American standard of 480 Vac at 60 Hz.
- While in voltage-following mode, the PCS utilizes a 3-wire delta output to export or import power to/from the grid all power is made phase leg to phase leg.
- While in voltage-forming mode, the PCS utilizes a 4-wire wye output to support unbalanced loads.

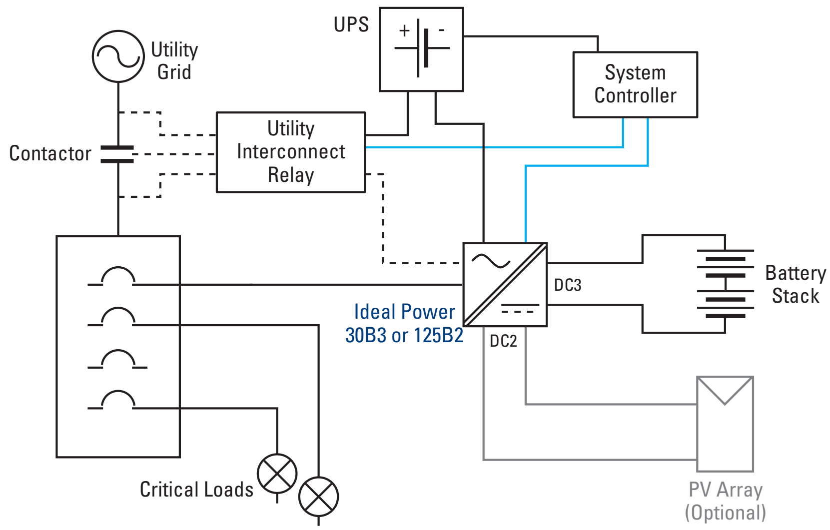
4.0 SYSTEM LAYOUT & COMPONENTS

A backup power system is typically comprised of nine primary elements as shown in Figure 1. Note this conceptual schematic neglects standard circuit safety devices such as disconnects. An electrical engineer should be engaged to do the detailed system design and ensure conformance with applicable electrical codes.

1. Primary utility grid
2. Utility line isolation device, typically a 3-phase contactor
3. Utility interconnect relay
4. Uninterruptible power supply (UPS)
5. Critical loads electrical panel
6. Ideal Power's 30B3 or 125B2 PCS
7. Battery System
8. PV Array (optional, 30B3-4DF model only)
9. System Site Controller

FIGURE 1: Backup Power with 30B3 or 125B2

Blue lines indicate software communication; dotted lines indicate hardware control or sensing



Utility Isolation Device – Contactor

The contactor is used to electrically disconnect and reconnect a segment of the local facility's electrical system from the main utility grid. It will separate and isolate the electrical subpanel that is wired to the facility's critical loads. It is controlled by the utility interconnection relay. Note that an intermediate control relay and low-voltage power supply may be required at this interface.

Utility Interconnection Relay

In a grid-tied only application of the ESS, the IPWR PCS handles conformance with the interconnection and safety requirements in accordance with its UL1741 listing. This includes anti-islanding provisions which prevents the PCS from energizing a dead electrical grid. No interconnection relay is required in such voltage-following only applications. However, to support back-up power applications, the PCS must to be freed of that responsibility, allowing it to energize the dead grid, but only at the local facility level.

To support backup power applications, the utility interconnection relay and contactor are added to the system design. The relay is responsible for managing conformance with utility interconnect requirements such as IEEE1547 near the Point of Common Coupling ("PCC") where it will issue a grid disconnect signal if the grid goes outside code mandated voltage and frequency limits.

Common utility interconnect relays include:

SEL-547	www.selinc.com/products/547/
Basler Electric BE1-11i	www.basler.com/Product/BE1-11i-Intertie-Protection-System

The utility interconnection relay controls the contactor and senses the voltage on both sides of the contactor. Broadly, it should be programmed to operate on the following logic:

- If the contactor is closed, the relay senses the grid voltage and will open the contactor when the grid goes out of the mandated voltage/frequency range.
- If the contactor is open, the relay senses the grid voltage and load bus voltage and will only close the contactor when both of these two conditions are met: the grid voltage has been in range for at least five minutes (per IEEE 1547) and the load bus is not energized.
- Some relays such as the SEL-547 include a sync check function which can close the contactor if grid voltage and load bus voltage are in phase and synchronized. This function should be disabled to avoid closure on coincidental synchronization. Connecting a utility grid to the PCS while it is grid-forming may damage the PCS.

Local Utility Interconnection requirements

Although IEEE1547 is a common interconnection standard, utilities across the US may adopt and enforce variations of it. Furthermore, utilities will typically stipulate validation and test requirements for an interconnection involving a relay and contactor scheme. This may require reports from the relay manufacturer and in-person commissioning witness tests by a utility personnel or other authorized representative.

In some cases, a secondary redundant relay has been required. Ideal Power highly recommends engaging a utility interconnection representative as early as possible in the process of designing a project to determine local utility interconnection requirements.

Uninterruptible Power Supply

The UPS is required to sustain power to the utility interconnection relay, system controller, PCS and any low-voltage contactor control power during the short outage between loss of the utility grid and formation of the backup grid by the PCS.

Critical Loads Panel

These are defined by the end user and should never exceed the nameplate rating of the PCS (30 kW for the 30B3 or 125 kW for the 125B2). Note that the UPS used for the system controller and utility interconnection relay should be integrated with the critical loads to maintain charge on the UPS.

Ideal Power PCS

With the support of a battery system, and optional PV array, the Ideal Power PCS will form a 3-phase grid on its AC1 port and support critical loads. It effectively "back-feeds" the critical load sub-panel, while the external islanding switchgear and contactor ensure grid safety (contactor confirmed open). The AC1 Control Method must be set to VCO. Note that the move from voltage-following to voltage-forming is not "blinkless." The PCS must be reconfigured and restarted by the system controller, resulting in power outages of several seconds.

Battery System

Stores electrical energy and allows bidirectional DC power flows to charge the battery from the grid or discharge the battery to the grid as desired. Usually incorporates its own battery management system along with DC contactors to handle self-protection. The battery should be connected to the DC3 bidirectional power port, and DC3's Control Method must be NET.

PV Array (Optional with 30B3-4DF model only)

PV should be connected to the DC2 port, which must have its Control Method set to MPPT. Note that the 30B3 is capable of creating a microgrid without PV but it must always have a battery attached in order to operate as a voltage-forming device.

Site System Controller

The system controller is responsible for reading and managing the overall state of the system to know the state of the utility grid and command the PCS into grid forming, backup power mode when necessary or transition back to the utility grid when appropriate.

5.0 OPERATION AND CONTROL SEQUENCE

The following sequences of operations are indicative samples and are not comprehensive.

Loss of Grid

1. The utility voltage or frequency goes out of acceptable range.

2. The interconnection relay senses this voltage/frequency excursion and triggers the contactor to open.

3. The load bus goes dead. The converter will go offline.

4. The site system controller receives a signal from the relay that the utility grid is out of range and confirmation that the contactor was opened.

5. The system controller re-configures the PCS enabling grid forming, and 4-wire wye.

6. The load bus is energized and backup power mode is active. The previous steps 4 and 5 together result in a short power outage (<4s 30B3; <8s 125B2) before re-energization.

7. The load will be automatically supported and will draw down battery energy.

Off-grid Operation

- If PV is connected to DC2 (30B3-4DF only applications), it will contribute to supporting the critical load, and will charge the battery whenever the available PV resource is greater than the loads. PV should be curtailed if the battery reaches its maximum state of charge (SoC).
- If the battery SoC reaches its minimum, the system controller should disable the converter to protect the battery from damage. This will immediately drop support of all critical loads.

Return of Grid

1. At some time during backup power mode the utility grid returns.

2. The interconnection relay waits the required 5 minutes ensuring the grid remains within range and then sends a ready-signal to the system controller.

3. The system controller receives the ready-signal and disables the PCS grid forming mode

4. The load bus goes dead.

5. As soon as the load bus goes dead the relay will close the contactor. This sensing and transition back to the grid typically results in a brief power outage less than two seconds.

6. The PCS is commanded by the site contoller to return to voltage-following mode and synchronizes to the grid shortly thereafter."

PCS Commands

The following sequence of commands are used to enable voltage-forming on the Ideal Power PCS for a standard North American grid output at 480 Vac / 60 Hz. These commands are detailed further in the 30B3 and 125B2 Quick Start Guides.

	Register ID	Register Name	Value	Notes
1	521	user_stop	1	Stop converter
2	428	system_op_mode	0	Auto-start disabled
3	304	p3_control_method	1	Set DC3 to NET
3	100	p1_port_type	0x0104	Wye, 4-wire connected, grid-forming
4	104	p1_control_method	0x0502	Set AC1 port to AC VOLTS, VCO
5	105	p1_param1_set_point	277	Set line to neutral to 277 Vac (480 Vac line-to-line)
6	106	p1_param2_set_point	6000	Set output frequency to 60 Hz
8	520	user_start	1	Start converter

Notes regarding PCS voltage-forming operation:

- The AC1 connection to the PCS includes a ground-referenced neutral wire connection for a 3-phase 4-wire wye support of the critical loads panel. This 4th wire enables support for unbalanced 3-phase loads wired to the panel.
- The time to form a backup power grid after the loss of the utility grid is <4s (30B3) and <8s (125B2), and is limited by the signal command and communications processing between the site master controller and the PCS. The PCS is not capable of supporting a "blinkless" or seamless pickup of loads when the utility grid is lost.
- The PCS has a voltage droop response and will sag approximately 10% at full load.
- The PCS is capable of picking up a load from a dead AC bus when it initializes the grid Note however that some tuning may be required of internal PCS control parameters depending on the characteristics of the electrical system and loads. It is highly recommended that a detailed critical load analysis be completed, prior to designing and installing the backup power system.

Please contact Ideal Power at support@idealpower.com if you have any outstanding questions regarding this Backup Power Application Note.

For additional questions, please contact:
Support@idealpower.com

WWW.IDEALPOWER.COM
4120 Freidrich Lane Suite 100 Austin TX 78744