Backup Power

Application Note 503

Backup Power Utilizing the Stabiliti™ PCS

Purpose and Scope

The Stabiliti™ Power Conversion System (PCS) is typically utilized for energy storage system (ESS) applications: sourcing or sinking energy into a utility grid connection. This mode of operation is known as voltage-following. Once disconnected and isolated from the grid, one or more Stabiliti's can also act as a grid-forming resource, providing backup power to select building loads. Two versions of the 30 kW Stabiliti offer backup capability: the 30C is a dual port AC/DC system, the 30C3 is a multiport AC/DC/DC system, which enables the direct integration of Solar + Storage. In bright-sun conditions, a multiport Solar + Storage 30C3 solution will dramatically extend backup power runtimes, compared to a battery-only 30C-based implementation. Lastly, note that some form of energy storage is always required for backup power: a PV-only system cannot voltage-form.

The Stabiliti's may be AC paralleled (up to 8: 240 kVA AC nameplate) while in grid-forming mode to support larger backup power demands. Whenever the grid fails, a group of Stabiliti's will first isolate themselves from the utility, then rapidly and automatically re-configure themselves to voltage-forming mode. This application note provides hardware, control recommendations and utility interconnection considerations for using one or more Stabiliti PCS' to support backup power applications.

The Stabiliti supports worldwide grid standards. Its factory defaults for North America grid interconnection are 480 Vac / 60 Hz. For grid interconnections outside of North America, both frequency and voltage are programmable to directly support 400 Vac / 50Hz or 415 Vac / 50 Hz grids. At these lower interconnection voltages, available AC power for both gird-following and grid-forming modes must be derated to 25 kVA. As an alternative, the PCS can be operated at 480 Vac / 50 Hz, providing full 30 kVA rating to a 400 Vac grid connection, via an external transformer.

Safety Considerations and Disclaimer

This application note should be used in conjunction with other product and safety documentation provided by CE+T America. 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 power systems, 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 local code requirements. 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 Modbus interface, and is comfortable using that interface to configure, monitor and command PCS operation.

Stabiliti™ Series PCS Backup Capabilities

- Once installed with appropriate external islanding hardware and controls introduced later in this document, the PCS will move automatically from voltage-following to voltage-forming modes without site controller intervention.
- While the transition to backup power with the PCS is essentially seamless, it is not an uninterruptable power supply and should not be depended upon to support highly sensitive equipment. The system described herein does not conform to UL 1778 (Uninterruptible Power Systems).
- While in voltage-following or voltage-forming mode, the PCS utilizes a 3-wire delta output: all power is made phase leg to phase leg when exporting or importing power from the grid.

- While in voltage-forming mode, the PCS requires an external transformer to support unbalanced phase-to-neutral and/or supporting loads at voltages other than 480 Vac.
- The PCS can operate at 400 Vac / 50 Hz or 480 Vac / 60 Hz to support different grid interconnection standards. Supporting other grid interconnect voltages, such as 208 Vac or 600 Vac requires an external step-down or step-up transformer.
- The PCS must have appropriate and sufficient energy storage to enable voltage-forming mode. PV-only based microgrids are NOT supported.

System Layout and Components

A backup power system is typically comprised of ten primary elements, as shown in Figure 1. Note for simplicity, this conceptual single-line does not indicate or call-out standard circuit safety devices such as AC or DC Disconnects, circuit breakers and/or fusing. Additionally, only one PCS is represented in the single-line, however up to eight systems may be paralleled to support larger backup load requirements.

An electrical engineer should be engaged to do the detailed system design to 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. Backup loads electrical subpanel
5. CE+T America Stabiliti™ 30C3 Series PCS (up to eight in parallel, only one shown)
6. Battery System
7. PV Array
8. System Site Controller
9. 24 Vdc Uninterruptible Power Supply (UPS)
10. Transformer

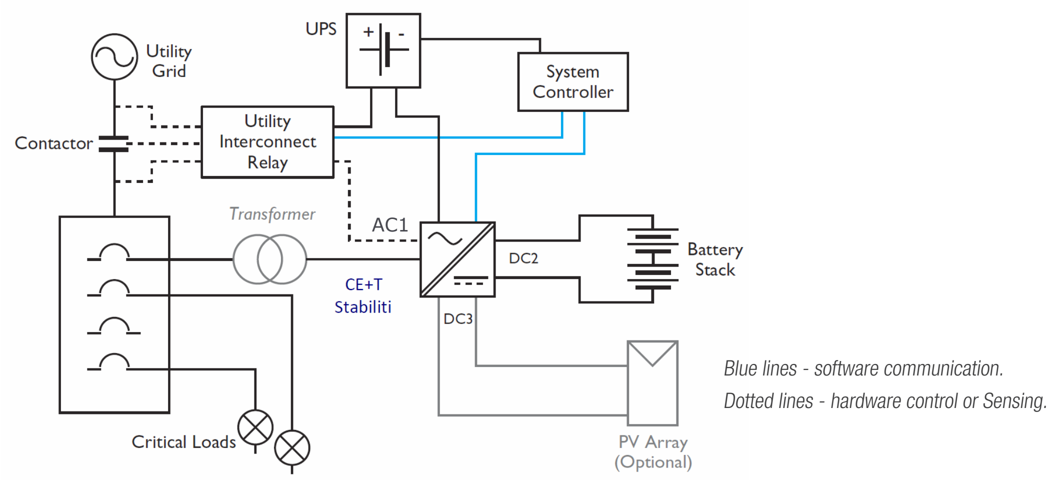

Figure 1. Backup Power with Stabiliti™ Series PCS

Primary Utility Grid – Interconnection Requirements

Although IEEE1547 is a common interconnection standard, utilities in North America and elsewhere often adopt and enforce variations of it, such as IEEE1547SA Rule 21 (now required for California interconnection). Furthermore, utilities will typically require different and more complex validation and test requirements for a distributed energy resource ("DER") interconnection that is capable of voltage-forming, as compared to DER systems that only voltage-follow. The utility may also dictate the specific brand and configuration of both the Isolation Contactor and Interconnection Relay required for interconnection approval. This may require reports from the relay manufacturer and in-person commissioning witness tests by a utility personnel or other authorized representative.

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 backup loads. It is controlled by the utility interconnection relay.

Utility Interconnection Relay

In a grid-tied only application of the ESS, the Stabiliti™ PCS handles conformance with interconnection and safety requirements in accordance with its UL listings. This includes anti-islanding provisions which prevents the PCS from energizing a dead electrical grid. An interconnection relay or contactor is typically not required for voltage-following only applications in North America. This may differ for other jurisdictions.

However, to support backup power applications, the PCS must have its anti-islanding algorithms disabled, allowing it to energize in-building wiring, specifically wiring that is connected to the backup loads subpanel.

For such 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 (contactor open) signal if the grid goes outside code mandated voltage and frequency limits. Contactor open and close command signals from the relay are also mirrored and transmitted to the PCS which reacts accordingly and automatically to transition from grid following to grid forming mode of operation. Multiple Stabiliti's may share a single contactor and interconnection relay.

Common utility interconnect relays utilized in North America 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 AC voltage on both sides of the contactor. In broad terms, it should be programmed to the following logic:

- If the contactor is closed, the interconnection relay senses grid voltage on all 3-phases and will immediately open the contactor when the grid goes out of a 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 these conditions are met: the grid voltage has been in range for at least five minutes (per IEEE 1547) and the critical load bus is either synchronized with the grid or not energized.
- In some cases, a secondary interconnection relay may be required for redundancy purposes. CE+T America highly recommends engaging a local utility interconnection representative as early as possible in the process of designing rapid backup solutions to determine utility interconnection requirements for voltage-forming equipment.

Backup Loads Subpanel

Prior to installation and commissioning, backup loads to be supported during grid-forming operation should be identified and their load profiles, including in-rush currents characterized. These loads must never exceed the nominal AC nameplate rating of the group of paralleled Stabiliti's.

CE+T Power Solutions Stabiliti™ Series PCS.

Once the contactor is confirmed open by the islanding relay the paralleled PCS' will immediately form a 3-phase grid on their AC port to provide power to the backup load panel. The external islanding switchgear and contactor are responsible for ensuring grid safety (contactor confirmed open; ensuring that no grid backfeed occurs). This rapid transfer capability is supported only when the AC1 Control Method is set to FPWR (Facility Power): rapid backup is NOT supported when AC1's Control Method is set to GPWR (Grid Power), or to NET.

Battery System

Stores electrical energy and allows bi-directional DC power flows to charge the battery from the grid and/or PV; as well as discharging the battery to the grid as desired. Usually incorporates its own Battery Management System "BMS" along with DC contactors to handle self-protection. The battery must be connected to the DC2 bidirectional power port and DC2's Control Method must be NET.

PV Array

PV is typically connected to the DC3 port, which must have its Control Method set to MPPT. Note that the PCS is capable of creating a microgrid without a PV array, but it must always have a battery attached to enable voltage-forming mode of operation.

Site System Controller

The system controller is responsible for monitoring and managing the overall status and health of the ESS, as well as the PCS operating state: which may be either voltage-following mode or voltage-forming mode. The system controller operates in concert with the interconnection relay and contactor to ensure that the ESS operating mode is appropriate and safe, given grid conditions.

Uninterruptible Power Supply

The 24 Vdc UPS is required to sustain power to the system controller, PCS, utility interconnection relay, and any low-voltage contactor control power during the brief transition between loss of the utility grid and formation of the backup grid by the PCS. A second high-voltage AC UPS may be required to support other site equipment, such as communications and network equipment. Note that all UPS' should be powered by the backup loads subpanel to ensure that its batteries remain charged during a prolonged grid outage.

Transformer

Based on the type of loads to be backed up, a transformer is generally required between the PCS' and the backup load subpanel to ensure proper voltage matching. Multiple Stabiliti's may share a common transformer.

Operation and Control Sequence

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

Loss of Grid

1. All paralleled PCS' should have a common set of control methods AC1 = FPWR; DC2 = NET; and DC3 = MPPT (if PV array is utilized).
2. The utility voltage or frequency goes out of acceptable range.
3. The interconnection relay senses this excursion and signals the contactor to open, this same control signal (known as "island") is also interconnected to all PCS's, who then prepare themselves for grid-forming operation.
4. The PCS' receive a 2nd control signal "island_ack" from the interconnection relay, which confirms that the contactor is open and the grid isolated. In response to this control signal, all PCS' immediately transition to grid-forming mode.

5. Although the move to grid-forming described above happens very quickly and completely independent of the site controller, the site controller should periodically poll the interconnection relay and PCS to register overall system status, as following or forming.
6. The backup loads will be automatically supported after the PCS' move to voltage-forming from voltage-following. As noted, the Stabiliti is not a UPS. This transition generally occurs within 80 to 100mS, and the lights may blink.

Voltage-Forming Operation

1. Any PV tied to port DC3 will contribute to supporting the backup load subpanel and will charge the battery whenever the available PV resource is greater than the loads. The system controller will monitor and curtail the PV whenever the battery reaches its maximum state of charge (SoC). This curtailment is easily made via a "softpower" command to the DC3 port on each PCS.
2. If the battery SoC reaches its minimum, the system controller should disable/stop the converter from voltage-forming to protect the battery. Doing so will immediately shutdown all backup load support. As an alternative, the system controller should curtail loads, prior to battery depletion, if such control capabilities are available.

Return of Grid

1. At some point during voltage-forming mode/load support, the grid returns.
2. To meet UL1741 safety requirements, the interconnection relay will wait five minutes to ensure the returned grid remains stable within acceptable voltage and frequency ranges. It then waits until the voltage, frequency and phase are synchronized on the backup load subpanel and utility side of the contactor. Upon phase synchronization the interconnection relay triggers the contactor to close using the island signal, which is also sensed by the PCS. Natural variations in the phase may result in a delay of several seconds (typically less than ten seconds) before synchronization occurs.
3. As the contactor closes, the PCS transitions to grid following mode. Unlike the transition to grid-forming described above, there is typically no blink or momentary loss of power on grid return.
4. The PCS will resume grid-following operation and power transfer as it had been commanded prior to the grid outage.

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