Energy Storage Systems

Application Note 602

Energy Storage Systems Utilizing the Stabiliti™ PCS

Purpose and Scope

The Stabiliti™ Series 30 kW bidirectional Power Conversion Systems (PCS) are designed to support commercial and industrial energy storage system (ESS) applications. This Application Note provides an overview of key ESS components, and the high-level systems design guidance presented is applicable to both systems deployed in North American as well as worldwide.

The Stabiliti is offered with either one or two DC power ports, both of which may be interconnected to solar photovoltaics (PV), batteries or other energy storage technologies such as flywheels or super-caps. The 30C model is a dual port (AC/DC) PCS typically paired with a battery. The 30C3 model is a multiport (AC/DC/DC) PCS that is typically used in Solar + Storage applications. Alternatively, the 30C3 can support two independent batteries. Although they share a common enclosure and hardware platform; the 30C cannot be field upgraded to a 30C3.

An ESS has been traditionally composed of three primary components: a bidirectional PCS, a battery, and an energy management control system. The Stabiliti™ Series 30C3 PCS offers a compelling fourth component to the ESS: direct integration of solar into the ESS value-stream. Please note that multiple 30C or 30C3 systems may be easily paralleled to support higher AC nameplate applications, for simplicity this document and its related single-line drawings reflect an ESS based on a single Stabiliti.

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 electricity, battery systems, and PV energy sources. 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 our product datasheets for detailed specifications upon which to base any detailed designs.

Overall Energy Storage System

The primary and secondary components of an ESS are described here. An indicative, generic single line diagram follows but does not include all components listed.

PCS: the PCS controls power flows on-demand between an AC electrical system, a battery, and optionally PV. The PCS incorporates low-level self-protection and grid-protection features as required by UL and IEEE for North America grid interconnection. Certification to international standards is pending.

Battery: stores electrical energy and supports bidirectional DC power flows to charge the battery from the grid; or discharge the battery to the grid as desired. When the battery is utilized with the 30C3, equipped with PV, additional power flows are made available: the battery can be charged from PV; and/ or PV + battery power can be "summed" and exported as firm power to the grid. Most modern battery technologies incorporate their own battery management system (BMS) along with DC contactors to handle low-level self-protection.

Energy Management System (also known as system or site controller): Usually contained within an embedded computer, the EMS monitors and controls the PCS; batteries; and other in-building energy resources such as smart meters. With knowledge of building energy use, the EMS makes economically-driven decisions on power charging/discharging and provides an interface for customers and operators.

Electrical Meters: One or more precision power meters are often employed to monitor different segments of the site's electrical system to provide building energy use intelligence for the Energy Management System. Revenue grade metering may be necessary on multiple legs including the ESS to thoroughly reconcile building usage and energy production for government or utility energy storage incentive programs.

Personnel and Circuit Protection Devices: This may include fuses, circuit breakers, surge protection devices, disconnect switches, emergency stop buttons and grounding systems to protect humans, equipment, and the grid from electrical malfunctions and dangers.

Control Panel: Houses a collection of electronics and communications devices to support the ESS such as power supplies, uninterruptible power supplies (UPS), meters, relays, communications adapters, Ethernet switches, modems and the EMS.

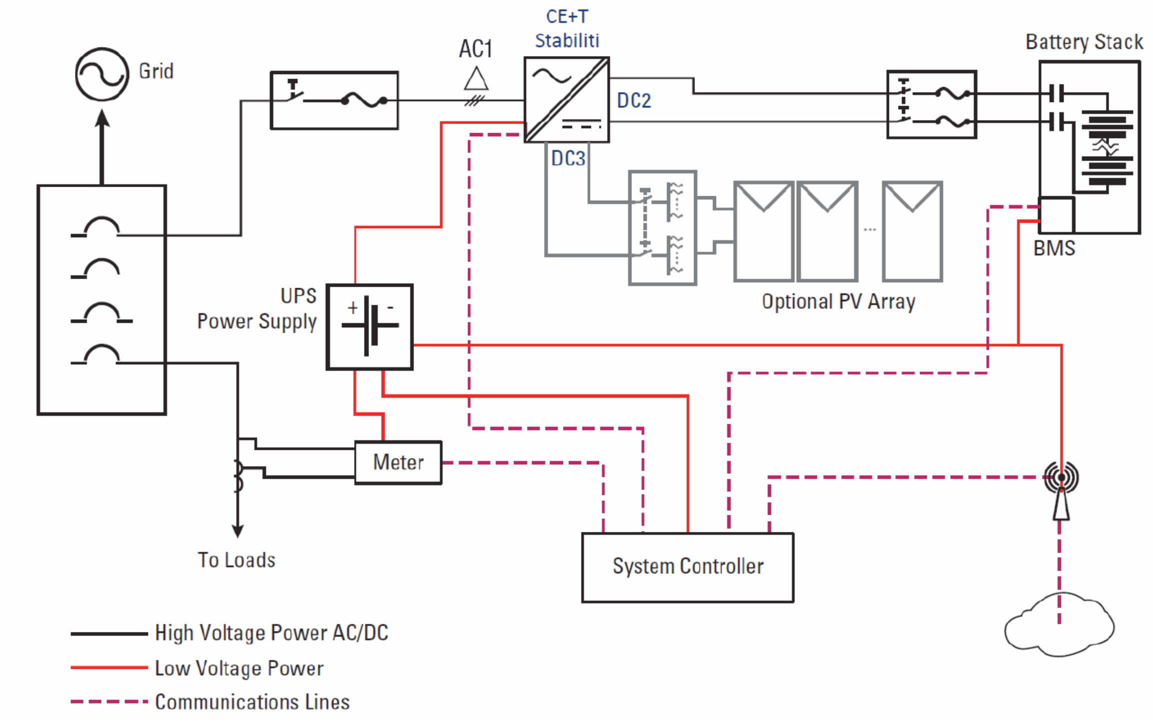

Figure 1. Energy Storage Systems Schematic Example

ESS Electrical Interfaces

AC Power Connections

- The Stabiliti™ is electrically connected to the utility grid through the AC1 port in a 3-phase, 3-wire delta configuration. Bare wires are landed at built-in power terminal blocks.
- The Stabiliti™ operates at 480 Vac, 60 Hz for North America applications.
- For applications outside of North America, the Stabiliti™ will typically operate at 400 Vac / 50 Hz. When operating at this lower AC line voltage, the unit's AC output is derated to 25 kVA.
- For lower AC line voltages such as the 3-phase, 208 V standard found in North America, an external step-down transformer is required. Refer to Application Note 102 for guidance on transformer design.

AC Circuit Protection & Switchgear

- The Stabiliti has integral AC overvoltage surge protection built-in at the AC terminals. Overcurrent protection is handled within the PCS through software-managed rapid fault detection and shut down.
- Hardware-based overcurrent protection must be provided separately, typically by way of an external fused AC disconnect. Specific external disconnect requirements may vary by jurisdiction: circuit disconnect functionality, manual or automatic, is not provided by the PCS.

DC Power Connections

- The Stabiliti™ is electrically connected to one or more battery stacks through a 2-wire, unipolar connection at the DC2 battery power port. Utilizing an external PV Combiner, the solar is connected through a 2-wire, unipolar connection at the DC3 power port.
- Both DC2 and DC3 utilize bare wire connections which are landed at built-in terminal blocks.
- The PCS requires a minimum PV or battery bus voltage of 200 Vdc and can accommodate up to 1000 Voc, with full 30 kW DC power nameplate rating available above 500 Vdc. Recommended PV string voltages range from 600 Vmp to 900 Voc; with similar ranges recommended for battery systems.
- Below 500 Vdc, both DC2 and DC3 are current limited to 60A. For example, a 380 Vdc battery at 60A can be charged or discharged at approximately 23kW maximum.
- Multiple parallel battery stacks may be required for increased energy capacity in the ESS. In this case an external battery combiner box will be required, including applicable overcurrent protection.

DC Circuit Protection & Switchgear

- The PCS is galvanically isolated between the AC and DC ports thereby allowing the DC2 and DC3 connections to be either ground referenced or floating. Note that that both ports must share the same wiring configuration: ground referenced or floating.
- The Stabiliti has integral ground fault detection built in at the DC terminals. Depending on the wiring configuration selected, the appropriate ground fault detection method will be utilized: GFDI for ground-referenced DC circuits and IMI for floating DC circuits.
- Overcurrent protection is handled within the PCS through software-managed rapid fault detection and shut down for both DC2 and DC3.
- DC voltage limits (minimum/maximum) as applicable to an individual battery, and/or PV operating voltage ranges may be configured within the PCS software which will treat them as fault limits.
- DC2 and DC3 disconnection functionality, manual or automatic, is not provided by the PCS. Hardware-based overcurrent protection must be installed on both DC2 and DC3 port, typically by using a pair of external fused DC Disconnects. Specific protection requirements often vary by locale, check with your local authority having jurisdiction (AHJ) to ensure compliance with local safety standards.

Control Panel

System Controller

- The system controller hosts the Energy Management System software that generally provides the economic decision making for the ESS operation. It is typically an industrial computer running a Linux or Windows Embedded operating system, or alternatively a Programmable Logic Controller (PLC). Note: he EMS is not part of the Stabilti PCS, it is a separate component.
- The system controller requires communications interfaces with all the other primary and secondary hardware components for monitoring, data capture and analysis and control. The PCS physically connects to the controller by way of a serial RS485 link or Ethernet, utilizing Modbus RTU or Modbus TCP respectively as the communications protocol.

- Battery Management Systems (BMS) will generally connect to the controller by way of a CAN bus interface, but other BMS communications may also be available.
- Electrical meters will also require a communications link to the system controller: RS485 Modbus RTU is the most common meter interface with Ethernet Modbus TCP also available.
- Remote connectivity over the Internet is a critical feature for an ESS for monitoring, troubleshooting and technical support as well as firmware updates. This may be accomplished through a local LAN or a cellular Internet connection and may require additional hardware for a wireless connection.

Low Voltage Power Supply & Control

- The Stabiliti™ draws its auxiliary supply power first from the AC grid when present or from an external 24 Vdc power supply when the grid is unavailable. Most of the other hardware devices such as the battery BMS and controller will also require an external power supply to operate. Standardizing on 24 Vdc power may be possible for all devices including low voltage control of relays or contactor coils.
- A small backup UPS is recommended to supply power to all the devices in the case of a grid loss or other fault conditions.
- The PCS includes an input for an emergency stop circuit.

Mechanical and Environmental Requirements

- The 30C and 30C3 weigh approximately 140 pounds (64 kilograms). and are vertically mounted on an included wall bracket. The PCS enclosure is rated NEMA 3R for outdoor applications.
- System cooling is provided by forced convection drawn from underneath and vented out the top front of the enclosure. For outdoor installations, clearance of 36” is required underneath the PCS and 18” in front for sufficient air flow. If the PCS is installed indoors, clearance underneath may be reduced to 18”. If the ambient temperature exceeds 50°C additional active cooling of the PCS may be required.
- Batteries will require additional racking: many lithium battery packs from leading vendors are designed to fit in a standard 19” equipment rack. Both DC and AC disconnect switches, when mandated by electrical code, must be mounted to be visible and accessible on or near the outside of the ESS for safety.
- Check with the battery manufacturer as to their cooling requirements. Source other components to be rated for rugged environmental conditions.
- Other ESS components such as the system controller will require enclosures and applicable environmental protection whether for indoor or outdoor applications. The ESS may be enclosed in one overall package or installed as separate pieces.

Energy Management Software System

PCS Supervision

- Interfacing with the Stabiliti™ requires building a software driver to communicate by Modbus, polling relevant monitoring registers for data on regular intervals along with functionality to read and write relevant registers to configure, control and monitor the unit.
- Modbus interfacing includes interpretation of data types and scaling factors. At the next higher level of abstraction, it is necessary to understand and build broader functions and control loops to process logical state transitions and control methods of the converter.
    - The PCS provides status information along with basic electrical data for monitoring voltage, current, frequency and power. Operating set points and configurations may be set including power limits, ramp rate and control methods whether current or AC and DC power control. During regular operation the PCS may be dynamically commanded to change power or current level. Please refer to the Stabiliti™ Quick Start Guide and Modbus Register Map for full details of available data and commands.

- For ongoing operations and maintenance of the system it is important to incorporate PCS fault-handling logic, logging of data and events and support for an remote Telnet, FTP and web browser links to facilitate both troubleshooting and remote firmware updates to the system.
    - The PCS includes some ability to do automatic fault handling and reset. Active, ongoing fault conditions are indicated while historical and transient fault conditions are logged with a timestamp on the most recent faults logged.

Battery Supervision

- Similar to the PCS, the battery management system will also require a software driver to poll for data and send commands then higher-level functions to manage transitions and operate within applicable limits such as voltage limits, pre-charge, contactor closure and state of charge.
- For ongoing operations and maintenance of the battery system it is important to incorporate battery fault-handling logic, logging of data and events and support remote updates if offered by the battery supplier.

Energy Storage System Supervision

- The control software will have to establish and manage the system-level state machine and applicable coordination between the PCS, battery and other connected assets. This will include operating sequences such as commanding the PCS appropriately to ensure overcharging or deep discharging of the battery never occurs.
- In addition to the primary ESS components, such as the battery and the PCS, other hardware components and assets will also require software monitoring and control: energy meters are a prime example.
- The primary value of the Energy Management Software is to make decisions to charge or discharge based on economic factors such as reducing peak power demands, effectively shifting or reducing loads on the local utility and storing excess solar energy for use at a later time. Typically, this will require building software intelligence for tracking and predicting loads and local generation and responsiveness to utility signals.
- Compared to a 30C based ESS, a grid-connected 30C3 supports energy flows between all three power ports. The system controller must regularly decide and control where to direct available solar energy and battery energy. This requires slightly more complicated control decision logic, compared to a 30C-based ESS, but will help achieve the possible economic advantages of combining storage with solar.
- The 30C and 30C3 also operate in microgrid (voltage-forming) mode, with appropriate external islanding switchgear; providing power to a backup load panel is easily accomplished.
- Remote monitoring and control of the system is essential to address long-term O&M needs, build customer engagement and provide continuous improvements. This part of the control system will typically include a web browser-based user interface, mechanisms for operator alerts and remote diagnostics and historical data analytics. Information security is a critical element of any Internet connected system and appropriate firewalls, authentication and encryption should be employed.

Additional ESS Configurations

The following additional configuration options are provided in brief for high-level system considerations.

Backup Power

- An ESS may be called on to provide back-up power in the case of an outage. Unlike traditional PV Inverters, both the 30C and 30C3 Converters are capable of rapidly moving from a grid-following state to a grid-forming state. Note that the 30C and 30C3 are not blink-less UPS's: the transition to grid-forming typically requires 80 to 100mS.

- Enabling backup operation requires adding an external utility interconnection relay and external 3-phase contactor to handle the disconnection/connection from the grid. These components ensure that the PCS cannot back-feed the grid, creating an in-building electrical island where the ESS serves a backup load panel.
- The transition is handled automatically by way of direct interaction between the PCS and a utility interconnection relay/contactor. The system controller will also require a communication link and software interface with this interconnection relay as an important asset to the system.
- The PCS has a 3-phase, 3-wire delta connection, which limits it to directly supporting 3-phase balanced loads. For 3-phase unbalanced loads external transformers are necessary to support line to neutral loads. Refer to Application Note 102 for guidance on transformer design.

Multiple Parallel PCSs

- The Stabiliti™ may be operated in parallel connected to the same bus on both the AC grid side and DC battery side if desired for a particular AC nameplate requirement. The PCS has appropriate filtering on AC and DC sides to handle electrical dynamics on both the AC and DC busses.
- To take advantage of the built-in ground-fault detection of the PCS and reduce or eliminate need for DC battery combiners it may be worthwhile to employ separate DC2 busses for individual Converters.
- Multiple Converters are capable of collectively forming a grid for back-up power or a microgrid without the need for external synchronization links. However, controlling multiple Converters requires independent data collection and commands for each separate unit. The PCS does not inherently accommodate a master/slave parallel control scheme.

Microgrids

- • A microgrid is defined as a segment of an electrical system, often an individual facility, which has the ability to island (disconnect) from the main utility and self-sustain for an extended period of time using on-site generation resources. The CE+T America PCS is capable of acting as the central grid former in a microgrid however the Energy Management System will play a more complex role to manage a microgrid. Discussion of Stabiliti™ operation and application within microgrids is beyond the scope of this document.

Disclaimers and Intellectual Property Notice

This document is provided “as is” and CE+T America Inc. (CEA) makes no representations warranties, expressed or implied, with respect to the information contained herein. CEA has made reasonable efforts to ensure the accuracy of information herein at the time of publication; however, information is constantly evolving and CEA does not purport the information provided is correct, comprehensive or exhaustive. This document is for informational purposes only; you should not act upon information without consulting CEA or its authorized distributors.

For additional questions, please contact:

tech.support@cetamerica.com

www.cet-america.com
300 Shawnee Drive, Suite 700, Suwanee, GA. 30024