

## Application Note 203

# Battery Precharge Sequence for Stabiliti™ Series PCS

### 1.0 PURPOSE AND SCOPE

This application note details the battery precharge control sequence for use with Ideal Power's ("IPWR") Stabiliti™ Series of power conversion systems (PCS) (Model Numbers: 30C and 30C3). Implementing this precharge control sequence as described below minimizes battery in-rush currents, prolonging the life of system components in both the PCS and battery. IPWR strongly recommends that this precharge sequence be implemented in your controller system software. This document assumes that the reader is already familiar with the Stabiliti™ Modbus Interface.

### 2.0 Overview

This application note details how to precharge at PCS DC2 or DC3 port. Battery in-rush currents can be minimized by matching battery stack voltage with PCS DC port voltage prior to electrically connecting the two systems. This can be achieved in two ways:

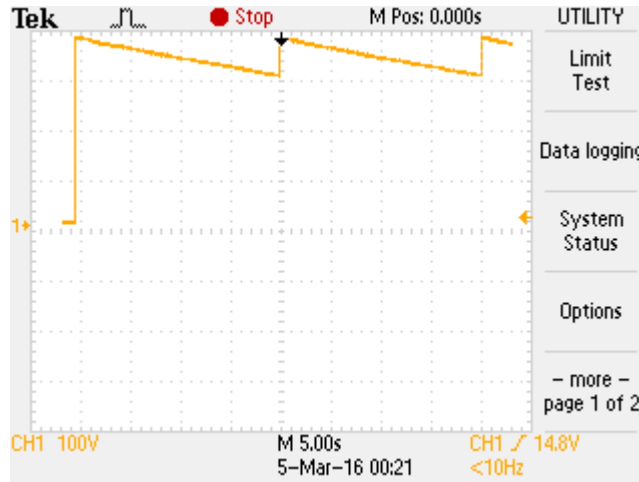
1. **Method 1** involves precharging DC2 or DC3 port line capacitors from the utility AC grid through port AC1.
2. **Method 2** involves precharging DC2 port line capacitors from a PCS 24 Vdc auxiliary power supply using the integral precharge circuit. This method is particularly useful for microgrid blackstart situations where no AC grid is present.

**Method 1** uses the AC Power (GPWR) Control Method, while the DC port is configured with Control Method NET. The DC precharge target voltage is set by configuring the max DC voltage of the applicable port to ~5% above the target battery stack voltage. If the battery is connected to the DC2 port, configure and control the settings associated with that port starting at Modbus register 129. If the battery is connected to the DC3 port, configure and control the settings associated with that port starting at Modbus register 193.

With battery contactors open, execute the code sequence detailed in Section 3.1 of this document. The PCS will quickly charge its DC output line capacitors to the target voltage, and then trip off, due to the preconfigured over voltage limit condition. The DC output voltage will then slowly decay for 20 seconds, at which time the PCS will restart and again charge the DC line caps to the target voltage noted. The 20 second timeout is the converter's default system automatic restart count-down timer for internal fault conditions such as over voltage faults. This cycle will continue indefinitely and produce a saw-tooth wave form as shown in Figure 1.

The precharge sequence exploits this recurring waveform: command the site controller to monitor both voltages and close the battery contactors once the PCS DC port voltage approximately matches the battery voltage. This is best done during the period of voltage decay. Note that a small voltage imbalance is not an issue. Once the battery contactors are closed, the saw-tooth immediately stops, and you will observe a fixed voltage on the PCS DC port.

**Figure 1: PCS DC Port Precharge Output Waveform, relative to Earth Ground**



**Method 2** employs a precharge circuit, built into the Stabiliti™ PCS. This is a new feature of this Series not previously seen in past Ideal Power products. The PCS 24 Vdc auxiliary power supply is used to precharge the line capacitors therefore this method may be used in conjunction with a small UPS for microgrid blackstart situations where no AC grid is present. With only a small 24 Vdc UPS, the PCS can be cleanly connected to a high voltage battery and then form a 3-phase voltage to bring up a microgrid. The precharge circuit only services the DC2 port therefore a battery should be connected to this port to take full advantage of this capability.

The DC precharge target voltage is set by configuring the voltage window  $\pm 5\%$  around the target battery stack voltage. The DC2 port is not directly controlled during this method of precharging.

With battery contactors open, execute the code sequence detailed in Section 3.2 of this document. On command, the precharge circuit will drive a low current flow to the DC2 line capacitors and automatically bring up the voltage to within the specified voltage window within one minute. The system will then hold the DC2 terminal voltage within the window using a loose control loop. During this period, command the site controller to monitor both voltages and close the battery contactors once the PCS DC2 port voltage approximately matches the battery voltage. Note that a small voltage imbalance is not an issue. Once the battery contactors are closed you will observe a fixed voltage on the PCS DC2 port and the precharge circuit may be disabled.

If there are more than one Stabiliti[™] PCS connected to the same DC battery bus there are additional considerations for precharging. One integral precharge circuit is only capable of precharging one PCS therefore all precharge circuits present should be configured the same and used simultaneously to perform the precharge of the bus. Precharge control will fault if the bus does not reach 200V within 10 seconds therefore precharge circuits should be initiated at the same time to ensure the minimum is achieved in time.

### 3.0 Control Sequences

#### 3.1 Method 1: Utility AC Grid to DC Precharge

*The sequence below is written to reflect the commands and Modbus registers for a DC2 port precharge with applicable DC2 commands provided subsequently in brackets.*

1. Set register 141, p2\_v\_pn\_max\_limit (205, p3\_v\_pn\_max\_limit) to the target battery stack voltage +5%.
2. Set register 142, p2\_v\_pn\_min\_limit (206, p3\_v\_pn\_min\_limit) to -20.

*This configuration prevents the under voltage limit from immediately causing a fault when the precharge sequence is launched. A negative value is used to handle possible negative readings of the nominally zero disconnected voltage. The PCS measurement system accommodates negative and floating voltages and when disconnected may float slightly around 0 Vdc.*

3. Set register 129, p2\_control\_method (193, p3\_control\_method) to 0x301 (decimal 769), the DC Current Control Method.
4. Set register 65, p1\_control\_method to 1, the NET Control Method.
5. Set register 132, p2\_current\_setpt (196, p3\_current\_setpt) to 20 for 2 A.
6. Set register 267, system\_op\_mode to 1: this command enables the PCS auto-start feature.

*The factory default for register 267 is 0 which enforces manual system operation. Manual operation requires that user\_start be set to 1 after each new Control Method assignment is made or after a fault is encountered. In the automatic mode, the PCS will transfer power immediately after a correct command is entered, and if a fault occurs, it will automatically countdown and restart after 20 seconds. This will achieve the desired saw-tooth voltage waveform.*

*This command to enable auto-start sets the DC current from the DC port to 2 A and will rapidly charge the internal capacitors. Once the targeted DC port voltage is reached the saw-tooth waveform as described above will result.*

7. When battery voltage and the decaying DC port voltage (decaying DC line capacitor voltage) approximately match, close your battery contactors. Note that upon completion of the countdown timer and system restart the PCS will begin charging the battery at 2 A unless you idle the ports immediately, as described below.
8. Set register 65, p1\_control\_method to 0 (IDLE Control Method).
9. Set register 129, p2\_control\_method (193, p3\_control\_method) to 0 (IDLE Control Method).
10. Restore register 267, system\_op\_mode to its original value. Restore register 141, p2\_v\_pn\_max\_limit (205, p3\_v\_pn\_max\_limit) to the maximum protection limit for the battery voltage. Restore register 142, p2\_v\_pn\_min\_limit (206, p3\_v\_pn\_min\_limit) to the minimum protection limit for the battery voltage.
11. Batteries and PCS now have voltages matched, all contactors are closed and charge/discharge power flows may now commence.

#### 3.2 Method 2: Integral Precharge Circuit

1. Set register 277, precharge\_hi\_lim to the target battery stack voltage +5%.
2. Set register 278, precharge\_lo\_lim to the target battery stack voltage -5%.
3. Initiate the precharge by setting register 275, precharge\_control to 1.

*This command will gradually charge the internal capacitors and can achieve 1000 Vdc within ~1 minute. Once the high precharge voltage limit is reached on the DC2 port, the voltage will be loosely controlled and begin to oscillate slowly in the window between the configured high and low limits.*

4. When battery voltage and the DC2 port voltage approximately match, close the battery contactors.
5. Stop the precharge by setting register 275, precharge\_control to 2.
6. Batteries and PCS now have voltages matched, all contactors are closed and charge/discharge power flows may now commence.

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#### **FOR ADDITIONAL QUESTIONS, PLEASE CONTACT:**

support@ideалpower.com  
WWW.IDEALPOWER.COM  
4120 Freidrich Lane, Suite 100 Austin, Texas 78744