

BATTERY MONITORING FEATURES IN ARGUS CXC SYSTEM CONTROLLERS AND PERIPHERALS



Power

Accurate data guides intelligent investment in backup power solutions - solutions that pay off.

Argus has devoted years of research and development to provide users with the most advanced monitoring and control capabilities for single or multiple lead acid battery strings within a DC power system. Effective monitoring and control of battery conditions can significantly increase the reliability and longevity of a communications power system and provide significant capital and operational savings.

1. OVERVIEW

Argus has dedicated several years of research and development to provide users with advanced monitoring and control capabilities for single or multiple lead acid battery strings within a DC power system. Effective monitoring and control of battery condition can significantly increase the reliability of a communications power system and provide significant operational and capital savings over the long term.

The Argus Cordex series of controllers (CXC) come in a variety of configurations including panel mount, rack mount, modular, and shelf-integrated models. Every CXC configuration is equipped standard with advanced software features. Optional Cordex “peripherals”, such as the Battery Monitor System, can also be easily installed as an add-on to provide additional monitoring capabilities.

Battery related features in the standard CXC software package include, but are not limited to:

- **Dynamic Charge Current Control:** Limits battery recharge current to a fixed value. Helps to prevent thermal runaway.
- **Battery Test:** Sets rectifier voltage low and performs safe discharge of battery through the connected system loads
- **Battery Capacity Prediction:** Calculates battery capacity after a discharge
- **Battery Runtime Prediction:** Estimated runtime based on current battery capacity and system load.
- **Temperature Compensated Float Voltage:** Increases charge voltage with battery temperatures below 25°C (77°F) and decreases charge voltage above 25°C (77°F), maximizing life and capacity of battery and helps prevent thermal runaway.
- **Battery Equalize:** Manual, automatic and periodic equalize charge modes. Optional Battery Current Terminate function to optimize the equalization interval.
- **Battery Boost Mode:** Offline, high-voltage battery charge mode with interlock safety feature
- **Battery Monitor System:** An add-on CXC peripheral which provides individual cell monitoring, temperature monitoring, and shunt monitoring for single or multiple battery strings.

These are just a subset of many features integrated into every standard CXC software package. The Argus Cordex series of system controllers provide many monitoring and control features that go well beyond historic expectations of simple power system set up and alarming.

Argus has integrated many of these features into the CXC series of controllers to help reduce the burden of additional monitoring costs for users. Site visits for hands-on battery condition monitoring and 3rd party monitoring devices are typical capital and operation expenditures. The CXC can help eliminate this additional expense beyond the cost of the basic power system controller.

Battery run time and capacity prediction can assist network engineers in determining future budgets for battery replacements as well as guaranteeing that specific site run time requirements are met.

Detailed battery monitoring and smart battery charge management is a must for any user to maintain complete reliability for their critical network equipment.

2. BATTERY SETUP

Algorithms have been developed by Argus to be non-battery specific; that is, they are not dependant on a specific battery manufacturer. **Argus battery monitoring is currently only available for lead-acid style battery models.**

Performance will vary from battery type to type so the algorithms have been developed to learn the characteristics of the battery and adapt. Even batteries of the same make and model will vary and as time passes batteries will age differently—this is due to many variables including time, temperature, number of discharges, severity of discharges, power quality and maintenance.

The user must first set up the type of battery (or batteries) used in the system from the “Configure Batteries” Menu. Reference Figure 1.

- **Capacity Rating:** The total capacity of a single battery string (or sum of total capacity from multiple battery strings) in Ampere-Hours. The AH rating is based on a 20-hour rate (C/20) and should be obtained from the manufacturer’s specifications if possible. This value will be used in calculations for charge current control and capacity estimation.

- **Capacity Calibration:** Allows the user to enter a value to effectively “calibrate” the battery capacity. This is necessary when batteries are first commissioned and whenever an independent test is done to measure the battery capacity.

- **Open Circuit Voltage:** Allows the user to set the open circuit voltage of battery. This value should be obtained from manufacturer’s specifications.

- **Peukert Number:** The Peukert number relates to the internal resistance of a battery and provides an indication (inversely) of the expected capacity; that is, a lower number (closer to 1.0) is better. This number can be entered in two ways. If the user has a Peukert number from the battery manufacturer, then it can be entered as a simple, one step numeric entry. If the Supervisor does not have a Peukert number, it must be calculated using the integrated calculator tool on the page. This multi-step process involves entering four numbers derived from battery manufacturer’s specifications. The CXC software manual has specific details on calculating Peukert numbers.

- **Temp Comp Slope:** Allows the user to enter the desired temp comp slope. This value should be obtained from manufacturer’s specifications.

- **Number of Cells:** Allows the user to enter the number of cells in the battery string. Typically (24) cells for a 48Vdc battery.

Battery Properties		
Capacity Rating	100.0	AH
Capacity Calibration	100	%
Open Circuit Voltage	51.36	V
Peukert Number	1.440	
Temp Comp Slope	2.50	mV/°C
Number of Cells	24	

Figure 1: Battery Properties Settings

3. CHARGE CURRENT CONTROL

The dynamic charge current control allows the user to set up a fixed maximum battery charge value, even when system is connected to a set of dynamic loads.

Charge Current Control is ideal for sites with generator backup for maximizing generator life and efficiency and minimizing fuel costs. The features can also be of benefit for systems with lower capacity battery disconnects.

Charge Current Control also prevents damage to the battery due to uncontrolled recharging and helps to prevent thermal runaway.

This feature requires that the battery properties have been filled out and also requires that a shunt is installed in the power system for accurate measurement of battery charge current.

- **Charge Rate Amps:** Allows the user to enter the maximum battery current permissible. The Charge Rate C/X field (see below) is automatically recalculated if this field is modified.
- **Charge Rate C/X:** Allows user to enter the charge rate. The field entry corresponds to a fixed factor (typically 5). The Charge Rate Amps field is automatically recalculated if this field is modified.

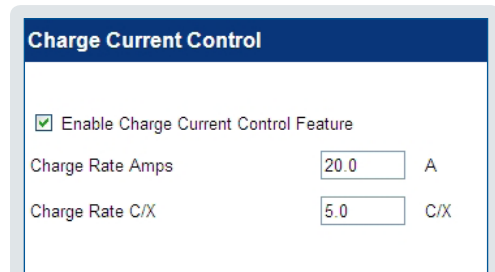


Figure 2: Charge Current Control Settings

4. RUN TIME AND CAPACITY PREDICTION

Using a combination of real time battery monitoring and battery tests, the CXC is able to provide a user with an estimated battery run time and current battery capacity prediction. The runtime prediction values are calculated based on the battery properties of the installed system, the load characteristics, low voltage disconnect settings, temperature and the current capacity of the battery.

The Battery Runtime value, as well as the Battery Capacity value, are displayed on the Battery Live Status page. These values are also accessible as signals for custom alarming of these conditions. Users can set up various alarming (relay contacts, SNMP traps, email notification, etc) should the values exceed a custom-set threshold.

These calculations are critical for understanding the current health of the installed batteries and to ensure proper runtime has been commissioned at the site based on current load and battery capacity.

4.1 Battery Monitor

Enabling the battery monitor allows for real time analysis of battery and system conditions. The monitor does require that the battery property information be entered by the user.

- **Load Type:** Allows the user to enter the type of load on the system: constant power, current or resistive. This is used for battery capacity calculations.
- **Disconnect Voltage:** This entry should be same value as the LVD setting. This value is critical for calculating battery runtime for the system during an AC outage.
- **Reset Battery Monitor:** The monitor should be reset when installing (or replacing) new batteries.

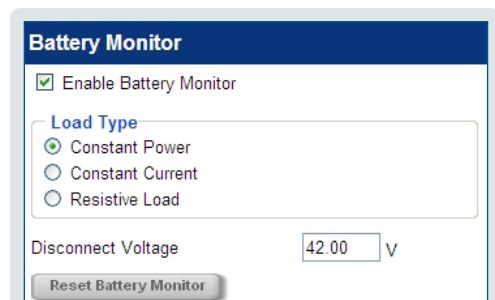


Figure 3: Battery Monitor Settings

4.2 Battery Test

The Battery Discharge Test is used to update the current battery capacity status. The test can be initiated manually, or be set up to run automatically. The Battery Test helps to ensure the current battery capacity is accurately shown.

During a Battery Test, the rectifier charge voltage is set to a (user-adjustable) value lower than a standard float voltage which initiates a battery discharge. The discharge current and voltage is constantly monitored to determine the current capacity for accurate battery health and runtime diagnosis.

- **BT Termination Voltage:** This menu item controls the termination (or end) voltage of the BT; +0.5V above Rectifier BT Voltage is recommended
- **Rectifier BT Voltage:** This menu item enables the Supervisor to set the Rectifier BT Voltage to the desired value during the test (mode). This setting should have a minimum of LVD + 1V.
- **Rectifier BT Timeout:** This menu item controls the maximum duration of the Battery Test.
- **Auto BT:** Allows the user to initiate automatic battery testing. The Interval value determines the number of days in between tests.
- **Remote BT:** This feature will force a transition to BT mode when a user-defined condition (custom alarm) is true. The custom alarm must be setup on the CXC and then selected from the drop down box on the Remote BT settings window.

Battery Test

BT Termination Voltage	47.00	V
Rectifier BT Voltage	47.00	V
Rectifier BT Timeout	8.0	Hrs
<input type="checkbox"/> Enable Periodic Auto BT		
Interval	365	Days
<input type="checkbox"/> Enable Remote BT		
Remote BT	Custom 1	

Figure 4: Battery Test Settings

4.2.1 Battery Test Limitations

Before the test can begin, at least one rectifier must be sourcing current, the battery must not be sourcing current and a discharge must not have occurred within the last 96 hours. For this purpose, a battery discharge occurs when the battery discharges to >3% depth of discharge (i.e., less than 97% of current capacity)

If a Periodic Equalize (EQ) Interval ends while a battery test is active, EQ will not be entered. An overlay will pop up to indicate that the Periodic EQ Interval will be restarted (EQ will not be entered until another Interval elapses). Battery Discharge Auto-equalize will be activated (if enabled) after the battery test to properly recharge the batteries.

Rectifier alarms that are a result of the battery test are suppressed.

4.2.2 Activity During Battery Test

When the battery is discharging, a Battery On Discharge (BOD) alarm will be active.

During a battery test, the mode symbol in the upper left corner of the LCD will be similar to the "Float"-mode symbol except that the letters "FL" will be replaced with a "BT".

During the test, the runtime hours will be accessible via the CXC. The runtime hours will reflect how long is remaining in the discharge test.

4.2.3 AC Failure During Battery Test

If the AC fails during a battery test, the test will be aborted. This will place the rectifiers into a state that will allow them to resume providing power to the load when AC returns. If the Runtime is being displayed, it will continue to update.

4.2.4 Addition of Rectifiers During Battery Test

If rectifiers are added to the system when a battery test is active, they will be placed into the same state as the other rectifiers; they will be placed into BT mode (for rectifiers that support BT mode), or placed into remote shutdown.

4.2.5 Cancelling the Battery Test

Battery Test Mode can be cancelled by pressing the System FL/EQ key. When the FL/EQ button is pressed during the test, an overlay will pop up to prompt for confirmation to abort the battery test. A message will appear, reading “BATTERY TEST ABORTED”.

The abort will be logged as an event with a text message: “BT mode aborted”.

4.2.6 Battery Test Completion

After the discharge, a message will appear with the capacity estimate to indicate the test is done. The format will be “BATTERY TEST COMPLETE: 96%”. This message will disappear when VAR is pressed.

The end of the test will be logged – when the terminal voltage is reached or a Timeout is reached – with the text message: “BT mode ended”.

The rectifier alarms that were suppressed will be reactivated when the rectifiers are turned back on.

The new capacity estimate can be displayed on the CXC at any time before, during, or after the test.

4.2.7 Other Conditions

- If the voltage falls below 47V (or 23.5V) by the time 3% DOD is reached, the test is aborted. The battery capacity will be set to 0%. This must be manually reset before the next battery test is initiated.
- The test will be terminated if any LVD begins a countdown for any reason.

5. TEMPERATURE COMPENSATION

The automatic battery temperature compensation (Temp Comp) will function with all Cordex series rectifiers (CXR) and controllers (CXC).

Temp Comp may be active in either float or equalize mode. Enabling of temperature compensation while in equalize mode can be accomplished from the battery configuration window.

Temperature inputs are available on the CXC for monitoring a lead-acid battery string. Temperature sensor readings can be displayed on the GUI in either Celsius (°C) or Fahrenheit (°F) scales.

The CXC will have the flexibility to display the breakpoints in voltage as well as temperature, also enabling them to be entered as voltage or temperature.

The detection of thermal runaway will be limited to a programmable Battery Over Temperature Alarm. This will enable the Supervisor to select a temperature that will trigger an alarm. This alarm could also be used to trigger a battery disconnect.

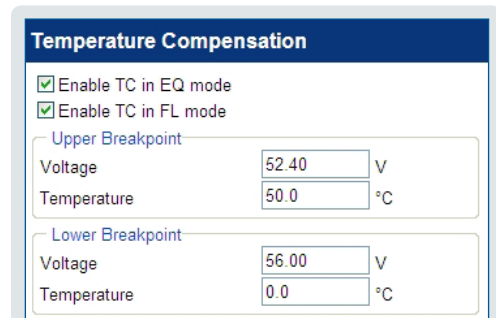


Figure 5: Temp Comp Settings

5.1 Theory

Battery life expectancy and performance is directly related to battery ambient temperature. The optimum temperature for battery operation is 25°C (77°F). Without compensation, battery life is seriously compromised at temperatures above 25°C, while battery performance is reduced below it.

Adjusting the battery's float or equalize voltage to correspond with temperature fluctuations will ensure maximum battery performance and life expectancy. With the CXC, this may be accomplished by using the software's built-in automatic temperature compensation function.

This function works by adjusting the system, every ten minutes, as the temperature changes and provides for a maximum voltage change of 0.1V over this interval.

While this may seem like a small voltage change, even if the battery had a temperature compensation slope as high as 5.5mV per °C, the CXC would still be able to track a temperature change in the battery of up to 4.5°C or 8°F per hour. Due to the large thermal mass of the battery string, even an extreme rise or drop in environmental temperature would be very unlikely to cause this kind of temperature change in the battery over a one hour period.

Temp Comp occurs at standard rates commonly referred to as slope-compensation settings. For maximum performance, it's important to match the battery slope compensation with the setting recommended by the battery manufacturer. This is not to be confused with slope regulation; which refers to the process of regulating current among a group of parallel-operating rectifiers.

The Temp Comp feature has programmable "breakpoints". These are the points at which Temp Comp will cease. Further temperature decreases or increases will NOT increase or decrease the output voltage. This protects the connected load from excessive voltage conditions. As Temp Comp is active in either float or equalize mode, breakpoints should be set with this in mind.

The Temp Comp feature also incorporates fail-safe circuitry to prevent it from driving the rectifier system to a voltage higher than is suitable for the load or battery.

5.2 Operation of Battery Temperature Compensation

The CXC can accommodate up to four sensors for lead acid battery temperature monitoring. If more than one probe is used and the temperature readings are within 5°C (9°F) of one another, the temperature readings will be calculated to an average. If the readings difference exceeds 5°C, it is assumed that thermal runaway is occurring in one battery string and the calculation changes from average to the highest reading. If any reading is suddenly outside the norm (i.e. shorted leads or open leads), that reading is discarded and the associated Temp Sensor Fail alarm is issued. The temperature calculation will then return to the average of the remaining sensors, or next highest reading.

Temp Comp has been programmed as a low priority item; all commands and operations will take precedence over Temp Comp. If a command is issued during a Temp Comp cycle, the cycle will be put on hold until the command is completed. If any operation is happening when the Temp Comp cycle occurs, the cycle will be put on hold until the operation is completed. Temp Comp will resume when the command or operation is completed.

The Temp Comp feature can be enabled or disabled in the CXC's Batteries menu.

6. BATTERY EQUALIZE MODES

Battery Equalize mode is a high voltage, short duration charge designed to ensure optimal battery life and performance. Equalize is used for two basic purposes: first, for providing a quick battery recharge after an AC power failure, and second, as a battery maintenance solution.

The user should always refer to the battery manufacturer’s recommendations for equalize charging.

The Cordex CXC controllers offer three methods of initiating an Equalize charge: Manual, Automatic and Periodic. The CXC also incorporates a Battery Current Terminate (BCT) Equalize function for termination of equalize mode based on the rate of charging.

6.1 Battery Charge Auto Equalize

Battery Charge Auto Equalize, also referred to as recharge equalize, can be used after a prolonged AC power failure, when the battery voltage has decreased to a low level.

Once the batteries have decreased beyond the auto equalize low voltage threshold, the CXC will enter an armed mode. When AC power returns, the system voltage begins to increase, which charges the batteries.

Once the system voltage increases to the high voltage threshold, the CXC enters the equalize mode and begins to equalize charge the batteries for a period specified by the user in the AUTO-EQ DURATION submenu. This is done to ensure the EQ duration is not effectively reduced by the time it takes to recharge the battery back to the nominal system voltage.

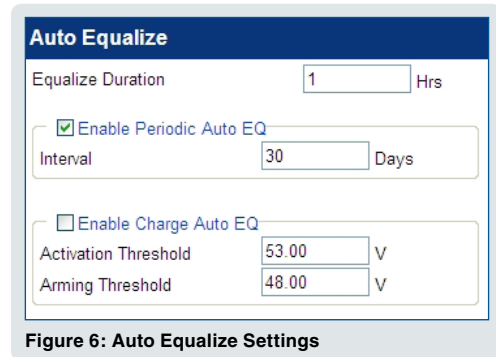


Figure 6: Auto Equalize Settings

6.2 Periodic Auto Equalize

Periodic Auto Equalize can be used for maintaining the long-term integrity of a battery string. Over time, individual battery cell voltages may vary greatly. As a result, to ensure that batteries remain in optimum condition, they should be equalize-charged at regular intervals. The CXC enables the user to program the time between automatic equalize charging of the battery string in the AUTO-EQ INTERVAL submenu.

6.3 Battery Current Termination (BCT) Equalize

The BCT Equalize feature provides an alternative method of ending EQ mode early to prevent over-charging of the battery, thus prolonging battery life. It will only be active when EQ mode is caused by a Battery Charge Auto Equalize.

Initially the CXC will use the Battery Charge Auto Equalize duration setting. As the battery is recharging, the rate of change of the recharge current decreases. Once the battery charge current falls below a programmable setting for 3 hours, BCT Equalize duration is activated and the batteries will now be kept in equalize for an amount of time equal to the BCT EQ Duration.

After this time, the system returns to FL mode. If the Charge Auto Equalize duration expires before the rate of change stays below the programmable setting for 3 hours, the CXC will enter FL mode and BCT Equalize is cancelled.

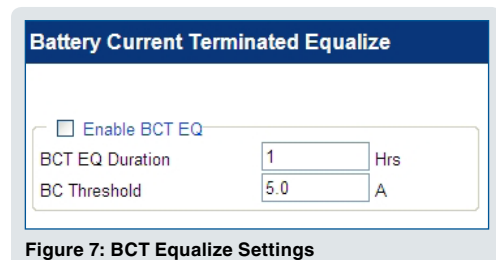


Figure 7: BCT Equalize Settings

6.4 Battery Boost Mode (BST)

This feature allows for an equalize charge of a battery at a higher voltage relative to the connected load. Activation is manual and certain conditions must be met to prevent damage to the load.

A custom alarm must be created to include all the desired factors that must be taken into account before activating BST mode. This mode will then only be permitted if the alarm is false.

Once activated, BST mode concludes with a timeout or whenever the status of the custom alarm is true and reverts to FL mode. BST mode can also be cancelled if the conditions that are required in order to activate BST mode have changed.

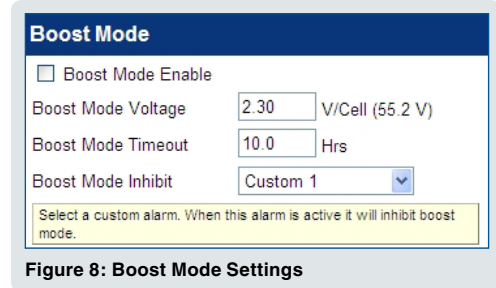


Figure 8: Boost Mode Settings

7. BATTERY MONITOR SYSTEM (BMS)

The Battery Monitor System (BMS) is a series of add-on devices used with a Cordex controller to provide extensive battery monitoring capability. The BMS is comprised of various CXC peripherals which communicate on a token ring network and then via CAN communications to the system controller. All monitored signals are accessible via the CXC GUI for detailed reporting, alarming and logging of battery conditions.

The BMS has the capability of monitoring individual cell voltages for multiple battery strings even for high voltage plants. The BMS can also determine cell temperatures, string voltage and can monitor shunts and current transducers. The BMS is an ideal solution for sites with a large number of battery strings, especially high DC voltage strings, where periodic manual cell voltage monitoring can be cost prohibitive.

7.1 Battery Monitor System Devices

The BMS is comprised of the following devices:

7.1.1 Battery Cell Monitor Controller (BCMC):

The brain of the BMS. This device communicates detailed battery status for up to four(4) battery strings to the central CXC controller via CAN communications. This CXC peripheral is typically installed into the main power system rack or enclosure in a 1RU rack mount panel.

Each battery string is monitored by a variety of “ring” devices, all daisy chained via standard 6-conductor telephone cables. Various ring devices are available for different monitoring requirements of the individual battery string.

The BCMC also has the capability for monitoring a single DCCT on each battery string input for current measurement.

LED indicators located on the front of the BCMC display individual battery string status, as well as the status of the BCMC device itself.



Figure 9: BCMC Front and Rear View

7.1.2 Battery Cell Monitor (BCM)

The Battery Cell Monitor (BCM) is a “ring” device which provides individual cell voltage and temperature measurement. The BCM is installed directly onto a battery block or cell via signal leads. The BCM kit includes 1/4” and 3/8” lugs for connecting to most standard battery terminals.

The BCM’s, and all other “ring” devices are interconnected via standard 6-conductor telephone wire with RJ-12 style connectors.



Figure 10: BCM's Installed on 12V Battery Blocks

7.1.3 Shunt Monitor (SM)

The Shunt Monitor (SM) is another “ring” device which interfaces into a standard 50mV shunt for monitoring of current.

Up to four (4) Shunt Monitors may be installed per battery string input for multiple measurements if desired, such as charge current and float current probes.

This device can also be used for shunt multiplexing in distribution bays as well.

The SM comes in the same size device as the BCM with multiple mounting options.

7.1.4 High Voltage Monitor (HVM)

The High Voltage Monitor (HVM) is another “ring” device used for determining accurate battery string voltages.

Up to four (4) HVM devices may be installed per Battery String Input. Multiple HVM's can be used for measurement of complete, or even partial string voltages.

The HVM comes in the same size device as the other “ring” devices with multiple mounting options.

7.1.5 BMS Monitoring

All system signals reported by the BMS are accessible via the CXC for implantation in alarming, email notifications and data logging. The CXC web interface also has a status indication page detailing battery system status.

The status indication screen gives a top-level overview of battery strings voltages and DCCT current readings from each of the four battery strings inputs from a specific BCMC peripheral.

The bottom half of the screen details specific information from an individual battery string. Additional battery string information is available by selecting the appropriate tab for the battery string required.

Under each battery string tab, the user can access:

- Total number of “ring” devices connected
- Min, max and average cell voltage summary
- Min max and average cell temperature summary
- Current and temperature readings from any Shunt Monitors installed
- String voltage and temperature readings from any High Voltage Monitors installed

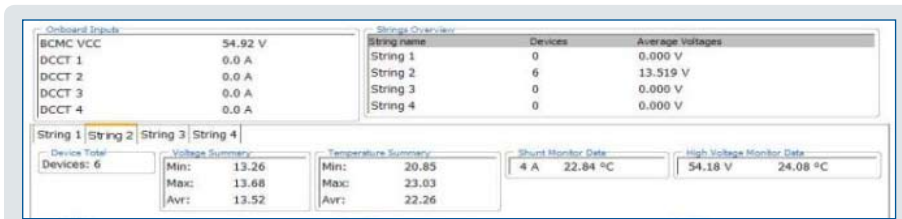


Figure 11: BMS System Overview from CXC Web GUI

In addition to the above, the status screen provides a bar graph chart detailing temperatures and voltages of all individual battery cell monitors connected. A high and low voltage alarm threshold can be setup within the CXC for alarm purposes and to show a visual indication of upper and lower alarm limit thresholds on the bar graph. If a cell voltage or temperature reading falls outside acceptable limits, the reading will display a bar in red, signaling the cell is out of tolerance.

Any individual cell reading (whether as an alarm or not) may be selected from the screen by the user, which will provide a local flashing LED indication on the BCMC device in question. This will assist on-site technicians with determining the physical location of the failed cell.

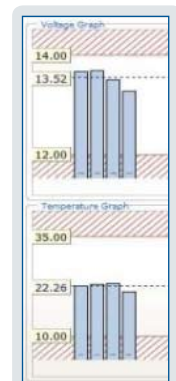


Figure 12: BCM Device Monitoring

ACRONYMS

AC: Alternating Current

BCM: Battery Cell Monitor

BCMC: Battery Cell Monitor Controller

BMS: Battery Monitor System

BT: Battery Test

BST: Boost Mode

CAN: Controller Area Network

CX: Cordex

CXC: Cordex Controller

CXR: Cordex Rectifier

DC: Direct Current

DCCT: "DC" Current Transducer

DOD: Depth of Discharge

EQ: Equalize

FL: Float

HVM: High Voltage Monitor

LCD: Liquid Crystal Display

LVD: Low Voltage Disconnect

SM: Shunt Monitor

SNMP: Simple Network Management Protocol