



Nuvation Energy G5 High-Voltage BMS

NUVG5 Product Manual

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The content in this document must be followed in order to ensure safe operation of Nuvation Energy BMS.



The G5 High-Voltage BMS is to be installed in a location with restricted access. Only **skilled persons** may install or service a system containing hazardous voltages that may be present when the system is energized.



Do **NOT** energize the system until all connections to the Stack Switchgear unit and Cell Interface modules have been made.



The wiring of the battery cell voltage and temperature sensing should be verified **before** connecting to the Cell Interface modules. The temperature sensing must be isolated from the cell voltage sensing. Although the Cell Interface includes protective circuitry to make it more resilient to brief wiring errors, the same circuitry can result in the battery cells being slowly discharged. Over time, these wiring errors can cause damage to the Cell Interface and/or the cells.



Properly insulate or remove any unused wires. Unused wires can couple excessive system noise into Nuvation Energy BMS which can disrupt communication and lead to undesirable behaviors.



Nuvation Energy BMS relies on your system charger to charge the battery cells; do not leave your charger off while Nuvation Energy BMS is powered from the stack for prolonged periods of time. Nuvation Energy BMS should be shut down when the system is in storage to minimize the drain on the cells.



Insulated handling is required of any connector carrying potentials over 60 V DC relative to chassis.



Please be aware of high voltages present in your system and follow all necessary safety precautions.



The provided module enclosures are not fire enclosures.

1. Introduction

Thank you for choosing Nuvation Energy.

Nuvation Energy's Stack Switchgear provides an integrated battery stack management solution that includes all the hardware and software required to integrate a battery stack into your energy storage system. Each Stack Switchgear unit contains Nuvation Energy High-Voltage BMS modules and is designed to be used with other products in the Nuvation Energy BMS family.

1.1. About this Manual

This *Nuvation Energy G5 High-Voltage BMS: NUVG5 Product Manual* is a comprehensive manual, providing:

- Details about all the features offered by your Nuvation Energy G5 High-Voltage BMS
- Mounting and wiring instructions to install this product safely
- Guidance on integrating the device into your energy storage system
- Guidance on operating the Nuvation Energy BMS Operator Interface



This document applies to Nuvation Energy BMS G5 Faraday software release (Firmware version 5.7.0, Operator Interface version 0.64.0). Content may be inaccurate or incomplete for other versions.



We thrive on your feedback and what we build is driven by your input. Please submit support tickets to support@nuvationenergy.com.

2. Product Overview

The Nuvation Energy G5 High-Voltage BMS provides cell-level and stack-level control for battery stacks up to 1500 VDC. The G5 Stack Switchgear and G5 Cell Interface modules operate together as a complete system called the G5 High-Voltage BMS.

Both Nuvation Energy G5 Stack Switchgear and G5 Cell Interface are designed to enable UL 1973 certification of the battery stack. The UL 1973 Recognized Nuvation Energy BMS (*Note: certification pending*) in each stack ensures safe battery operation and significantly reduces the effort of certifying the energy storage system to meet UL 1973 and UL 9540.



Figure 1. G5 High-Voltage BMS.

A single Nuvation Energy G5 Stack Switchgear unit manages each stack and connects it to the DC bus of the energy storage system. The G5 Stack Switchgear is a pre-configured assembly that incorporates the major functions of Nuvation Energy G5 High-Voltage BMS into a rack-mountable unit which includes stack monitoring, electrical disconnects, pre-charging, current sensing, fuses, and fan control.

G5 Cell Interface modules in each stack connect directly to battery cells to measure cell voltages and temperatures and provide cell balancing.

Typically, a single battery stack uses one G5 Stack Switchgear and one or more G5 Cell Interface modules. A breakdown of a single battery stack is shown in [Figure 2, "G5 High-Voltage BMS single system diagram"](#)

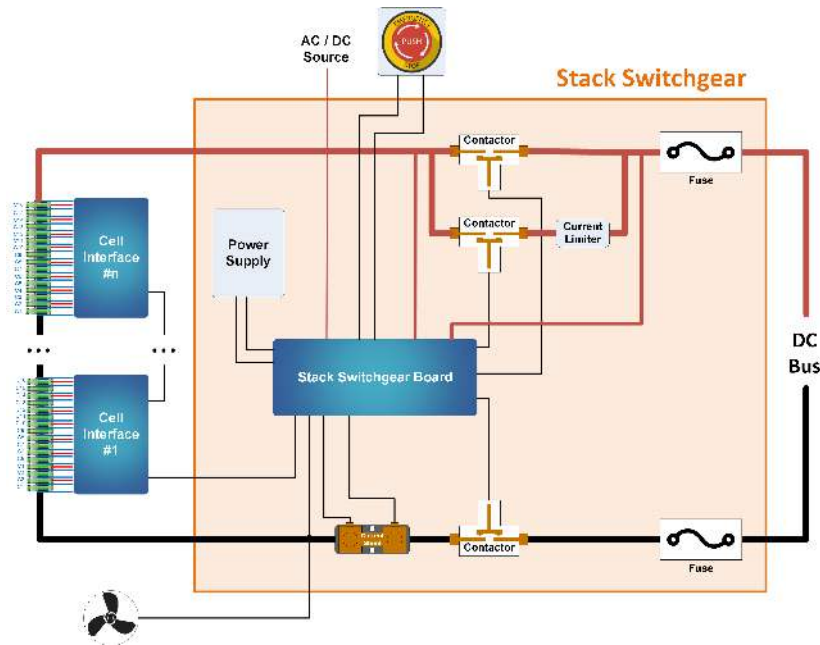


Figure 2. G5 High-Voltage BMS single system diagram

In a multi-stack G5 High-Voltage BMS configuration, as shown in [Figure 3, "G5 High-Voltage BMS multi-stack diagram"](#), each G5 Stack Switchgear unit is responsible for monitoring the state and safety of one battery stack. All G5 Stack Switchgear units connected to a single common DC bus in the system may be managed by a single Nuvation Energy Multi-Stack Controller and operated via the Nuvation Energy Operator Interface. The Operator Interface GUI provides a unified view and central control of multi-stack system.

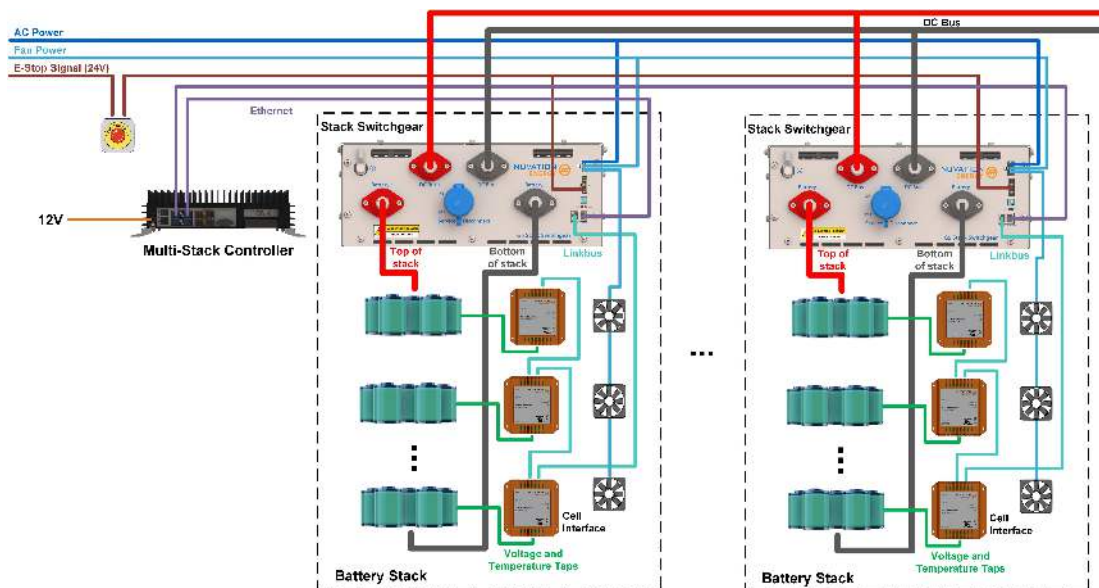


Figure 3. G5 High-Voltage BMS multi-stack diagram

2.1. G5 Stack Switchgear

The following variants of the Nuvation Energy G5 Stack Switchgear are available:

- G5 Stack Switchgear, 1500 V, 100 A
- G5 Stack Switchgear, 1500 V, 200 A
- G5 Stack Switchgear, 1500 V, 300 A

The high-level system design of G5 Stack Switchgear is shown in [Figure 2, "G5 High-Voltage BMS single system diagram"](#). Within a battery stack, the G5 Stack Switchgear connects to the daisy-chained Nuvation Energy G5 Cell Interface modules. The G5 Cell Interface modules convert cell voltage and temperature measurements to digital values to be relayed to the G5 Stack Switchgear, and enable or disable cell balancing as required. Daisy-chaining the G5 Cell Interface modules facilitates the design of flexible and scalable battery energy storage systems.

The G5 Stack Switchgear has high-voltage, high-current connectors that are accessible on the front of the unit. These connect the battery stack to the rest of the system, which is typically a common DC bus. Safety precautions are required to handle and connect cables into this unit.



Figure 4. Nuvation Energy G5 Stack Switchgear

The external interfaces to this unit are:

- Battery Stack and DC Bus connectors
- Service Disconnect Switch
- 10/100 Base-T Ethernet RJ45 jack (Modbus-TCP)
- Link Bus RJ45 connector
- Fan control input and output
- Power In
- Power LED and Fault LED
- Earth bonding connection (grounding stud)

- Enable, Shutdown, and Disconnect inputs
- General purpose I/O
- Factory Reset and Under Voltage Lockout (UVLO) Enable Config Switch
- AC Fan Circuit Breaker

2.2. G5 Cell Interface

The Nuvation Energy Cell Interface is the direct link between the individual battery stack cells and the rest of the Battery Management System. It facilitates battery monitoring and balancing functionalities.

In a stack managed by the G5 Stack Switchgear, one or more G5 Cell Interface modules are used to convert and relay cell voltage and temperature measurements digitally to the G5 Stack Switchgear.

The NUVG5-CI-24, G5 Cell Interface - 24 channel can monitor up to 24 series-connected cells and up to 8 external temperature sensors.



Figure 5. Nuvation Energy G5 Cell Interface

The external interfaces to this module are:

- Cell Voltage and Temperature Sensors connector
- 2 Link Bus connectors



The G5 Cell Interface connects to the battery stack-referenced signals through high voltage rated connectors. Safety precautions are required to handle and connect cables into this module.

2.3. G5 BMS Software

The Nuvation Energy G5 BMS Software is composed of two parts: the Operator Interface and the G5 BMS Firmware.

2.3.1. Operator Interface



Figure 6. Operator Interface Dashboard

The Operator Interface is a browser-based graphical view of the system state, data, and configuration.

Key Features:

- **Provides Unified View of Entire Battery** - Access diagnostics and performance data of the battery stack
- **Statistics** - Provides stack-level voltage, temperature & current statistics for all cells
- **Real-Time** - Streams measurements and control signals for real-time display and recording
- **Faults and Warnings** - Aggregated for system-wide overview, plus detail drill-down for battery pack diagnostics
- **SOC and SOH** - Calculates State of Charge (SoC) and State of Health (SoH) for the battery stack
- **Communications Status** - Ensures that measurements, control signals, and other data are propagating properly throughout the entire system for safe operation
- **Flow-Through I/O** - Provides a single entry point to all measurement and control points in the BMS

2.3.2. G5 BMS Firmware

The G5 BMS Firmware is a highly configurable software that manages the stack operation and controls. It enables the BMS to be used as a protection device against unsafe voltage, temperature,

and current conditions in battery systems.

2.3.2.1. Key Features

- **Configuration Registers** - Numerous configuration options, called 'registers', to tune the G5 High-Voltage BMS for the specific end-application.
- **Functional Safety** - Functional safety according to IEC-60730-1 specification is accomplished through several key capabilities of the software.
 - **Protection Functions** - Provides protection functions for a battery against hazardous voltage, temperature, and current conditions.
 - **Sensor Fault Detection** - Detects sensor faults in cell voltage, temperature, stack voltage, and stack current.
 - **Shorted Shunt Detection** - Detects short circuit failures, and wiring defects.
 - **Microelectronic Fault Detection** - Implements extensive internal verification to ensure that processors, memories, and communication paths are functional and the safety software is executing correctly.
 - **Contactor Life Tracking** - Monitors the life of the contactors during the operation of the G5 Stack Switchgear. Contactor life is degraded when the contactors are opened at elevated load currents.
 - **DC Bus and Stack Connector Temperature Monitoring** - Monitors the temperature at the high power connections to the G5 Stack Switchgear. High temperatures on these connectors are an indication of untertorqued connections which can lead to a battery fire.
- **Continuous Cell Balancing** - A proprietary algorithm for continuous cell balancing leading to shorter maintenance time. The battery does not have to remain above a specific cell voltage threshold for balancing to occur.
- **Balancing Counters Per Cell** - A counter per cell for the number of times a cell was passively balanced is maintained and persisted on the G5 High-Voltage BMS. This data provides a clear indication of cells which often have smaller relative capacities within the stack.
- **Configurable Modbus Points** - Provides a configurable read/write access of G5 High-Voltage BMS registers over the Modbus TCP interface.
- **Fault/Warning Bitfields** - The status of all G5 High-Voltage BMS faults and warnings are collected in separate bitfield registers. The fault/warning status can be determined by a few register reads or mapped into Modbus points via the Configurable Modbus Points feature.

3. Functional Overview

The Nuvation Energy G5 High-Voltage BMS provides many functions to allow flexible and configurable management/control of a stack. The following sections provides a brief summary of the product functions.

Monitor DC Bus and Stack Voltages

The G5 Stack Switchgear measures both the DC Bus and the battery stack voltages. These measurements allow for improved pre-charge and multi-stack capability.

Configurable for Different Battery Chemistries

The G5 Cell Interface is capable of measuring cells which vary in voltage between 1.6 and 4.3 volts. This range of voltage can support many lithium and lead-acid cell chemistries. A maximum of 480 cells can be measured by using a maximum of 20 G5 Cell Interface modules connected to one G5 Stack Switchgear.

Configurable Safe Limits of a Stack

As part of a UL 1973 certification, the safe operational range of a stack must be enforced by the G5 Stack Switchgear. A factory configuration is used to provide the initial safety configuration and is used within the certification process. Nuvation Energy provides a safety manual to guide the process of how to configure a stack for certification review. Once a safety configuration is established, the factory configuration can be locked to prevent further modification.

User Configurable Operational Range

After a stack is deployed, a user may choose to further limit the operational range of a stack. For example the PCS may require a minimum voltage that is higher than the stack's minimum voltage. For cases such as this, the G5 Stack Switchgear has a user configurable set of operational limits that can be set to meet these additional constraints. These configurations can be persisted into non-volatile storage and write protected with a password. A short list of these operational limits include:

- High and Low Cell Voltage
- High and Low Stack Voltage
- High Charge Current and High Discharge Current
- High and Low Cell Temperature

GPI/GPO Interfaces

Two GPIs and two GPOs are available to allow interfacing with external connections such as:

- PCS emergency OFF
- E-Stop output
- External indicator LEDs
- Ground Fault Detector Input
- Manual clear faults
- DC-OK

Internal Temperature Monitoring

The G5 Stack Switchgear has seven internal thermal measurements which are connected to a warning/fault. Likewise, each G5 Cell Interface module monitors its internal temperature and reduces passive balancing at high temperatures.

Dedicated Enable, Shutdown, and Disconnect inputs

The G5 Stack Switchgear provides separate Enable, Shutdown, and Disconnected inputs. These inputs allow for external control to power on the Battery Management System, gracefully shutdown the Battery Management System, or safely open the contactors to disconnect the battery stack.

External Fan Control

The G5 Stack Switchgear can be used to control external AC or DC fans for cooling the battery cells. The fans are enabled by the Battery Management System when battery cell temperatures exceed configurable thresholds. There is also a manual control configuration to allow external control of the fans via software command.

Cell Open Wire Detection and Diagnostics

The G5 Stack Switchgear is capable of detecting wiring and circuit problems on each cell voltage channel. The following scenarios are detectable:

- Open circuits
- Short circuits
- High impedance connections/wiring
- Internal Battery Management System hardware failures

Under Voltage Lockout

When a battery monitoring device derives its power from the battery stack, it is vital that during critically low cell/stack voltages that all derived power is removed. The G5 Stack Switchgear provides an Under Voltage Lockout (UVLO) fault that can be used to disconnect the power of its monitoring electronics to prevent further damage to critically low cells. If the UVLO event were to occur, the G5 Stack Switchgear can be restarted with the use of 24V dry-contact switch.

Sunspec Modbus TCP with Configurable Points

The G5 Stack Switchgear provides MESA 801/802/803 data models over its Modbus TCP port. Furthermore, the device can be configured to map internal data registers to a reserved set of Modbus points. This functionality allows internal data that is not within Sunspec data models to be accessed over Modbus TCP.

Continuous Balancing

The G5 Stack Switchgear implements a balancing algorithm that estimates charge imbalances of the stack cells and applies balancing to these imbalanced cells during operation. The use of continuous balancing significantly increases operational time of the battery system managed by the Nuvation Energy BMS by decreasing the maintenance time to balance cells within the stack.

4. Installation Instructions

4.1. Safety Instructions

The content in this document must be followed in order to ensure safe operation of Nuvation Energy BMS.



The G5 High-Voltage BMS is to be installed in a location with restricted access. Only **skilled persons** may install or service a system containing hazardous voltages that may be present when the system is energized.



Do **NOT** energize the system until all connections to the Stack Switchgear unit and Cell Interface modules have been made.



The wiring of the battery cell voltage and temperature sensing should be verified **before** connecting to the Cell Interface modules. The temperature sensing must be isolated from the cell voltage sensing. Although the Cell Interface includes protective circuitry to make it more resilient to brief wiring errors, the same circuitry can result in the battery cells being slowly discharged. Over time, these wiring errors can cause damage to the Cell Interface and/or the cells.



Properly insulate or remove any unused wires. Unused wires can couple excessive system noise into Nuvation Energy BMS which can disrupt communication and lead to undesirable behaviors.



Nuvation Energy BMS relies on your system charger to charge the battery cells; do not leave your charger off while Nuvation Energy BMS is powered from the stack for prolonged periods of time. Nuvation Energy BMS should be shut down when the system is in storage to minimize the drain on the cells.



Insulated handling is required of any connector carrying potentials over 60 V DC relative to chassis.



Please be aware of high voltages present in your system and follow all necessary safety precautions.



The provided module enclosures are not fire enclosures.

4.2. G5 Cell Interface

4.2.1. Installation Overview



During all stages of the installation, appropriate Personal Protective Equipment (PPE) must be worn. This is especially critical when working with live voltages.

To complete the installation of the G5 Cell Interface, the following is required:

Cables

To connect your G5 Cell Interface you will require the following cables for each module:

- 1x Voltage and Thermistor cable
- 1x Ethernet cable

These cables are available for purchase as a kit.

The instructions below are for applications using cable harnesses purchased from Nuvation Energy. To build custom cables, refer to [G5 Cell Interface Connectors](#) for connector pin-out and specifications.

Tools and Materials

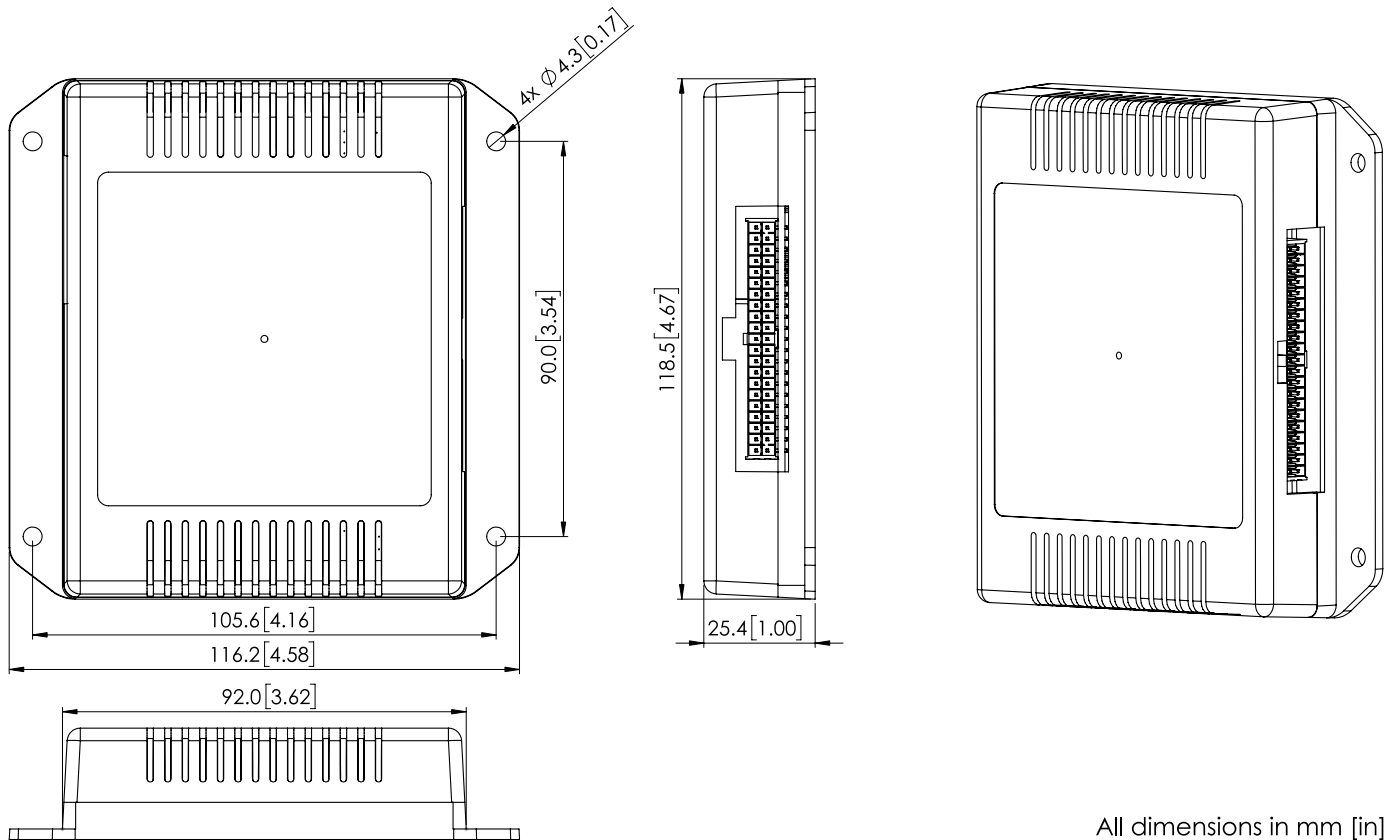
You will need the following tools and materials to complete your G5 Cell Interface installation:

- Fasteners and tools for attaching the G5 Cell Interface to the end desired surface.
- G5 Cell Tap Checker - To test cable connectivity. Contact support@nuvationenergy.com to purchase

4.2.2. Mechanical Installation

4.2.2.1. Dimensions and Weight

The overall dimensions of the G5 Cell Interface are 118.6mm x 116.3mm x 25.4mm and weighs approximately 116g. The G5 Cell Interface is available in a bulkhead-mountable enclosure as shown below.



All dimensions in mm [in]

Figure 7. Mechanical Drawing of G5 Cell Interface



Please refer to <https://www.nuvationenergy.com/technical-resources> for access to CAD files.

4.2.2.2. Installation Location and Position

Mounting Clearances

The G5 Cell Interface produces up to 15 W during cell balancing. A portion of this heat is transferred to the bulkhead.

Extra space should be provided around the G5 Cell Interface module to allow for improved airflow and ease of installation/maintenance.

4.2.2.3. Mounting Instructions

The G5 Cell Interface is rated to operate in the temperature range of -20 °C to 60 °C. It is designed for indoor use.

The G5 Cell Interface should be mounted against a flat surface with vent above the Nuvation Energy logo pointing up to the sky.



Ensure the enclosure is connected securely to Earth, either by grounding the mounting surface or by using a dedicated Earth Bonding Conductor.

Ensure appropriate fasteners (not included) are used to mount the G5 Cell Interface. These fasteners will vary depending on the material and construction of the mounting surface.

It is suggested to use #8-32 screws with a split lock washer for the mounting holes provided on each side flange of the G5 Cell Interface.

4.2.3. Electrical Connections



The G5 Cell Interface connects to the battery stack-referenced signals through high-voltage rated connectors. Safety precautions are required to handle and connect cables into this module.

4.2.3.1. Getting Started

Connection sequence

- Step 1: [Connect the Cell Voltage and Temperature Cable](#)
- Step 2: [Connect the Link Bus Cable](#)



The wiring of the battery cell voltage and temperature sensing should be verified **before** connecting to the Cell Interface modules. The temperature sensing must be isolated from the cell voltage sensing. Although the Cell Interface includes protective circuitry to make it more resilient to brief wiring errors, the same circuitry can result in the battery cells being slowly discharged. Over time, these wiring errors can cause damage to the Cell Interface and/or the cells.

4.2.3.2. Connect the Cell Voltage and Temperature Cable



Your G5 Stack Switchgear is pre-configured to expect a defined number of thermistors based on the information provided to Nuvation Energy during order fulfillment. Failure to use the same number of thermistors will result in undesirable G5 Stack Switchgear behavior. Please contact support@nuvationenergy.com if there is a change requiring a G5 Stack Switchgear configuration update.

The Temperature cable provides 10 kΩ NTC thermistors for temperature measurement of the cells and/or surrounding area. These sensors are used by Nuvation Energy BMS to detect over and under temperature conditions and adjust battery current limits to compensate for cell temperature.

Cable Isolation

Because the sensors are referenced to the CELL0 input on the G5 Cell Interface, care must be taken to ensure that they are electrically isolated from any common or ground potential, and from all other cell voltage terminals of all G5 Cell Interface modules in the system

The thermistors must also be isolated from the cell voltage terminals, as well as any metal work or other exposed conductors, in such a way that they will not make an electrical connection to a cell terminal in the event of vibration/failures.

Connection Procedure



If you are building your own cables, please refer to the pin out for this connector in [Cell Voltage and Temperature Connector](#).

Connect Thermistor Sensors to Surface

It is recommended to use thermally conductive/electrically non-conductive epoxy to adhere the thermistors to the cells.

Connect Cable to G5 Cell Interface

Connect the 'Cell Voltage and Temperature' cable to the 'Cell Voltage and Temperature' connector on the G5 Cell Interface.

4.2.3.3. Connect the Link Bus Cable

The Link Bus cable is used to connect G5 Cell Interface modules in a daisy chain (called the Link Bus chain) by connecting the 'Link In' of one G5 Cell Interface to the 'Link Out' of the next G5 Cell Interface. In this series-connected chain of modules, each connection is made from the Link In connector of the module with higher potential to the Link Out connector of the module with lower potential.

The Link Bus provides a data channel to subsequent G5 Cell Interface modules in the Link Bus chain.

Connection Procedure

1. Connect one end of the cable to the 'Link Out' connector on the G5 Cell Interface
2. Connect the other end of the Link Bus cable to the 'Link In' connector on the next G5 Cell Interface.

For multiple G5 Cell Interface modules, use additional Link Bus cables to connect the 'Link Out' on the current G5 Cell Interface to the 'Link In' of the next G5 Cell Interface in the chain.

The 'Link Out' of the last G5 Cell Interface module in the Link Bus chain is to be left unconnected. The 'Link In' of the first G5 Cell Interface module in the Link Bus chain will be connected to the G5 Stack Switchgear during the installation of the G5 Stack Switchgear.

4.3. G5 Stack Switchgear

4.3.1. Installation Overview



During all stages of the installation, appropriate Personal Protective Equipment (PPE) must be worn. This is especially critical when working with live voltages.

To complete the installation of the G5 Stack Switchgear, the following is required:

Mounting Brackets

Brackets for shelf mounting are included. Optionally, you can request Front-securing Brackets for 19" Rack mounting if appropriate for your application.

Cables

To connect your G5 Stack Switchgear you will require the following cables:

- 1x Power Cable for either AC or DC power.
- 1x Voltage and Thermistor cable to connect to the G5 Cell Interface
- 1x Ethernet cable for communication with the G5 Cell Interface

These cables are available for purchase as a kit.

The instructions below are for applications using cable harnesses purchased from Nuvation Energy. To build custom cables, refer to [G5 Stack Switchgear Connectors](#) for connector pin-out and specifications.

Tools and Materials

You will need the following tools and materials to complete your G5 Stack Switchgear installation:

- M13 and M17 wrench
- Torque wrench with range 60-130 inch pounds
- Fasteners and tools for attaching the brackets to the end desired surface.
- G5 Cell Tap Checker - To test cable connectivity. Contact support@nuvationenergy.com to purchase

4.3.2. Mechanical Installation

4.3.2.1. Dimensions and Weight

The G5 Stack Switchgear is 4U (rack-units) tall. The unit weighs 23.5 kg [51.8 lbs].

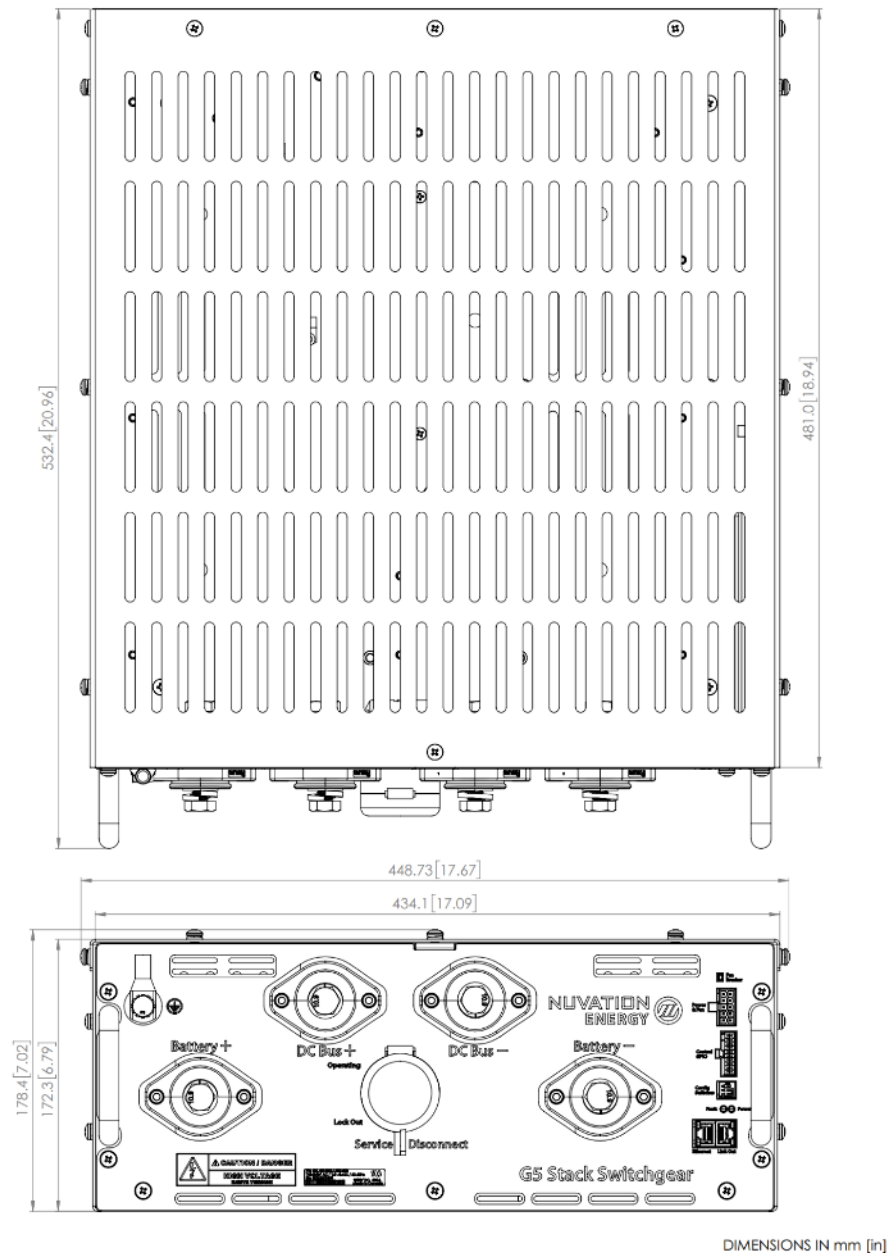


Figure 8. Mechanical Drawing of G5 Stack Switchgear



Please refer to <https://www.nuvationenergy.com/technical-resources> for access to CAD files.

4.3.2.2. Installation Location and Position

The G5 Stack Switchgear is primarily designed to fit in a standard 19" rack with a 23"-deep cabinet. However, other mounting possibilities are supported, as the following subsections discuss. By default, the G5 Stack Switchgear ships with brackets for shelf mounting. Depending on the desired application, brackets can be ordered with part numbers listed in [G5 Stack Switchgear Ordering Information](#).

The G5 Stack Switchgear must be installed in a horizontal orientation with the vent-slots pointing up to the sky. The G5 Stack Switchgear is not designed to be installed in any other orientation.

Mounting Clearances

To maintain safe operating temperatures, it is recommended to leave 1U of space above the unit for airflow. Depending on the environment, active airflow, and ambient temperature, some cases may require additional space.

4.3.2.3. Mounting Instructions

Fasteners (M5 x 8 mm) for attaching the brackets to the G5 Stack Switchgear unit are included with any mounting bracket order.



If fasteners other than the provided hardware is used, the screws cannot extend into the G5 Stack Switchgear more than 8 mm. High-voltage and high-power elements that exist inside the unit could arc to the screw if it intrudes too deep into the unit.

Fasteners for attaching the brackets to the end desired surface are not provided, due to the application-specific nature. In order to source these fasteners however, note that the corresponding bracket slots have widths designed for M5 screws.



Third-party side-support angle brackets are necessary to uphold the weight of the unit, in this mounting application.

Some examples include RASA22BK3 or RAAB2436BK products by Hammond Manufacturing (<https://www.hammfg.com/>).

After removing the G5 Stack Switchgear from its packaging, perform the following steps based on the mounting brackets purchased.

Shelf-Mount



Figure 9. Shelf-mount - using brackets NUVP-SSG-SB

A G5 Stack Switchgear may also be mounted to the surface on which it rests, with the aid of shelf-mount brackets, as shown above.

1. Install the brackets on the G5 Stack Switchgear.
2. Place the G5 Stack Switchgear on the shelf at the desired location. Ensure the G5 Stack Switchgear is in a horizontal orientation with the vent-slots pointing up to the sky.
3. Attach the G5 Stack Switchgear (with brackets installed) to the shelf.

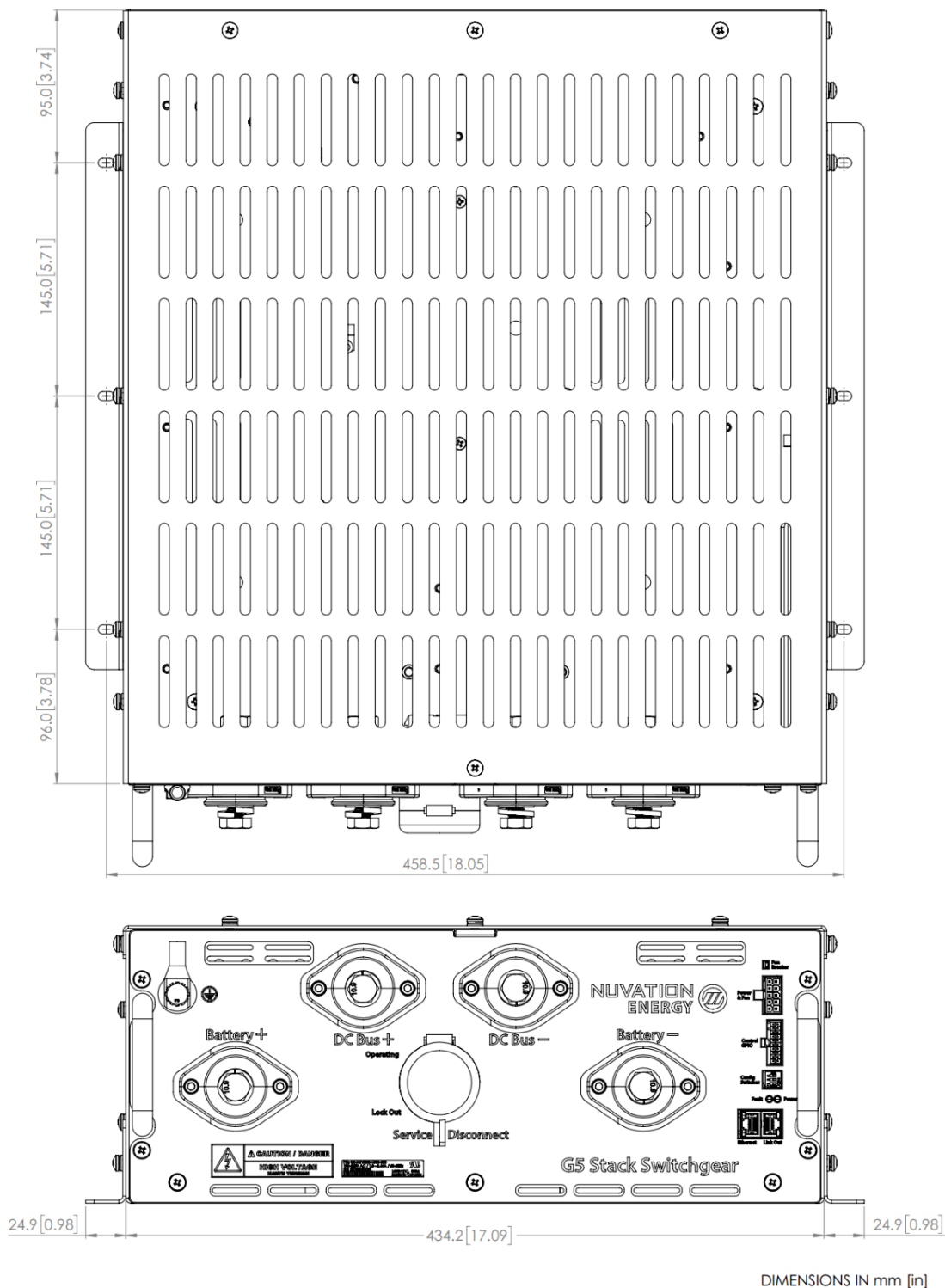


Figure 10. Dimensions, shelf-mount

Front-securing Rack-Mount, 19"



Figure 11. Rack-mount, 19", front-securing - using brackets NUVP-SSG-RB-19

The mounting brackets allow for adjusting how far the unit protrudes or recedes from the front of the rack. These brackets are designed to secure the front of the unit with respect to the front of the rack.

1. Install the side-support angle brackets on the rack at the desired location.
2. Install the brackets on the G5 Stack Switchgear.
3. Place the G5 Stack Switchgear onto the installed side-support angle brackets. Ensure the G5 Stack Switchgear is in a horizontal orientation with the vent-slots pointing up to the sky.
4. Secure the G5 Stack Switchgear to the rail of the rack using the brackets installed.

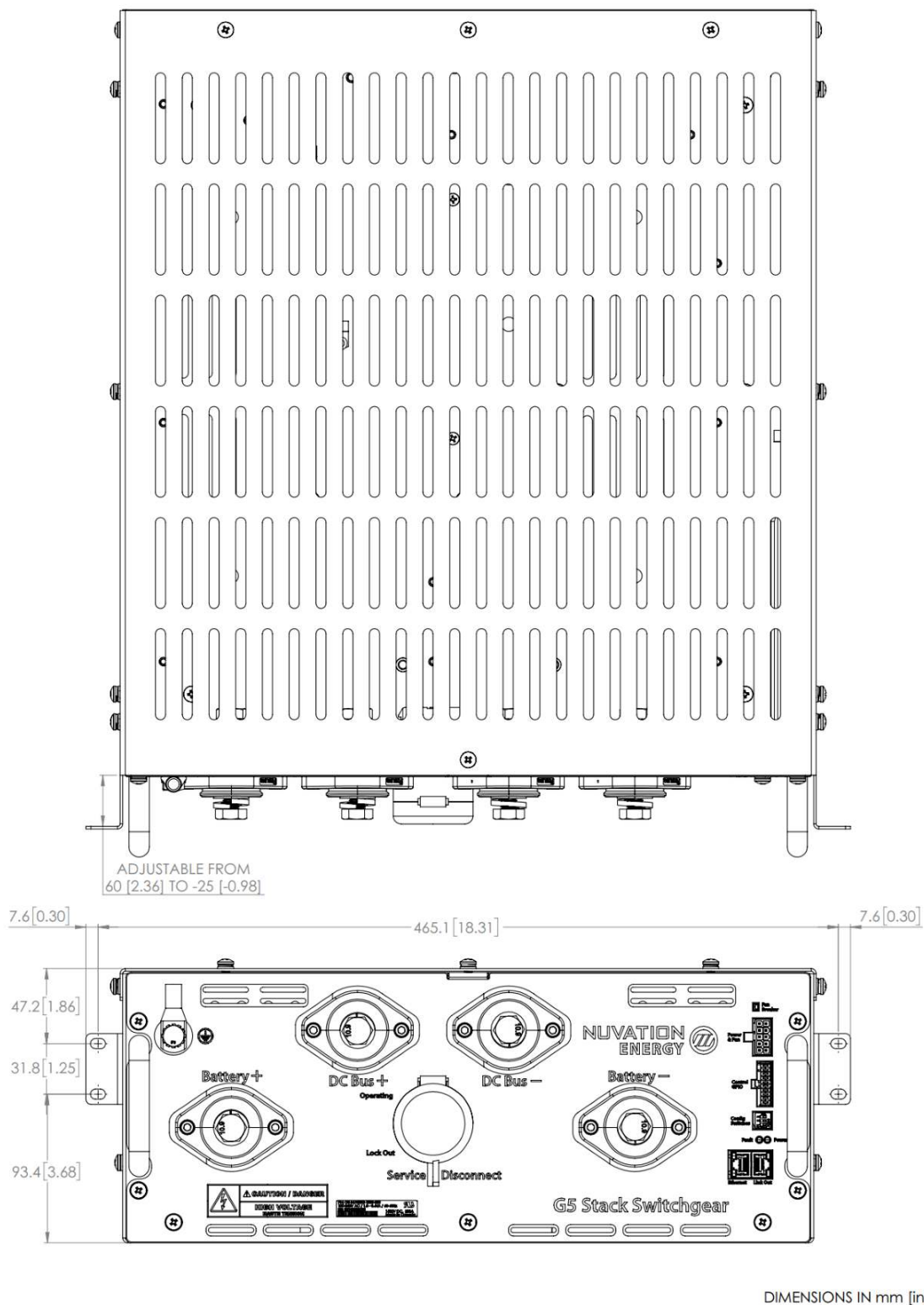


Figure 12. Dimensions, rack-mount, 19", front-securing

4.3.3. Electrical Connections



Before making any connections, ensure that the service disconnect switch is in the **Lock Out** position.



The G5 Stack Switchgear is configured for a specific battery topology based on the details provided to Nuvation Energy during order fulfillment. Failure to use the same number of G5 Cell Interface modules and/or using a different battery topology will result in undesirable G5 Stack Switchgear behavior.

Please contact support@nuvationenergy.com if there is a change in the system design that would require a G5 Stack Switchgear configuration update.

4.3.3.1. Getting Started

- Step 1: [Ensure system is de-energized](#)
- Step 2: [Ground the G5 Stack Switchgear](#)
- Step 3: [Connect Power In and Fan Control](#)
- Step 4: [Connect control to General Purpose Input/Output \(GPIO\) cable](#)
- Step 5: [Connect Ethernet cable to external computer \(PC\)](#)
- Step 6: [Connect Link Out cable to G5 Cell Interface](#)
- Step 7: [Set the Config Switches](#)
- Step 8: [Connect Battery Stack to DC Bus](#)
- Step 9: [Energize G5 Stack Switchgear and Fans](#)

Below is a overview image of the external interfaces available on the front of the G5 Stack Switchgear.



Figure 13. G5 Stack Switchgear external interfaces

4.3.3.2. Ensure system is de-energized



Ensure that the Service Disconnect switch is in the **Lock Out** position.

Service Disconnect

The manual Service Disconnect switch is accessible on the front of the G5 Stack Switchgear. Use the lock-out/tag-out to ensure that the battery stack does not connect to the DC bus or power conversion system during installation.

Ensure the service disconnect switch is in the **Lock Out** position and lock-out/tag-out the switch by locking the cover.



Figure 14. Service Disconnect



The service disconnect switch removes power to the internal contactors—it does not physically break the connection (this is done by the contactors themselves).

In the event of damage to the internal contactors (i.e. a welded contactor), the service disconnect switch cannot guarantee that the DC bus has been disconnected from the battery. It is therefore recommended to check for voltage present on the Battery Stack and DC Bus terminals with a voltmeter before working on the stack to ensure the contactors have opened fully.

Verify G5 Stack Switchgear is de-energized

Using a multimeter check the Battery Stack and the DC Bus terminals respectively to verify that the G5 Stack Switchgear is de-energized.

4.3.3.3. Ground the G5 Stack Switchgear



Figure 15. Grounding bolt

The G5 Stack Switchgear must be bonded to the rack or Earth through a suitably sized conductor by NEC standards. From NFPA 70, Table 250.122, the wire size must be chosen based on the rating of the automatic over-current device in the circuit, as shown in [Table 1, "Minimum grounding wire size"](#).

Table 1. Minimum grounding wire size

G5 Stack Switchgear Current Rating (A)	Grounding Wire (AWG)	
	Copper	Aluminum
100	8	6
200	6	4
300	4	2

An M8 lug (not included) should be used (e.g. Panduit Corp LCMA50-8-L), along with an M8 bolt and tooth lock washer (both included), as shown in [Figure 15, "Grounding bolt"](#).

In order to make the connection:

1. Strip the insulation
2. Crimp the lug
3. Screw the lug onto the terminal

The recommended tightening torque is 15 N-m [130 in-lbs].

4.3.3.4. Connect Power In and Fan Control



If you are building your own cables, please refer to the pin out for this connector in [Power and Fan Connector](#). For specifications of this input, see [Section 5.1.1, "G5 Stack Switchgear"](#).



The G5 Stack Switchgear requires a 100 V to 240 V AC or a 24 V DC power to be supplied from an external source. Power is connected via feed-through connectors labeled 'Power In' on the front panel. Power is connected via the Fan and Power In cable connector.

Fan control enables the G5 Stack Switchgear to control external AC or DC fans for cooling the battery cells. The fans are enabled by the BMS when battery cell temperatures exceed configurable thresholds.

The power source for the fans must be supplied to the G5 Stack Switchgear. It can be either AC or DC, depending on the fan selection for the system. This can be the same power source used for powering the G5 Stack Switchgear.

The figure below provides the internal wiring implementation of the fan control parts shown above.

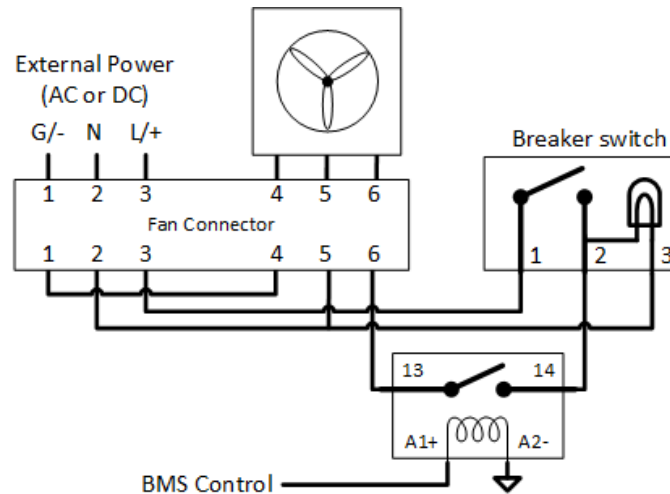


Figure 16. Battery cooling fan control wiring diagram

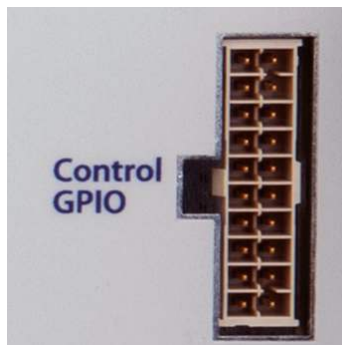


Both power to the G5 Stack Switchgear and the fans are both expected to be de-energized before installation; this usually involves turning off each respective breaker at a panel.

4.3.3.5. Connect control to General Purpose Input/Output (GPIO) cable



If you are building your own cables, please refer to the pin out for this connector in [I/O Connector](#).



Connect the I/O cable to the connector on the front of the G5 Stack Switchgear.

4.3.3.6. Connect Ethernet cable to external computer

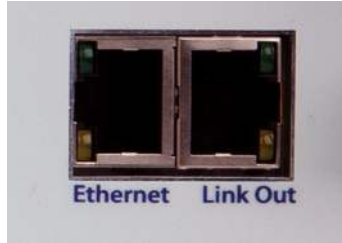


Figure 17. Ethernet Connector

The Ethernet connector is a standard RJ45 Ethernet jack. It may be used to connect the G5 Stack Switchgear to an external system, such as:

- A laptop, to configure operating parameters and observe status
- A local area network (LAN) connection, for wired internet access
- A Nuvation Energy Multi-Stack Controller
- Energy control systems, such as power conversion systems and energy controllers
- An Ethernet switch, to access any number of the above devices

Any Cat5e-rated or higher Ethernet cable of suitable length may be used to connect to this RJ45 jack.

4.3.3.7. Connect Link Out cable to G5 Cell Interface

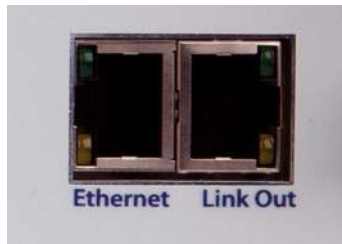


Figure 18. Link Out Connector

Install the Link Bus cable between the G5 Stack Switchgear and the first G5 Cell Interface in the Link Bus chain.

The Link Out connector provides communication to the G5 Cell Interface modules.

Typically, the Link Bus is connected to the G5 Cell Interface module which measures the most negative cell, with each subsequent G5 Cell Interface module measuring increasingly positive cells. Although any order of the G5 Cell Interface modules in the Link Bus chain can be acceptable, the order of the cells in the software registers and the Operator Interface may not be as intuitive as the aforementioned order (i.e. order of increasing potential).

If the G5 Cell Interface modules are not already connected to the battery (e.g. battery cell connection, temperature sensors, and Link Bus cables between the G5 Cell Interface modules), this can be done now. For instructions on connecting the G5 Cell Interface modules to the battery, refer to [Section 4.2.3, "Electrical Connections"](#).

4.3.3.8. Set the Config Switches



Figure 19. Config Switches

Set the switch positions for the desired functionality that they manage. The following table describes the functionality per config switch.

Table 2. Config Switch Settings

Switch	Name	Position	Description
1	Factory Reset	Off	No action
1	Factory Reset	On	Enables a user to select a Factory Reset during the subsequent power on
2	IP Reset	Off	No action
2	IP Reset	On	Enables a user to select an IP Reset during the subsequent power on
3	UVLO	Off	UVLO is disabled
3	UVLO	On	UVLO is enabled



Changes in config switch settings must occur when the Nuvation Energy Stack Switchgear is powered off.

4.3.3.9. Connect Battery Stack and DC Bus



Due to the nature of batteries, live voltages are always present; for this reason, these connections should be completed last. In order to reduce the risk of a short, only install one connection at a time.



The G5 Stack Switchgear is configured for a specific battery topology based on the details provided to Nuvation Energy during order fulfillment. Failure to use the same number of G5 Cell Interface modules and/or using a different battery topology will result in undesirable G5 Stack Switchgear behavior.

Please contact support@nuvationenergy.com if there is a change in the system design that would require a G5 Stack Switchgear configuration update.

The front panel of the G5 Stack Switchgear has four high-power connectors, as illustrated below. Two of these are for the positive and negative terminals of the battery stack; the other two are for the connection to the DC bus (or a power conversion system in a single stack system). The colors are coordinated such that red is for the positive connections and black is for the negative connections.

The connectors use M10 screws (included) and are intended for M10 lugs (not included, e.g. Panduit

Corp LCMA50-10-L).

Flexible snap-on terminal covers are included. The maximum acceptable terminal lug tongue width is 1.1 inches and the maximum wire size is 4/0. The recommended tightening torque is 6.8 N-m to 9.0 N-m [60 to 80 in-lbs].

Table 3. Battery Stack and DC Bus Connector Assignment



Name	Description	Connected to Device
Battery (-)	Negative terminal of battery stack	Battery stack
Battery (+)	Positive terminal of battery stack	Battery stack
DC Bus (-)	Negative terminal of DC bus	External equipment
DC Bus (+)	Positive terminal of DC bus	External equipment

A typical NUVG5-SSG-1500-300 installation capable of up to 350 A should use 4/0 AWG 90°C copper cable rated 1500 V DC or higher, based on Table 310.15(B)(17) of the NEC (Allowable Ampacities of Single-Insulated Conductors Rated Up to and Including 2000 Volts in Free Air). This should be evaluated on a per-project basis in accordance with site-specific conditions and local codes. The installer shall be responsible for installing cables in accordance with all applicable electrical codes.

In order to make the connection:

1. Feed the wire through the terminal cover
2. Strip the insulation
3. Crimp the lug
4. Screw the lug onto the terminal
5. Torque to the recommended specifications above
6. Slide the terminal cover onto the terminal
7. Torque to the recommended specifications to 60 to 80 in-lbs



The battery stack terminals are always energized and should be handled as such.

Although the DC bus terminals are disconnected from the battery by the Stack Switchgear unit's contactors, the DC bus can still be energized by other components on the DC bus (e.g. power conversion system or other stacks). The DC bus terminals should always be treated as though they were energized.

A simple voltage check (i.e. across the positive and negative terminals) is not always sufficient, *especially* with grounded battery stacks. It is recommended to also check

for voltage between each conductor and ground.

4.3.3.10. Energize G5 Stack Switchgear and Fans

Power to both the fans and the G5 Stack Switchgear, disconnected in [Section 4.3.3.4, "Connect Power In and Fan Control"](#), can now be energized and begin operation of the G5 High-Voltage BMS.

4.4. G5 Operator Interface

4.4.1. Download and Install the G5 Operator Interface

The G5 Operator Interface is used to access the Nuvation Energy BMS. The latest Operator Interface release will be available online at: <https://www.nuvationenergy.com> In the interim, please contact support@nuvationenergy.com for a copy.



Browser Compatibility

The G5 Operator Interface currently supports the most recent versions of Mozilla Firefox and Google Chrome. Other browsers such as Internet Explorer are not supported. Please install a supported browser before attempting to access the Operator Interface.

4.4.2. Connect to the G5 Operator Interface

Ensure your computer is connected directly to the G5 Stack Switchgear via an Ethernet cable. You will need to configure the network adapter on your computer to match the settings on your G5 Stack Switchgear.

Identify the Battery Management System IP

By default, G5 Stack Switchgear is configured with a static IP address of 192.168.1.21, unless noted otherwise on a label on the G5 Stack Switchgear.

Identify the parts of the Battery Management System's IP Address

The IP address has two parts - the network ID and the host ID.



Figure 20. Parts of an IP address

Write down the network ID and host ID parts of the Battery Management System's IP address.

Determine a valid IP address to assign to the PC

The Network ID for the PC IP address must be the same as the Battery Management System. The Host ID number can be any number from 2 to 255 as long as it is not the same as the Host ID of the Battery Management System. For example if the Battery Management System IP address is 192.168.1.21, the IP address of the PC could be 192.168.1.12 or 192.168.1.49 or any 192.168.1.x where x is not 21.



If you have multiple stacks, note down the Host ID from the IP address of each stack's Battery Management System. The Host ID number assigned to the PC

must be different from this list.

Setup the Static IP address on the PC

Instructions below are for a PC running Windows OS:

1. Go to Control Panel > All Control Panel Items > Network Connections
2. Right-click your network adapter that connects to your G5 Stack Switchgear and select Properties
3. Click Internet Protocol Version 4 (TCP/IPv4) and click Properties

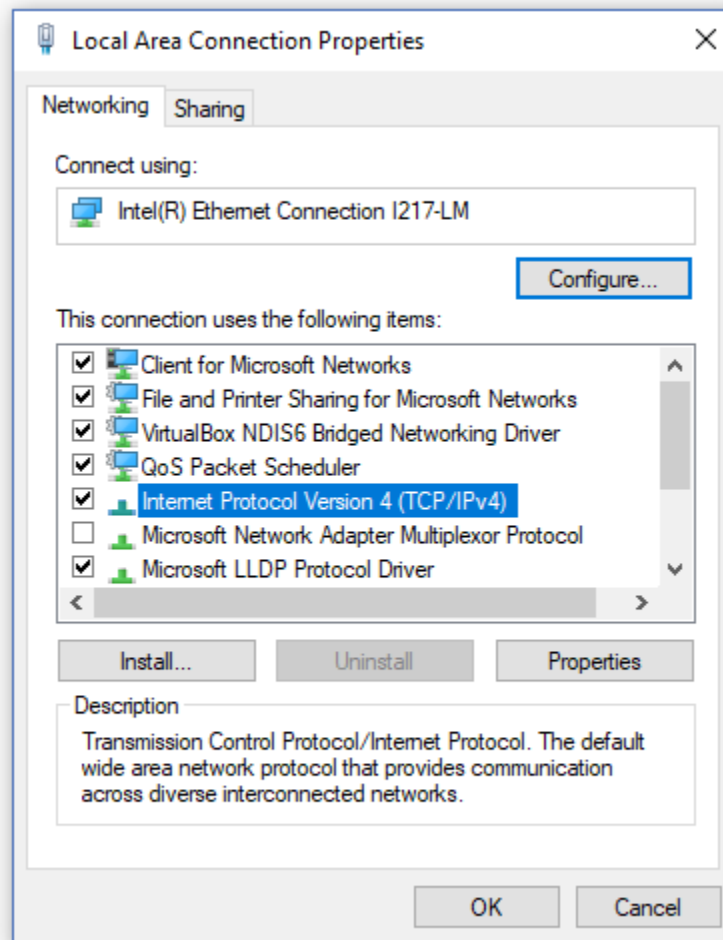


Figure 21. Network Adapter Properties on Windows.

4. Update your network adapter TCP/IPv4 settings to the following:
 - Static IP Address: The IP address must have the same Network ID as the G5 Stack Switchgear and a Host ID that isn't already in use.
 - Refer to the instruction above to determine a valid IP address for the PC.
 - Subnet Mask: 255.255.255.0

- Default gateway: The Network ID must be the same as the G5 Stack Switchgear and the Host ID should be 1.
 - For example, if the G5 Stack Switchgear IP address is 192.168.1.21, the gateway address would be 192.168.1.1

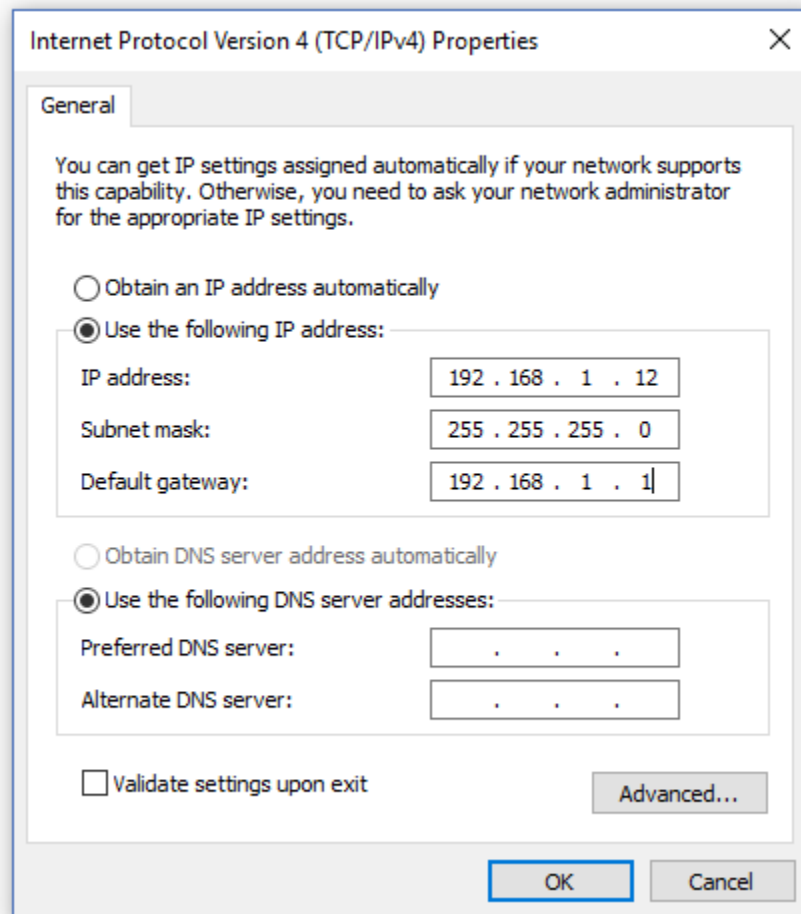


Figure 22. Network Adapter Settings on Windows

5. Ensure your computer is on the same network as your G5 Stack Switchgear.
 - You can connect an Ethernet cable directly between it and the network adapter of your PC.
6. Open the Nuvation-Energy-Operator-Interface.html file in your web browser.
 - This is usually done by double-clicking on the file. If your default browser is not a supported browser, you may need to specify the browser to use.
 - For example, on Windows you may need to right click on the file, select Open with, and then choose Chrome or Firefox from the list.

4.5. First Power-up

Once the G5 Cell Interface modules chain and the G5 Stack Switchgear are connected to the battery, the G5 Stack Switchgear can be powered (internal power and fan power).

Power on the G5 Stack Switchgear

Put the Service Disconnect switch in the **Operating** position. The power LED (green) will turn ON to indicate that the G5 Stack Switchgear is powered.

For more details on the Status LEDs, please refer to [Section 5.2, "Status LEDs"](#).

Clear Faults

On initial power-up, it is common to see that the fault LED (red) is also ON. This indicates that a fault has been detected; the next step will be to clear this fault.

Faults are *latching*, i.e. will remain in faulted state until cleared even if fault condition is removed. Begin by clearing all faults. If any faults remain, investigate the cause of each fault and resolve the issue. Once all faults are cleared, the Stack Switchgear is able to connect the battery to the DC bus.

5. Operating Instructions

5.1. Operating Limits

5.1.1. G5 Stack Switchgear



Exceeding the ratings will damage the system.

5.1.1.1. External Specifications

Symbol	Parameter	Min	Typ	Absolute Max	Units
V_{input_AC}	Input Voltage AC	100	-	240	V AC
f_{input_AC}	Input Frequency	45	50/60	65	Hz
V_{input_DC}	Input Voltage DC	21	24	27	V DC
P_{input_AC}	AC Input Power for BMS	-	24	88	W
P_{input_DC}	DC Input Power for BMS	-	10	50	W
V_{fan_DC}	Cooling Fan DC Voltage	-	-	27	V DC
V_{fan_AC}	Cooling Fan AC Voltage	-	-	250	V AC
P_{fan_DC}	Cooling Fan Power	-	-	96	W
P_{fan_AC}	Cooling Fan Power	-	-	120	W
$P_{total-input_AC}$	Total Input Power for BMS and Fan	-	-	144	W
$P_{total-input_DC}$	Total Input Power for BMS and Fan	-	-	106	W
GPI and Enable/Shutdown/Disconnect Specifications					
I_{max}	On Current	10	12	15	mA DC
V_{max}	Off Voltage	-	-	27	V DC
GPO Specifications					
V_{max}	Open Blocking Voltage	-	-	60	V DC
I_{max}	Closed Maximum Current	-	-	400	mA DC
R_{on}	Closed-State Resistance	-	-	2	Ω

5.1.1.2. Electrical Characteristics

The part number of the G5 Stack Switchgear captures its product rating. The voltage rating is an absolute maximum rating, and the current rating is a continuous rating (also referred to as the 'nominal' rating). Input power is internally regulated to be compliant with NEC class 2 requirements.

Part number format: NUVG5-SSG-<absolute-max-voltage>-<continuous-current-rating>-<fuse-rating>

The table below captures the absolute max rating for voltage and the continuous current rating for current. For the fuse rating, please see [Section 5.1.1.2.1, "Fuse Rating"](#).



The G5 Stack Switchgear can handle short current overages above the continuous rating. Any charge or discharge current above the continuous rating must not exceed 5 minutes per hour and must not exceed the specified absolute max rating. Sufficient time to allow the system to cool down afterward is required.

Table 4. 1500 V DC, 100 A G5 Stack Switchgear: NUVG5-SSG-1500-100-x

Symbol	Parameter	Continuous	Absolute Max	Units
V_{stack_ov}	Stack Over-Voltage Threshold (triggers contactors to open)	1500	1500	V DC
V_{stack_uv}	Stack Under-Voltage Threshold (triggers contactors to open)	0	-	V DC
$I_{discharge_oc}$	Stack Discharging Over-Current (triggers contactors to open)	100	150	A DC
I_{charge_oc}	Stack Charging Over-Current (triggers contactors to open)	100	150	A DC
I_{cont_max}	One time contactor maximum breaking current	-	1500	A DC

Table 5. 1500 V DC, 200 A DC G5 Stack Switchgear: NUVG5-SSG-1500-200-x

Symbol	Parameter	Continuous	Absolute Max	Units
V_{stack_ov}	Stack Over-Voltage Threshold (triggers contactors to open)	1500	1500	V DC
V_{stack_uv}	Stack Under-Voltage Threshold (triggers contactors to open)	0	-	V DC
$I_{discharge_oc}$	Stack Discharging Over-Current (triggers contactors to open)	200	250	A DC
I_{charge_oc}	Stack Charging Over-Current (triggers contactors to open)	200	250	A DC
I_{cont_max}	One time contactor maximum breaking current	-	1500	A DC

Table 6. 1500 V DC, 300 A DC G5 Stack Switchgear: NUVG5-SSG-1500-300-x

Symbol	Parameter	Continuous	Absolute Max	Units
V_{stack_ov}	Stack Over-Voltage Threshold (triggers contactors to open)	1500	1500	V DC
V_{stack_uv}	Stack Under-Voltage Threshold (triggers contactors to open)	0	-	V DC
$I_{discharge_oc}$	Stack Discharging Over-Current (triggers contactors to open)	300	350	A DC
I_{charge_oc}	Stack Charging Over-Current (triggers contactors to open)	300	350	A DC
I_{cont_max}	One time contactor maximum breaking current	-	1500	A DC

Table 7. Battery Cell and Temperature Sensor Specifications for all Configurations

Symbol	Parameter	Min	Typ	Absolute Max	Units
Battery Cell Specifications					
C_{ov}	Cell Over-Voltage Threshold (triggers contactors to open)	-	Configurable	-	V
C_{uv}	Cell Under-Voltage Threshold (triggers contactors to open)	-	Configurable	-	V
Temperature Sensors Specifications					
T_{ut}	Under-Temperature Thresholds Charge/Discharge (triggers contactors to open)	-	Configurable	-	°C
T_{ot}	Over-Temperature Thresholds Charge/Discharge (triggers contactors to open)	-	Configurable	-	°C
T_{fan_en}	Fan Enable Temperature Thresholds Charge/Discharge	-	Configurable	-	°C

Fuse Rating

The fuse rating code is denoted by the x at the end of the product part number. The G5 Stack Switchgear fuse rating is determined by the application power profile, which is based on continuous power, cycle duration, and cycle frequency.

A Nuvation Energy Application Engineer will assist with determining a suitable fuse rating when an order is placed.

Table 8. Fuse rating and code

Fuse Rating	Code
200 A	1
250 A	2
315 A	3
350 A	4
400 A	5
450 A	6
500 A	7

For e.g., a NUVG5-SSG-1500-100-1 is a "1500 V DC, 100 A" G5 Stack Switchgear, with a 200 A fuse rating.

5.1.2. G5 Cell Interface



Exceeding the maximum ratings will damage the G5 Cell Interface module.

5.1.2.1. Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Absolute Max	Units
Link In Specifications						
I_{P_LINK}	Output Current	-	-	-	22	mA DC
I_{N_LINK}	Output Current	-	-	-	22	mA DC
Link Out Specifications						
I_{P_LINK}	Output Current	-	-	-	20	mA DC
I_{N_LINK}	Output Current	-	-	-	20	mA DC
Battery Cells Specifications						
$C_{(n)} - C_{(n-1)}$	Input Cell Voltage Range	-	1.6	-	4.3	Vdc
V_{sum}	Voltage between C0 and C12		11.2	-	51.6	V DC
	Voltage between C12 and C24		11.2	-	51.6	V DC
I_{Active}	Between C0 and C12	Linkbus communication, $V_{sum} = 43.2V$	-	13	20	mA
	Between C12 and C24	Linkbus communication, $V_{sum} = 43.2V$	-	9	11	mA
$I_{Standby}$	Between C0 and C12	No Linkbus communication, $V_{sum} = 43.2V$	-	70	225	μA
	Between C12 and C24	No Linkbus communication, $V_{sum} = 43.2V$	-	70	225	μA
	Between $C_{(n)} - C_{(n-1)}$	No Linkbus communication, $V_{sum} = 43.2V$	-	1.2	15	μA
TME	Total Measurement Error		± 0.1	± 1.6	± 2.8	mV DC
$I_{(n)}$	Cell Balancing Current	$C_{(n)} - C_{(n-1)} = 4 V DC$	145	150	159	mA DC
V_{ins}	Internal reinforced insulation rating from Chassis/COM	-	-	-	1500	V DC
Temperature Sensors Specifications						
$I_{(n)}$	Output Current to Temperature Sensor	-	-	-	300	μA
$R_{t(n)}$	Temperature Sensor Resistance at 25 °C	-	-	10	-	k Ω
$T_{(n)}$	Input Temperature Sensor Voltage Range	Cell 0 = 0 V	0	-	3	V
V_{ins}	Internal reinforced insulation rating from Chassis/COM	-	-	-	1500	V DC

5.1.2.2. Maximum Stack Deployment

G5 Cell Interface modules are deployed as a daisy chain to monitor the cells of a stack. G5 Stack Switchgear can support a maximum of 20 G5 Cell Interface modules.

Limits Due to Cell Voltage Scan Rate

The required scan rate of the cell voltage measurements for a stack will determine the maximum number of G5 Cell Interface modules that the G5 Stack Switchgear can support for that stack configuration.

The following are approximate cell voltage scan rates for different lengths of G5 Cell Interface daisy chains where all cells are installed.

Table 9. Cell Voltage Scan Rates for CI-24

CI-24 Chain Length	Scan Rate [Hz]
1	4.43
5	3.20
10	2.38
15	1.88
20 (max)	1.51

5.1.3. Environmental Conditions

The Nuvation Energy G5 High-Voltage BMS environmental conditions are captured in the table below.

For transportation, it is recommended that the G5 Stack Switchgear be shipped in its original packaging via pallet whenever possible.

Symbol	Parameter	Min	Typ	Absolute Max	Unit
Thermal Specifications					
T _a	Operating Temperature	-20	25	60	°C
	Storage Temperature	-30	25	60	°C
Humidity Specifications					
RH	Operational Relative Humidity	5	-	85	%
	Storage Relative Humidity	5	-	85	%
Shock and Vibration Specifications					
Vertical	Vertical shock/vibration (SAE J2380)	-	-	10	m/s ²
Longitudinal	Longitudinal shock/vibration (SAE J2380)	-	-	10	m/s ²
Transverse	Transverse shock/vibration (SAE J2380)	-	-	10	m/s ²
Pulse vibration	On each axis (SAE J2464)	-	-	245	m/s ²

5.2. Status LEDs

The status LEDs provide an indication of the functional status of the G5 Stack Switchgear and G5 Cell Interface A more detailed status may be accessed via the G5 Operator Interface.

5.2.1. G5 Stack Switchgear Status LEDs

The two LEDs on the front panel of the G5 Stack Switchgear indicate health and functional status to the user.



Figure 23. Fault and Power LEDs

Power LED

The **POWER** LED (green) indicates that the system is powered on (AC power is provided and the AC power input breaker is closed).

Fault LED

The **FAULT** LED (red) indicates that the system is in a fault state and requires attention to become operational. The Operator Interface's fault page can be used to find the nature of the fault.

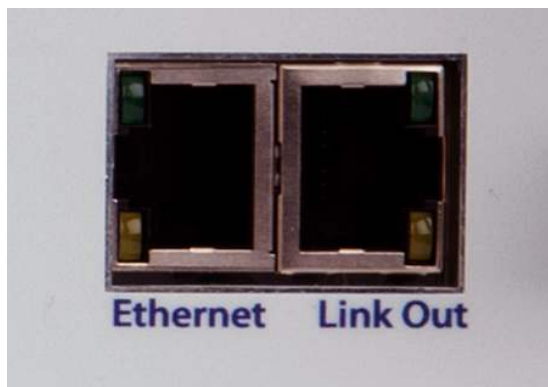


Figure 24. Ethernet and Link Out LEDs

Ethernet LEDs

There are two LEDs on the left side of the connector labelled 'Ethernet' on the G5 Stack Switchgear.

The upper LED is the *Activity* LED. A solid light means a connection between the devices. The LED will flash whenever data is being transmitted. No light means that there is no current connection.

The lower LED is the *Line Speed* indicator for Ethernet data speeds. It will be orange for 10 Mbit and green for 100 MBit line speeds.

Link Out LEDs

There are two LEDs on the right side of the connector labelled 'Link Out' on the G5 Stack

Switchgear.

The upper LED is the green *Activity* LED. This LED state combined with the Power and Fault LEDs states provide information on the G5 High-Voltage BMS state. Examples of the states indicated include :

1. Factory and IP Resets
2. Firmware Upgrades
3. Faulted states
4. Self-Test
5. Service Lockout

The lower LED is the yellow *Link Bus State* indicator. This LED will blink to indicate successful Link Bus communication with at least one or more G5 Cell Interface. When this LED is off, it indicates there is no communication with any G5 Cell Interface. When this LED is lit solid, it indicates a Linkbus related fault has tripped.

5.2.2. G5 Cell Interface Status LEDs

Activity LED

There is one blue LED mounted internally on the PCB within the G5 Cell Interface enclosure. To observe whether this LED is lit, an observer would have to look through the slots in the enclosure.

The activity LED is lit when the G5 Cell Interface is receiving valid traffic over its Link-bus interface. Communication failures in a Link-bus chain can be observed by ensuring each successive G5 Cell Interface connected to the G5 Stack Switchgear has a lit Activity LED.

5.3. Using the Operator Interface

5.3.1. The Dashboard Tab

The default tab of the Operator Interface is the Dashboard. The Dashboard contains a high-level overview on the state of the battery stack. This is the only page required for daily monitoring of the battery stack.

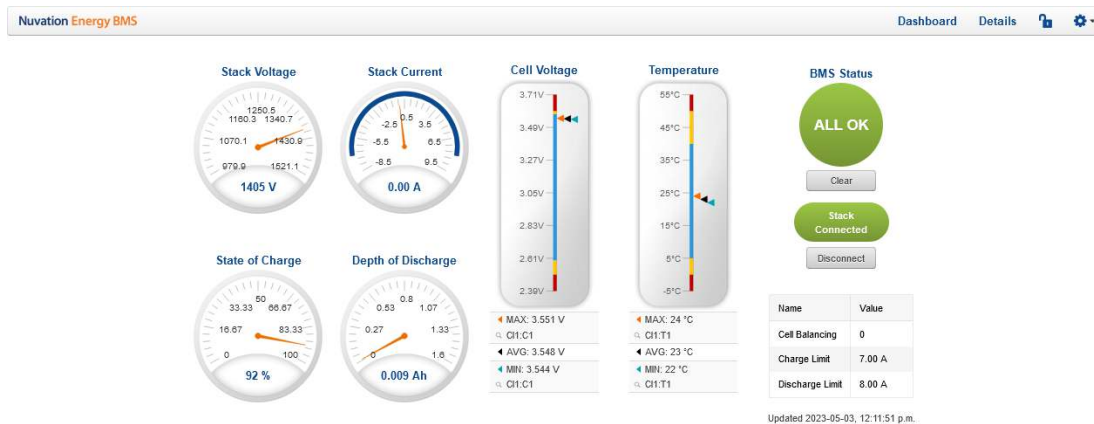


Figure 25. Nuvation Energy BMS Operator Interface Dashboard screenshot

5.3.1.1. Warnings and Faults

Before going into the details of the gauges and information presented in the dashboard, it is important to understand what a fault and a warning Nuvation Energy BMS status means.



An ALL OK indicates that there are no faults or warning. This is the normal state for Nuvation Energy BMS.



A Warning indicates the state of the battery system has been detected outside of its normal operational range. The cause of the warning should be identified and a corrective action should be performed. For instance, if the warning is a thermistor temperature measurement has become too hot, the battery system should be cooled to bring the measurement back into the normal operational range.

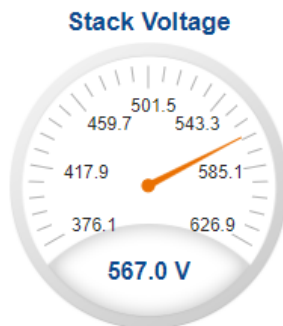


A Fault indicates the state of the battery system has been detected outside of its safe operational range. The cause of the fault must be identified and a corrective action must be performed. For instance, if the fault is a cell voltage measurement has become too low, the cell maintenance manual must be reviewed to identify what remedial actions are required.

A Fault is more severe than a Warning and the source of the fault must be discovered and resolved before attempting to clear and continue operating the battery system.

5.3.1.2. Stack Voltage

The stack voltage radial meter shows the total battery stack voltage.



5.3.1.3. Stack Current

The stack current radial gauge shows the battery stack current as well as the maximum charge current limit and the maximum discharge current limit. The acceptable current range is visualized on the gauge by the blue arc. An absence of the blue arc indicates the battery stack cannot be charged or discharged in its present condition.

A negative current value indicates the battery stack is charging. A positive current value indicates the battery stack is discharging.



5.3.1.4. State-of-Charge

The State-of-Charge radial gauge shows the battery stack's State-of-Charge. The battery stack is empty when the State-of-Charge value is 0% and full when the State-of-Charge value is 100%.

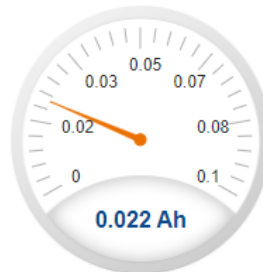
State of Charge



5.3.1.5. Depth-of-Discharge

The Depth-of-Discharge radial gauge shows how much energy has been taken out of the battery stack. In an ideal energy storage system, defined as a system with no power losses, the amount of energy shown in this gauge needs to be added back into the battery stack to fill it back up to 100% State-of-Charge.

Depth of Discharge



5.3.1.6. Cell Voltage

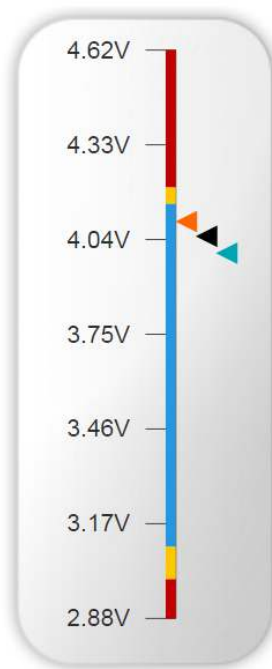
The cell voltage bar gauge shows the maximum, minimum, and average cell voltage measurements within the stack.

The high cell voltage and low cell voltage warning and fault threshold is visualized on the gauge with yellow and red segments. The blue segment depicts the acceptable cell voltage range.

If a triangle enters the yellow segment, a warning has occurred. If a triangle enters the red segment, a fault has occurred.

The maximum and minimum cell location in the stack and their voltage values are shown below the gauge, along with the average cell voltage value.

Cell Voltage



◀ MAX: 4.095 V

🔍 CI1:C3

◀ AVG: 4.05 V

◀ MIN: 3.998 V

🔍 CI1:C1

5.3.1.7. Temperature

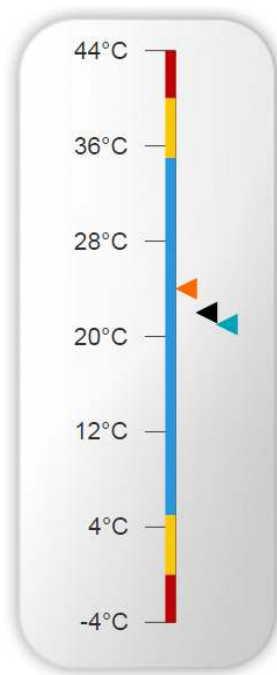
The temperature bar gauge shows the maximum, minimum, and average cell temperature measurements within the stack.

The high cell temperature and low cell temperature warning and fault threshold is visualized on the gauge with yellow and red segments. The blue segment depicts the acceptable cell temperature range.

If a triangle enters the yellow segment, a warning has occurred. If a triangle enters the red segment, a fault has occurred.

The maximum and minimum cell location in the stack and their temperature values are shown below the gauge, along with the average cell temperature value.

Temperature



◀ MAX: 24 °C

🔍 [CI7:T3](#)

◀ AVG: 22 °C

◀ MIN: 21 °C

🔍 [CI10:T4](#)

5.3.1.8. Nuvation Energy BMS Status

Nuvation Energy BMS status information contains information on the overall safety status of the battery stacks, the battery stack connection state, number of cells balancing, maximum charge current limit, maximum discharge current, and the time and date of the last update of the Dashboard.

Operation Status

Nuvation Energy BMS operation state is shown in the big status circular indicator.



Figure 26. Three possible Nuvation Energy BMS operation states

The normal state is All OK and the color of the indicator will be green. The warning state is Warning and the color of the indicator will be orange. The fault state is Fault and the color of the indicator will be red.

Clicking on the indicator will jump to a comprehensive status list of warnings and faults active in the battery stack.

Clicking on the Clear button below the state will cancel any warnings and faults that are not self-clearing.

Connection State

The battery stack connection state is shown in the oval indicator.



Figure 27. Three possible connection states

Stack Disconnected in a red oval indicates the SSG contactors are open, and the battery stack is unavailable to be charged or discharged.

Stack Pre-charging in an orange oval indicates the battery stack has connected its pre-charge circuit and is attempting to equalize the battery stack voltage to the system DC bus voltage.

Stack Connected in a green oval indicates the battery stack is available to be charged or discharged.

Clicking the Connect button initiates the stack connection sequence of events. Nuvation Energy BMS must be in the All OK state for the Connect button to be available.

Clicking the Disconnect button will disconnect the battery stack from the system DC bus.

Information Table

The information table shows the number of cells that are having excess energy bled off to maintain a balanced battery stack.

Name	Value
Cell Balancing	0
Charge Limit	7 A
Discharge Limit	8 A

The Charge Limit shows the maximum charge current limit value. The Discharge Limit shows the maximum discharge current limit value.

The Charge Limit and Discharge Limit values are visualized on the Stack Current radial gauge as the limits of the blue arc.

Last Update

The Updated time and date shows the last time the Operator Interface had successfully communicated with Nuvation Energy BMS and updated all items in the Dashboard with values from Nuvation Energy BMS. The time and date is based on the local computer/tablet; it does not come from Nuvation Energy BMS.

If the communication with a Nuvation Energy BMS is lost, a notification banner appears at the top of the display screen. The information shown on the Dashboard represents the last data received and is no longer recent. Refer to [Section 5.3.4.3, "Communication Loss"](#) for more details.

5.3.2. The Details Tab

The Details tab contains a much more detailed view into the status of Nuvation Energy BMS. The data values shown in this tab can be easily copied into a spreadsheet as a means of capturing the current state of Nuvation Energy BMS for manual data recording purposes.

The Details tab has multiple sub-sections called *accordions* that can be expanded to reveal more information. You can have multiple accordions expanded at the same time.



Figure 28. Nuvation Energy BMS Operator Interface Details tab screenshot

5.3.2.1. Addressing

The Addressing accordion presents the addressing information for your Nuvation Energy BMS.

Addressing		Last update: Fri Nov 29 2019 12:42:32 GMT-0500 (Eastern Standard Time)
Network	Address	
IP	192.168.1.21	
Modbus RTU	1	
CAN	10	

Figure 29. Addressing accordion in Details Tab

5.3.2.2. Battery

The Battery accordion contains values on the overall battery stack and the maximum charge current limit, the maximum discharge current limit, and the number of cells balancing in the battery stack. This information is identical to the values shown in the radial gauges, the bar gauges and the Information Table on the Dashboard.

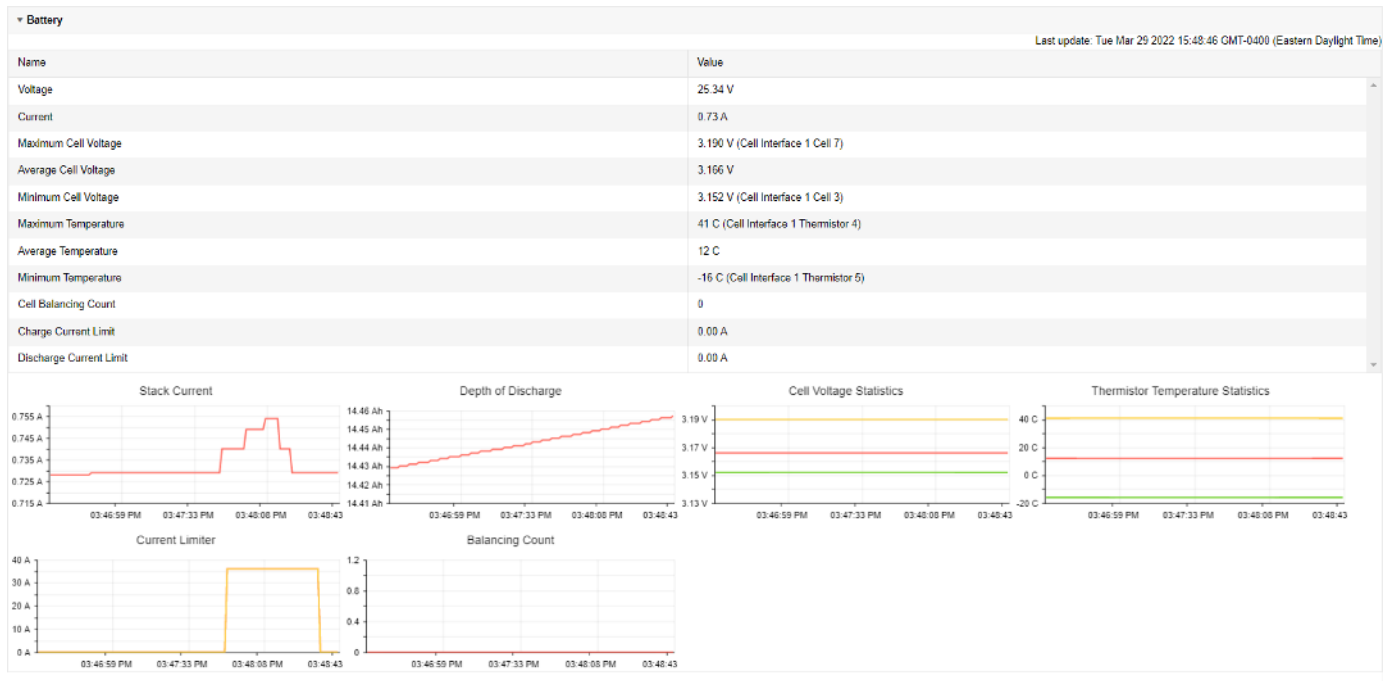


Figure 30. Battery accordion in Details Tab

5.3.2.3. Safety

The Safety accordion contains a comprehensive list of all possible Nuvation Energy BMS faults and warnings as well as the overall status of the battery stack. An active fault is shown as Tripped. An active warning or user trigger is shown as Triggered. A fault or warning that has not completed its self check is shown as Checking. In normal operation, all warnings and faults should be clear and the battery stack can be charged and discharged.

▼ Safety

Last update: Fri Mar 25 2022 17:25:44 GMT-0400 (Eastern Daylight Time)

Name	State	Trigger
Stack Under Voltage Fault	Clear	stack_fault_voltage_under
Stack Over Voltage Fault	Clear	stack_fault_voltage_over
Stack Low Voltage Fault	Clear	stack_fault_voltage_lo
Stack High Voltage Fault	Clear	stack_fault_voltage_hi
Cell Under Voltage Fault	Clear	stack_fault_cell_under
Cell Over Voltage Fault	Clear	stack_fault_cell_over
Cell Low Voltage Fault	Clear	stack_fault_cell_lo
Cell High Voltage Fault	Clear	stack_fault_cell_hi
Discharge Under Temperature Fault	Clear	stack_fault_discharge_therm_under
Discharge Over Temperature Fault	Clear	stack_fault_discharge_therm_over

Figure 31. Safety accordion in Details Tab

Clicking on the Clear Faults and Warnings button at the bottom of this accordion will clear any faults and warnings that are not self-clearing. The Clear button on the Dashboard can also be used.

Stack Under Voltage Lockout	Clear	stack_uvlo_stack_voltage
Cell Under Voltage Lockout	Clear	stack_uvlo_cell_voltage
Discharge High Current User	Clear	stack_trig_discharge_current_hi
Charge High Current User	Clear	stack_trig_charge_current_hi
Discharge Low Temperature User	Clear	stack_trig_discharge_therm_lo
Discharge High Temperature User	Clear	stack_trig_discharge_therm_hi
Charge Low Temperature User	Clear	stack_trig_charge_therm_lo
Charge High Temperature User	Clear	stack_trig_charge_therm_hi
Stack Low Voltage User	Clear	stack_trig_voltage_lo
Stack High Voltage User	Clear	stack_trig_voltage_hi
Cell Low Voltage User	Clear	stack_trig_cell_lo
Cell High Voltage User	Clear	stack_trig_cell_hi
Stack Controller Configuration Consistency Check Fault	Clear	sc_fault_config

Clear Faults and Warnings
Generate Report

Figure 32. Bottom of Safety accordion in Details Tab

Clicking on the Generate Report button at the bottom of this accordion will generate a safety report JSON file with a list of the Nuvation Energy BMS faults and warnings and their current state as well as the current firmware versions.

5.3.2.4. Cell Voltages

The Cell Voltages accordion lists voltage measurements for all Cells configured in the Configuration file. Cells that are not configured are displayed as a - (hyphen). Voltages in red indicate measurements which have triggered a Nuvation Energy BMS fault. Voltages that are highlighted in yellow are open wires. There is no differentiation between cells that are in the normal operating voltage range and cells that have triggered a Nuvation Energy BMS warning. There is also no indication of which particular cells are currently being balanced by the BMS.

Cell Voltages

Filter:

Off

Above

Below

Last update: Fri Mar 25 2022 16:21:03 GMT-0400 (Eastern Daylight Time)

	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9	Cell 10	Cell 11	Cell 12	Cell 13	Cell 14	Cell 15	Cell 16
Cl 1	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-
Cl 2	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-
Cl 3	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-
Cl 4	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-
Cl 5	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-
Cl 6	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-
Cl 7	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-
Cl 8	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-

Figure 33. Cell Voltages accordion in Details Tab

Cell Voltages

Filter: Off Above Below Legend: Open Wires

Last update: Wed Nov 20 2019 14:50:46 GMT-0500 (Eastern Standard Time)

	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9	Cell 10	Cell 11	Cell 12	Cell 13	Cell 14	Cell 15	Cell 16
CI 1	3.335 V	3.333 V	3.332 V	3.333 V	3.332 V	3.332 V	3.333 V	3.333 V	3.334 V	3.331 V	3.331 V	3.333 V	-	-	-	-
CI 2	3.334 V	3.333 V	3.333 V	3.334 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.334 V	3.334 V	-	-	-	-
CI 3	3.334 V	3.333 V	3.334 V	3.333 V	3.334 V	3.333 V	3.333 V	3.333 V	3.334 V	3.334 V	3.334 V	3.334 V	-	-	-	-
CI 4	3.333 V	3.335 V	3.334 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.334 V	-	-	-	-
CI 5	3.334 V	3.333 V	3.334 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-
CI 6	3.333 V	3.333 V	3.332 V	3.333 V	3.333 V	3.332 V	3.333 V	3.333 V	3.334 V	3.333 V	3.333 V	3.333 V	-	-	-	-
CI 7	3.334 V	3.333 V	3.333 V	3.333 V	3.334 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-
CI 8	3.333 V	3.334 V	3.333 V	3.334 V	3.333 V	3.333 V	3.333 V	3.334 V	3.333 V	3.333 V	3.333 V	3.333 V	-	-	-	-

Figure 34. Cell Voltages with open wires according in Details Tab

Filtering

You can filter the display to highlight cells with voltages above or below a value you specify. The values that match the criteria will be bolded and all other values will be faded.

Filter: Off Above Below

	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8
CI 1	3.334 V	3.333 V	3.332 V	3.333 V	3.332 V	3.333 V	3.333 V	3.333 V

5.3.2.5. Thermistor Temperatures

The Thermistor Temperatures accordion lists temperature measurements for all Thermistors configured in the Configuration file. Thermistors that are not configured are displayed as a dash. Temperatures in red indicate measurements which have triggered a Nuvation Energy BMS fault. There is no differentiation between thermistors that are in the normal operating temperature range and thermistors that have triggered a Nuvation Energy BMS warning.

Thermistor Temperatures

Filter: Off Above Below

Last update: Fri Nov 29 2019 12:50:06 GMT-0500 (Eastern Standard Time)

	Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	Index 7	Index 8
CI 1	27 °C	27 °C	27 °C	26 °C	27 °C	27 °C	-	-
CI 2	27 °C	27 °C	28 °C	27 °C	28 °C	27 °C	-	-
CI 3	26 °C	26 °C	27 °C	27 °C	27 °C	27 °C	-	-
CI 4	27 °C	27 °C	27 °C	27 °C	27 °C	27 °C	-	-
CI 5	28 °C	27 °C	27 °C	27 °C	27 °C	27 °C	-	-
CI 6	27 °C	27 °C	27 °C	28 °C	27 °C	27 °C	-	-
CI 7	26 °C	26 °C	26 °C	27 °C	27 °C	27 °C	-	-
CI 8	27 °C	27 °C	27 °C	28 °C	27 °C	27 °C	-	-

Figure 35. Thermistor accordion in Details Tab

Filtering

You can filter the display to highlight cells with temperatures above or below a value you specify. The values that match the criteria will be bolded and all other values will be faded.

Filter: Off Above Below

	Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	Index 7	Index 8
CI 1	27 °C	27 °C	27 °C	26 °C	27 °C	27 °C	-	-

5.3.2.6. Open Wire

The Open Wire accordion lists open wire diagnostics for all Cells configured in the Configuration file. Cells that are not configured are displayed as a - (hyphen). Diagnostic data that is highlighted in yellow indicates an open wire.

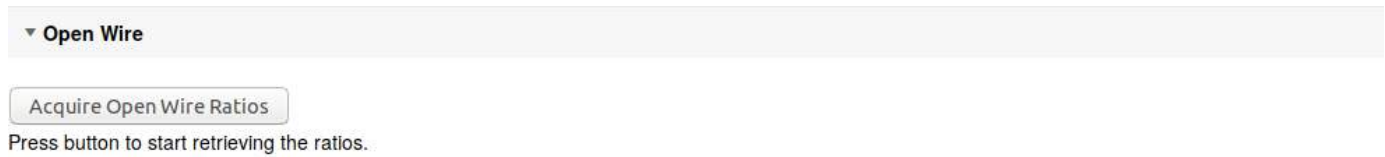


Figure 36. Open Wire accordion in Details Tab

To trigger diagnostics on all cells, click the "Acquire Open Wire Ratios" button. Once clicked, the open wire scanning process begins.

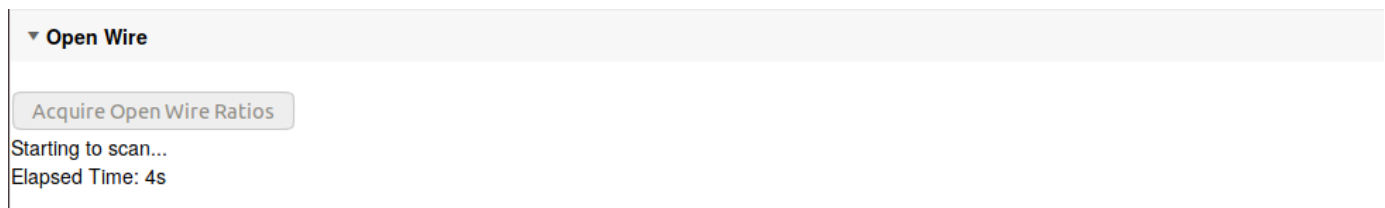


Figure 37. Open Wire acquiring accordion in Details Tab

Once the open wire scanning has completed and all diagnostics data is collected it is displayed in a tabular format with open wires highlighted in yellow.

Open Wire															
Acquire Open Wire Ratios															
Success getting open wire ratios															
Filter	Cell	Device	Device												
Legend	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9	Cell 10	Cell 11	Cell 12	Cell 13	Cell 14	Cell 15
Cell 1	0.920	0.921	0.922	0.922	0.919	0.919	0.921	0.920	0.920	0.921	0.916	0.920	-	-	-
Cell 2	0.920	0.921	0.922	0.924	0.924	0.925	0.925	0.925	0.924	0.925	0.923	0.921	-	-	-
Cell 3	0.920	0.920	0.922	0.924	0.924	0.925	0.925	0.924	0.925	0.924	0.922	0.920	-	-	-
Cell 4	0.922	0.922	0.921	0.924	0.924	0.925	0.925	0.923	0.923	0.923	0.924	0.923	-	-	-
Cell 5	0.920	0.922	0.921	0.921	0.922	0.922	0.922	0.922	0.922	0.921	0.920	0.920	-	-	-
Cell 6	0.920	0.920	0.920	0.920	0.920	0.920	0.920	0.920	0.920	0.920	0.920	0.920	-	-	-
Cell 7	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	-	-	-
Cell 8	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	-	-	-

Figure 38. Open Wire diagnostics accordion in Details Tab

The diagnostic values displayed are ratios of Voltage. Values very close to one (> 0.97) indicate a short condition. Values approaching zero (0.0 to 0.4) indicate an open wire connection.

Filtering

Use the filter to highlight ratios of Voltage that are above or below the specified value. The values that match the criteria will be bolded and all other values will be faded.

Filter:	Off	Approve	Below	<input type="text" value="0.9"/>				
	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8
Cl 1	0.900	0.920	0.600	0.900	0.920	0.900	0.600	0.900

5.3.2.7. SoC Calibration

The State of Charge Calibration accordion allows for calibration of SoC and reset of the measured capacity estimate. This accordion is only visible if the OCV is enabled (stack_soc.ocv_enabled). Both of these operations are only enabled when the battery is operational (not in service lockout) but disconnected (stack_control.actual_state == 0).

▼ SOC Calibration

Last update: Fri Mar 25 2022 16:27:06 GMT-0400 (Eastern Daylight Time)

Battery Charge

State of Charge	67 %
Depth of Discharge	0.150 Ah

Calibrate

SOC is calibrated from cell voltages using the open-circuit voltage curve. Battery contactors must be disconnected to calibrate.

Battery Capacity

Measured Capacity	0.000 Ah
Nameplate Capacity	1.500 Ah

Reset

Capacity is reset to stack nameplate rating while accounting for cell SOC imbalance. Battery contactors must be disconnected to reset.

Figure 39. SoC Calibration accordion in Details Tab

5.3.3. The Menu Options

The menu to the right of the Operator Interface provides access to tools and advanced options. Some of these options may be locked to prevent accidental changes.

The following options are available:

- Registers
- Service
- Connection
- Unlock
- About

5.3.3.1. Registers

This menu option navigates to the Register Browser. This screen allows you to read and write to registers.

When the Operator Interface is locked, the Register Browser is in a view-only mode, restricting the editing of registers.

Register Browser

Selected Register Information:

Component Index Register

Value

Read Write

Manual Register Configuration

Component Name	Description	Base Address	Instance Count per Stack
sc_clock	Clocking Component	0x29000	1

Figure 40. Register Browser

5.3.3.2. Service

This screen allows you to enter and exit Service Lockout in-order to perform an upgrade or configuration file import.

Importing a Configuration File



This is a restricted option requiring the Operator Interface to be unlocked to access this option.

This menu option allows you to import a configuration file.



The G5 High-Voltage BMS ships with a configuration file specific for its end application. Serious problems might occur if the configuration settings are incorrectly modified. If you need assistance with modifying the configuration file, please contact support@nuvationenergy.com.

Exporting a Configuration File



Nuvation Energy BMS does not preserve the originally imported configuration file with comments and formatting. The export feature will export a configuration file with an alphabetical listing of all registers and their set values.

To export your configuration file:

1. From the menu, select Service
2. Click Export Configuration

Upgrade



This is restricted option requiring the Operator Interface to be unlocked to access this option.



The firmware upgrade will erase the configuration file on your Nuvation Energy BMS. Please remember to export and save your current configuration file to save your current configuration file for future reference.



Please contact support@nuvationenergy.com before attempting a firmware upgrade. The current configuration file may not be compatible with different firmware version. Without a valid configuration file, the Stack Switchgear will be rendered non-functional.

Updating a Label

A label is the string displayed on the top banner of the Operator Interface. An owner can configure a name for each stack using the label. When the Operator Interface connects to a stack the operator knows immediately what stack they are connected to.



To update a label:

1. From the menu, select Service
2. Click Edit under the label section

Label

The label is used to identify which BMS you are connected to.

Edit

Apply

3. Enter a suitable name for the stack

4. Click Apply



The Operator Interface automatically saves the label in persistent storage when applied.



A label does not handle spaces. Use hyphens or underscores to delineate words.



Editing an IP Address

To edit an IP address:

1. From the menu, select Service
2. Click Edit under the ethernet section

Ethernet

The local IP network configuration used by this BMS.

IP Address

0.0.0.0

Netmask

0.0.0.0

Gateway

0.0.0.0

Edit

Apply

3. Enter the IP address of your choice

4. Click Apply



The updated IP is saved and in immediate use after the Apply action. Any prior connections via Modbus TCP would have to be reconnected using the updated IP.



Applying changes will disconnect the battery and restart the BMS.

5.3.3.3. Connection

The connection page allows you to change the IP address and timeout of the Nuvation Energy BMS that you are trying to access.

If you are connecting to a Nuvation Energy BMS that does not use the default IP address (192.168.1.21), you will need to change the connection settings in the Operator Interface to match the BMS.



In scenarios where there are multiple BMS systems, it is possible to direct multiple instances of the Operator Interface at the different BMS IP addresses.

5.3.3.4. Locking and Unlocking

The Operator Interface can be locked to prevent accidental or unintentional changes that could have serious impacts on the system. To further secure the system, a password can be set to ensure only authorized individuals can access these critical sections of the Operator Interface



The G5 High-Voltage BMS ships from the factory with password protection on the Operator Interface. Please contact support@nuvationenergy.com for the factory password and documentation for advanced modifications of the G5 High-Voltage BMS.

When the Operator Interface is unlocked, the lock indicator will be replaced with an unlocked indicator.



Figure 41. Operator Interface Locked indicator



Figure 42. Operator Interface Unlocked indicator

Lock the Operator Interface

To lock the Operator Interface, simply click the Unlocked indicator or bring up the settings menu and select Lock.



To prevent accidental changes to your Nuvation Energy BMS, always lock the Operator Interface after making your changes.

It is possible to require a password to unlock the Operator Interface.

Unlock the Operator Interface

To Unlock the Operator Interface, simply click the Locked indicator or bring up the settings menu and select Unlock. If a password has been set, the correct password will need to be entered to complete the unlocking process.

5.3.3.5. About

This screen displays version details for the underlying software for your Nuvation Energy BMS. The name and number of the current software release are displayed at the top of the About screen.

In the screenshot below, the release name is at the top in large blue letters. The version number following the release name has a format of yy.mm with yy representing the year and mm representing the month within that year that this Nuvation Energy BMS package was released.

The version numbers below the release name are the version numbers of the individual software packages running on your Nuvation Energy BMS.

When contacting support, please include the details in your About screen.

About This BMS

Software Version	
OI:	0.63.0
SC:	5.5.1 (Faraday Release Candidate 2.1)
SC BL:	5.5.1
AFE:	0.6.1

Figure 43. Sample About Screen

5.3.4. The Status Banner

The banner at the top of the screen is used to indicate high level changes in system status. During typical operation nothing is displayed and this indicates the Operator Interface is communicating with the BMS and the BMS is fully operational with no major diagnostics problems.


5.3.4.1. Service Lockout Indication

When the system is either entering or is in service lockout, a banner is displayed indicating this to the user.

A red rectangular banner with the text "Service Lockout" in white.

Service Lockout

Figure 44. Operator Interface Service Lockout indicator

A red rectangular banner with the text "Entering Lockout" in white.

Entering Lockout

Figure 45. Operator Interface Entering Service Lockout indicator

5.3.4.2. Self Check Indication

When the system is either exiting service lockout or has just booted, the system will execute a Self Check to verify a safe operation. A banner is displayed indicating the Self Check execution to the user.

A red rectangular banner with a white circle icon containing a checkmark, followed by the text "Self-Check" in white.

Self-Check

Figure 46. Operator Interface Self Check indicator

5.3.4.3. Communication Loss

When the Operator Interface can no longer communicate with the Battery Management System, a communication lost banner is displayed at the top of the display. It will provide the amount of time since disconnected and updates each second.

A red rectangular banner with the text "Communication to BMS lost: Data last updated 4 seconds ago" in white.

Communication to BMS lost: Data last updated 4 seconds ago

Figure 47. Operator Interface Communication lost indicator

5.4. G5 BMS Firmware Features

The following section details the software features of the G5 High-Voltage BMS

5.4.1. Continuous Balancing

G5 High-Voltage BMS introduces a new passive balancing operation which will increase the operational time of a battery stack and minimize the time spent balancing cells. Traditional voltage based balancing requires that the cells maintain a difference in voltages to identify the cells requiring balancing. This voltage difference must be maintained to allow balancing to act on the cells of the highest voltages. Such an operation can cause the battery stack to be offline for hours to allow the cell balancing to complete.

Continuous balancing is a new algorithm that minimizes this operational downtime by the following procedure:

1. A Nuvation Energy BMS continuously provide estimates on the imbalance in cells of a stack. The best results of imbalance estimations are often at the top of a charge cycle of a battery stack but can vary by the battery chemistry.
2. After the imbalance estimates have been captured, the software will begin to apply passive balancing to the cells with the highest imbalance. A stack can resume its operation while this balancing occurs.
3. BMS software provide status on the amount of imbalance remaining for the cells. After the imbalance has been removed, it is suggested that the stack could repeat its charge cycle to capture the next cell imbalance estimates.
4. This process is repeated while until the imbalance estimates are small and no longer trigger any balancing actions.



Cell imbalance estimations are periodically persisted and will recover after a reboot of the G5 Stack Switchgear



Cell balance estimations will be using confidence intervals and are only updated when there is a high confidence in the imbalance estimation. The best confidence estimates for imbalance are at the top of the charge cycle in the final few SoC percentages before a stack is full. It is highly suggested that the stack is controlled using a properly configured BMS current limits to approach the full state of a stack.

5.4.1.1. Cell Imbalance Estimations Configuration

Cell imbalance estimation is configured using the following registers:

Table 10. Cell Imbalance Estimation Configuration

Register	Suggested Value	Description
stack_soc_distribution_estimator[0]. enabled	1	Enables the estimation of SoC distribution used in the new balancing algorithm.

Register	Suggested Value	Description
stack_soc_distribution_estimator[0]. measurement_error	3	Standard deviation of the noise in the voltage measurements.
stack_soc_distribution_estimator[0]. ohmic_resistance_error	Nominal_resistance * 0.05	Standard deviation of the noise in the ohmic resistance estimates.
stack_soc_distribution_estimator[0]. ohmic_resistance_error	Nominal_resistance * 0.05	Standard deviation of the noise in the ohmic resistance estimates.
stack_soc_distribution_estimator[0]. critical_value	2	Value used to determine the upper and lower thresholds of confidence interval. For a normal distribution, a value of 2 indicates 95% confidence.
stack_imbalance_estimator[0]. upper_estimation_window	95	Defines an SoC estimation window, from full to a specific SoC point, where imbalance estimation can occur. A value of 95% means, imbalance estimation can occur between 95% and 100% SoC. Set this value to zero 100% when doing bottom-balancing
stack_imbalance_estimator[0]. lower_estimation_window	0	Defines an SoC estimation window, from a specific SoC point to empty, where imbalance estimation can occur. A value of 5% means, imbalance estimation can occur between 0% and 5% SoC. Set this value to zero 0% when doing top-balancing
stack_cell_state_estimator[0]. disable_measurement_update	1	Register to disable the measurement update in the recursive Bayesian filter for estimating the battery states



Cell imbalance estimation requires the configuration of an OCV table for the cells. Enabling imbalance detection is not meaningful without this configuration.

5.4.1.2. Cell Imbalance Estimation Components

Table 11. Cell Imbalance Components

Component	Instances	Description
stack_soc_distribution_estimator	480	Component that estimates the soc distribution at a per cell level using voltage measurements.
stack_soc_distribution	480	Component that stores the values of the soc distribution at a per cell level
stack_soc_distribution_fresh	1	Component to ensure the freshness of the soc distribution estimates
stack_soc_mean_stat	1	Component that calculates statistics such as min/max/average for the soc estimate
stack_soc_interval_width_stat	1	Component that calculates statistics such as Min/max/average for the soc interval width
stack_imbalance_estimator	1	Component that estimate cell level imbalance using the soc distribution values

Component	Instances	Description
cell_imbalance	480	Component that stores the value of the imbalance estimates at a per cell level
stack_cell_imbalance_stat	1	Component that calculates statistics such as min/max/average for the cell imbalance estimates

5.4.1.3. Cell Imbalance Estimations Status

The following registers provide an status of the imbalance estimates. The imbalance estimates are reduced by the amount of energy removed from applied balancing . Balancing will halt when all imbalance estimates are reduced to zero.

Table 12. Cell Imbalance Registers

Registers	Instances	Description
stack_imbalance_estimator[0].imbalance_estimation_uncertainty	1	Register used to qualify the uncertainty associated with the imbalance estimation.
cell_imbalance[0]. imbalance_estimate	480	Register to store the amount of estimated cell imbalance as output from the stack_imbalance_estimator

5.4.1.4. Continuous Balancing Configuration

Two new configuration registers have been added for configuring the continuous balancing algorithm

Table 13. Continuous Balancing Algorithm Configuration

Register	Suggested Value	Description
stack_balancing_selector[0].enable_soc_balancer	1	Enables the execution of the continuous balancing algorithm, that is based on cell level SoC.
stack_imbalance_estimator[0].balancing_resistor	25500000	Value of the resistor in the Nuvation Energy G5 Cell Interface used for balancing.



In addition to these configurations, the continuous balancing algorithm requires an initial cell model for improved performance.

+ Please contact support@nuvationenergy.com for help configuring the battery model.

5.4.2. Under Voltage Lockout (UVLO)

The Under Voltage Lockout feature is an emergency state detected by the firmware which will remove power from the G5 Stack Switchgear if the stack voltage or any cell voltage reaches a critically low value. This feature will help preserve the battery cells and prevent further damage by continuing BMS operation in this critical state. To enable this feature requires configuration setting of both hardware and the firmware.



Refer to [Table 2, "Config Switch Settings"](#) for details on the hardware configuration

to enable/disable the UVLO feature.



The Enable Input (refer to [I/O Connector](#)) can be asserted after a UVLO event to allow for a black start of the battery stack.

5.4.2.1. Configuration

The following faults/triggers must both be enabled and configured with appropriate voltage thresholds. The cell/stack faults are aggregated together by the `stack_uvlo_combined` component and its trigger output is used as an input to `ssg_uvlo_enable`.

- `stack_uvlo_cell_voltage`
- `stack_uvlo_stack_voltage`
- `stack_uvlo_combined`

Table 14. UVLO Enable Configuration

Register	Suggested Value	Description
<code>ssg_uvlo_enable[0].address</code>	<code>@stack_uvlo_combined[0].trig</code>	The register address read to indicate a UVLO event to trigger upon.
<code>ssg_uvlo_enable[0].address_enabled</code>	1	Boolean register that enables updates from the prior address configuration. UVLO feature is disabled when set to zero.
<code>ssg_uvlo_enable[0].inverted</code>	0	Boolean register to indicate if the data read from configured address register should be inverted.
<code>ssg_uvlo_enable[0].rising_edge_triggered</code>	0	Boolean register to indicate if the trigger is only updated on rising edges from the data read from the configured address register.
<code>ssg_uvlo_enable[0].falling_edge_triggered</code>	0	Boolean register to indicate if the trigger is only updated on falling edges from the data read from the configured address register.

5.4.3. Shutdown Input

The G5 Stack Switchgear provides a GPI Shutdown to allow for external shutdown. When the shutdown input is asserted for a minimum of 0.5 seconds, firmware will begin the process of disconnecting stacks (if connected) and then remove power from the G5 Stack Switchgear. The Shutdown input could remain asserted for longer durations. If the Shutdown is asserted continuously for 10 seconds, the G5 Stack Switchgear hardware will power down.



The Enable input can be asserted to reapply power to the G5 Stack Switchgear while in this shutdown state.



Shutdown will not be able to remove power if the UVLO feature is disabled in hardware. Refer to [Table 2, "Config Switch Settings"](#) for details on how to configure hardware to enable/disable UVLO. The firmware configuration for UVLO has no

impact for Shutdown feature. There is no firmware configuration required for the Shutdown feature.

5.4.4. Disconnect Input

A separate Disconnect input is available on the G5 High-Voltage BMS as noted in [I/O Connector](#). When the Disconnect input is asserted it will instruct the hardware/software to disconnect the stack. There are two modes of operation of the Disconnect input:

1. Nominal: Issues a software controlled disconnect sequence
2. Quick: Issues an immediate hardware controlled disconnect



For either mode, the BMS software requires a minimum assertion of 500 ms to make sure the Disconnect request is captured.



Review all the restrictions of this input behavior as noted in [I/O Connector](#)

5.4.4.1. Configuration

Table 15. Disconnect Input Configuration

Register	Description
ssg_hw_disconnect[0].mode	Configured with a value of either 0 = Nominal (software controlled) or 1 = Quick (hardware controlled)
ssg_hw_disconnect[0].inverted	Inverts the active state of the disconnect signal to the hardware. When inverted = 0, the Disconnect input is an active low signal while when inverted = 1, the Disconnect input is an active high signal.

5.4.4.2. Quick Disconnect

A quick disconnect provides the capability to configure the G5 Stack Switchgear to immediately disconnect a stack when its Disconnect input is asserted. Shortly after the assertion of the Disconnect input hardware will remove power simultaneously from all contactors. The minimum assertion period must be maintained on this signal while in this mode.

5.4.5. Fan Control (AC/DC)

The G5 Stack Switchgear provides the capability to configure the control of external AC and/or DC fans based on the current maximum cell temperature. The thresholds for this fan control has an independent configuration. The triggers for this fan control are not tied into any faults or warnings. However an independent warning for DC fan power failures is provided. Refer to [Section 5.4.5.2, "DC Fan Warning"](#) for the configuration of this warning.

The fan control also provides a means to configure manual fan control to assess fan wiring during installation or if there is a need to control the fans independently/externally from the G5 Stack Switchgear. This control management is detailed in the subsequent configuration subsection.

Please contact support@nuvationenergy.com for detailed instructions on wiring and installation of fans to the G5 Stack Switchgear.



The DC fan warning will currently trigger when no fans are installed. Please disable the warning if no fans are installed.

5.4.5.1. Configuration

The fan control introduces new triggers that are configured to control the fan output. These registers allow for temperature control in both the charge/discharge directions of the stack. These triggers are as follows:

1. `ssg_trig_fan_control_charge`
2. `ssg_trig_fan_control_discharge`

These charge/discharge triggers are aggregated to a single component named `ssg_trig_fan_control_aggregate`. These trigger components are based on standard hysteresis trigger components used in the BMS. It's recommended that the latched configuration of these registers be set to zero to allow the fans to automatically turn off as the temperatures of the cells drop below their configured limits.

There are separate controls to enable output for either or both AC or DC fan outputs. The configuration for this fan control is managed by the following registers.

Table 16. Fan Control Configuration

Register	Recommended Values	Description
<code>ssg_fan_control_ac[0].address</code>	Set to zero for manual control of AC fans or to the address of <code>ssg_trig_fan_control_aggregate[0].trig</code> register for cell temperature control of the fans.	Register to define the address of the register whose value is output to the AC fan control output.
<code>ssg_fan_control_ac[0].address_enabled</code>	Set to zero for manual control of AC fans or one to allow temperature control of the fans.	Register to define either the manual/temperature control of AC fans.
<code>ssg_fan_control_dc[0].address</code>	Set to zero for manual control of DC fans or to the address of <code>ssg_trig_fan_control_aggregate[0].trig</code> register for allow cell temperature control of the fans.	Register to define the address of the register whose value is output to the DC fan control output.
<code>ssg_fan_control_dc[0].address_enabled</code>	Set to zero for manual control of DC fans or one to allow a configuration for cell temperature driven control of the fans.	Register to define either the manual/temperature control of DC fans.

5.4.5.2. DC Fan Warning

The component `ssg_warn_fan_control_dc_error` provides information on failures of the DC fan operation as detected by the hardware driver. This warning uses a hysteresis trigger. The default settings of this trigger are the expected configuration for this warning.

Table 17. Default Settings for a DC Fan Warning

Register	Description
ssg_warn_fan_control_dc_error[0].disabled	1
ssg_warn_fan_control_dc_error[0].thresh	1
ssg_warn_fan_control_dc_error[0].time_hyst	0
ssg_warn_fan_control_dc_error[0].end_time_hyst	2000000
ssg_warn_fan_control_dc_error[0].latched	0



The DC fan warning will trigger when no DC fans are installed. The warning default configuration is disabled because of this behavior.



There is no equivalent warning for an AC fan.

5.4.6. Fault/Warning Bitfields

New registers have been added to the BMS firmware which aggregate the fault, warning and user defined triggers to separate bitfields. Likewise there is also a bitfield defined to identify the fault/warning/user triggers that are not initialized. This later data can be used to identify the cause(s) of why a BMS does not complete its self-test.

The following table lists the new bitfield registers.

Table 18. Aggregated Fault/Warning Bitfields

Register	Description
sc_bitfield_fault_triggered	Aggregation of all fault triggers to a bit field
sc_bitfield_warning_triggered	Aggregation of all warning triggers to a bit field
sc_bitfield_user_trig_triggered	Aggregation of all user defined triggers to a bit field

The registers for each bitfield component are defined as follows:

Table 19. Aggregated Bitfield Registers

Register	Description
sc_bitfield_*.bit_count	Number of aggregated bits in the bit field
sc_bitfield_*.bitfield	Aggregated bit field data
sc_bitfield_*.initialized	Indication of triggers that have been initialized. A trigger is initialized if the data it monitors has been received at least once. An uninitialized trigger is usually due to either a mis-configuration or a hardware failure that prevents data acquisition. An initialized trigger has passed its corresponding self check.

Several *helper* components are defined to identify which trigger each active bit in the bitfields is mapped to. The number of instances of each bitfield helper corresponds to the register value of `sc_bitfield_*.bit_count`. The helper instance index maps to each bit in the corresponding bitfield for `sc_bitfield_*.bitfield`. These bitfield associations are constant for the firmware released and will not

change due to any configuration change. The helper components available are as follows:

Table 20. Bitfield Helper Components

Component	Description
sc_bitfield_fault_helper	Helper component for the fault bitfield
sc_bitfield_warning_helper	Helper component for the warning bitfield
sc_bitfield_user_trig_helper	Helper component for the user trigger bitfield

Each helper component instance contains one register called:

```
sc_bitfield*_helper[*].base_address
```

These registers define the base address of the fault/warning/user trigger. The base addresses of every component can be read from a corresponding column on the Registers page accessed from the Operator Interface. Each helper instance is mapped 1:1 to the bit in the corresponding bitfield register.



Only a maximum of 63 bits are added to a bit field. This limit is imposed to avoid the case of 64 triggers being set which could be interpreted as an unimplemented point according to the SunSpec Modbus data models.

5.4.7. Balancing Counters per Cell

There is a persistent counter per cell of its number of cell balancing events. Every time during a cell measurement scan, any cell that is requested to be balanced has its corresponding counter incremented by one.

```
cell[instance].balancing_event_count
```

As long as the period of the CI scan does not change of over the life time of the stack operation, the total amount of balancing time can be calculated as follows:

$$\text{Total balancing time [s]} = \text{cell[instance].balancing_event_count} * \text{sc_linkbus.scan_period} / 1000000$$

The balancing event counters are persisted to non-volatile storage on a hourly period.

5.5. Communication Protocols

5.5.1. Modbus Protocol Support

Nuvation Energy BMS implements the SunSpec battery models defined in the Modular Energy Storage Architecture (MESA) as the top-level Modbus interface to the product. Specifically the BMS implements the MESA Draft 3 Storage models (800 Series).

The specifications for these models are available for download at <https://www.nuvationenergy.com/technical-resources>.



MESA Draft 3 is currently implemented on Nuvation Energy BMS.

5.5.1.1. Modbus TCP

This protocol is used for communications over TCP/IP networks. A single Modbus TCP connection is supported over port 502 for read and write access. All register data is transmitted as big endian (most significant byte first).

5.5.1.2. Implemented MESA Models

The MESA standards contain a number of 'models' that can be implemented by vendors to describe a storage device at various levels of detail. The models implemented by Nuvation Energy BMS are described in the sections below.

Detailed register maps for all Draft 3 models are found in the document *MESA-Energy-Storage-Information-Models_Draft_3.xlsx* found at the Nuvation Energy technical resources located at <https://www.nuvationenergy.com/technical-resources>.

Common Model

This model primarily contains information to identify the device (e.g. manufacturer, model, serial number) as well as the version of software running on the device. The Modbus address of this model is 40000. [Table 21, "Common Model Points"](#) describes the points of the Common Model as implemented in the BMS. A full description of the Common Model can be found in the SunSpec specification bundle.

Table 21. Common Model Points

Point Name	Address	Description	Note
SunSpec_ID	40000	Identifies this as a SunSpec Modbus Map	Set to 0x53756e53
ID	40002	Identifies Common Model Block	Set to 0x0001
L	40003	Length of block	Set to 66
Mn	40004	Device Manufacturer	Set to "Nuvation Engineering"
Md	40020	Device Model Number	Contents of BMS registers sc_mfg_info.manufacturing<0-3>

Point Name	Address	Description	Note
Opt	40036	Options	Set to "Fully Loaded"
Vr	40044	Version Information	Contents of the sc_fw_image.build_version and sc_fw_image.build_id BMS registers separated by a colon
SN	40052	Device Serial Number	Contents of BMS registers sc_mfg_info.serialnumber<0-1>
DA	40068	Device Address	Set to 0x1234

S801

This model describes an energy storage device at the highest possible level. State-of-Charge and overall alarm and warning states are found here. All mandatory points are implemented. The Modbus address of this model is 40070.

S802

This model describes a battery storage device. At this level, the critical operational information includes the charge and discharge current limits. All mandatory points are implemented. The Modbus address of this model is 40094.

S803

This model describes a lithium-ion battery in detail. Voltage, temperature, and current statistics are available at the pack and stack level within this model. All mandatory and most optional points are implemented. The Modbus address of this model is 40116.

End Model

This model marks the end of the implemented Modbus address space.

5.5.1.3. MESA Model Structure and Nomenclature

This section is a clarification of terms used to describe a MESA model. It is used to understand the terminology in the spreadsheet presented in the previous section.

Points

All MESA models are a collection of points (i.e. Modbus registers). These points can be one or more Modbus registers in length. By definition, each Modbus register is 16 bits wide. For points that are larger than one Modbus register, partial read accesses are not allowed. A modbus request to a MESA point must read all registers that make up the point. Otherwise, a Modbus read/write error is returned on such an access.

For example, the MESA s802 model has the Evt1 point which is of type bitfield32. In this case, the point spans 2 Modbus register and so a request to read this point must read 2 modbus registers.

Fixed/Repeating Blocks

MESA models are described as collections of Fixed and Repeating blocks of points. A Fixed block is a set of points that is always defined and never changes in its size. A Repeating block describes a set of related points (i.e. usually for a string of batteries) of which there could be multiple instances of the Repeating blocks. The points within a repeating block are the same but these sets of blocks are concatenated sequentially.

For example in the 803 model, there is a set of repeating blocks that describe data for a particular stack/string of batteries. Accessing the 803 repeating block corresponds to using a stack/string index (0, 1, 2, ...) to access the desired repeating block.

For a single-stack Nuvation Energy BMS there is only one 803 repeating block. If a stack/string is configured in Nuvation Energy BMS software to be installed, then accessing its 803 repeating block will provide a valid Modbus response.

Repeating blocks are taken into account in the length indicated in the model header.

Unimplemented Points

Any MESA point that is not implemented by a vendor will generate an unimplemented response. The response will be a valid Modbus read response but all point data returned will report unimplemented values. The unimplemented values vary by type as listed in the following table.

Table 22. Unimplemented Point Values

Type	Width (bits)	Unimplemented Value (hexadecimal)
signed int	16	0x8000
unsigned int	16	0xFFFF
signed int	32	0x80000000
unsigned int	32	0xFFFFFFFF
enumeration	16	0xFFFF
enumeration	32	0xFFFFFFFF

A write to a writeable MESA point that is unimplemented will generate a Modbus write error.

The MESA implementation on Nuvation Energy BMS has unimplemented points as follows:

Table 23. Unimplemented MESA Points

Model	Point Name	Description
801	Evt	Event status bit field
801	DisChaRate	Self Discharge Rate
801	MaxRsvPct	Maximum Reserve Percent
801	MinRsvPct	Minimum Reserve Percent
801	ChaSt	Charge Status
801	DerAlarmReset	Alarm Reset (read is unimplemented)

Model	Point Name	Description
802	CycleCt	Cycle Count
802	WMaxDisChaRte	NamePlate Max Discharge Rate
802	SoH	State of Health (reported in 803 model per string)
802	BatReqPCSSSt	PCS State Request
802	BatReqW	Battery Power Request
802	SoH_SF	State of Health Scale Factor
802	BatReqW_SF	Battery Power Request Scale Factor
803	StrEvt2	String Event 2
803	StrConFail	String Connection Fail

Scale Factors

All MESA points are integer values (signed or unsigned). To account for different range values beyond the data size (i.e. greater than 65535 for an unsigned 16 bit value) or some fractional value (i.e. 1.1), some MESA points have scale factors associated with them. The scale factor is another point within the model which contains a signed integer exponent of base 10 that scales a corresponding point value. For example, a scale factor of 2 would result in multiplying the corresponding point by 100. Likewise a scale factor of -3 would result in a scale factor of 0.001. Refer to the prior MESA Draft 3 spreadsheet for the relationship between MESA points and their scale factors. All scale factors are fixed for a model and do not change in value.

5.5.1.4. Operational Cases for MESA

There are two main operational cases for the control of Nuvation Energy BMS over its MESA interface:

1. An external controller (sometimes called "Energy Storage Controller") is used to coordinate power control functions of the BMS in conjunction with some other equipment (such as an inverter). This controller requires periodic and rapid responses of MESA point reads as well as some control over the operation of the BMS (such as stack connectivity). If there is a loss of communication between this controller and the BMS, the BMS will disconnect the stack(s) as a safety precaution.
2. An owner/operator of a battery system requires control of the BMS to monitor the activity of the batteries and track battery usage and its charge/discharge activities. This information can then be used to characterize the usage of the Battery Management System and to validate battery warranties of a vendor.

Read and write Modbus TCP operations can be performed over the standard Modbus port 502 (only a single connection is supported on this port).

The shortest polling periods expected for the MESA models during operation are listed below:

- All fixed model blocks: 100ms
- 801: less than 100ms
- 802: less than 100ms
- 803 Fixed Block: less than 100ms

- 803 Repeating Block(s): less than 100ms (single block), up to 1000ms (36 repeating blocks)

Depending on BMS system load and size, some requests could take up to 1000ms. The BMS typically samples data at between 250ms to 1000ms depending on configuration, so reading the data faster than this will not improve system behaviour and incurs unnecessary overhead.

These two operational cases will be discussed in detail in the following sections.

External Controller Communicating Over MESA Interface

An external controller typically polls Nuvation Energy BMS battery control points at a rate of 2–4 Hz. This controller reads data points required to manage current flow in the system. The following table summarizes the most important points an external controller may want to read from the BMS.

Table 24. MESA Points Read by an External Controller

Model	Block	Point Name	Address	Scale Factor	Purpose
801	Fixed	DERHb	40086	No	BMS Heartbeat counter incremented every second
802	Fixed	Evt1	40101	No	Bit field of all faults/warnings of a the BMS
802	Fixed	Vol	40105	Yes	External DC voltage of the battery system
802	Fixed	MaxBatACha	40106	Yes	Charge current limit calculated by the BMS
802	Fixed	MaxBatADischa	40107	Yes	Discharge current limit calculated by the BMS
803	Fixed	BTotDCCur	40127	Yes	Total DC current of the battery system

A controller may also want to command Nuvation Energy BMS to perform certain actions, such as connecting/disconnecting the battery. The following table provides the different writeable points in the MESA interface for different control functions:

Table 25. MESA Points Written to by an External Controller

Model	Block	Point Name	Address	Purpose
801	Fixed	ControllerHb	40087	Heartbeat register for external controller
801	Fixed	DERAlarmReset	40088	Clears all latched alarms in the BMS
802	Fixed	BSetOperation	40110	Commands Nuvation Energy BMS to connect/disconnect the battery

When configured, the heartbeat controller can be used to update the watchdog timer of Nuvation Energy BMS on single-stack and multi-stack implementations. If the heartbeat point is not updated within the watchdog timer period, a fault will be generated on the BMS stack and its corresponding contactors will be opened. The value written to the heartbeat point must increase in value and roll over to zero when the 16 bit range limit is reached.

The clearing of alarms of Nuvation Energy BMS is accomplished by writing a value of 1 to the DERAlarmReset point. This point is erroneously identified as read-only in the Mesa Draft 3 spreadsheet referenced earlier. Note that the alarm will not be cleared if the alarm condition is still present.



Only BMS Faults are cleared using this point. BMS Warnings are not cleared.

Commanding the Nuvation Energy BMS stack/string to connect/disconnect is accomplished through the BSetOperation point. This point accepts the enumerated values for these connect/disconnect operations. Additional connection logic (such as separate pre-charge circuitry) is managed automatically by the BMS when it is configured for such an operation.

External Nuvation Energy BMS Monitoring Over MESA Interface

An external data logger may want to access a variety of data from the BMS. In general, a data logger will not actively manage Nuvation Energy BMS; normally, it will not initiate actions such as connecting a battery stack to the DC voltage bus or clearing faults. A data logger should connect to one of the read-only Modbus connections (if available) to allow the writable Modbus connection to be available for separate external control functions. The following table contains the MESA data points exposed by the BMS that could be collected for logging purposes.

Table 26. MESA Points Read by External Data Logger

Model	Block	Point Name	Address	Scale Factor	Purpose
801	Fixed	SoC	40081	Yes	BMS State of Charge
801	Fixed	DERHb	40086	No	BMS Heartbeat counter incremented every second
802	Fixed	Evt1	40101	No	Bit field of all faults/warnings of a BMS
802	Fixed	Vol	40105	Yes	External DC voltage of the battery system
802	Fixed	MaxBatACha	40106	Yes	Charge current limit calculated by BMS
802	Fixed	MaxBatADischa	40107	Yes	Discharge current limit calculated by BMS
802	Fixed	BSetOperation	40110	No	BMS requested connection state of all stacks/strings
803	Fixed	BConStrCt	40118	No	Number of stacks/strings with contactor closed
803	Fixed	BMaxCellVol	40119	Yes	Maximum cell voltage measured
803	Fixed	BMaxCellVolLoc	40120	No	Module/String location of maximum cell voltage
803	Fixed	BMinCellVol	40121	Yes	Minimum cell voltage measured
803	Fixed	BMinCellVolLoc	40122	No	Module/String location of minimum cell voltage
803	Fixed	BMaxModTmp	40123	Yes	Maximum module temperature
803	Fixed	BMaxModTmpLoc	40124	No	Module/String location for maximum module temperature
803	Fixed	BMinModTmp	40125	Yes	Minimum module temperature
803	Fixed	BMinModTmpLoc	40126	No	Module/String location for minimum module temperature
803	Fixed	BTotDCCur	40127	Yes	Total DC current of the battery system

Model	Block	Point Name	Address	Scale Factor	Purpose
803	Fixed	BMaxStrCur	40128	Yes	Largest DC current reported by a stack/string
803	Fixed	BMinStrCur	40129	Yes	Smallest DC current reported by a stack/string
803	Repeat	StrSoC	40135 +Index	No	State of charge for a stack/string
803	Repeat	StrSoH	40136 +Index	Yes	State of health for a stack/string
803	Repeat	StrCur	40137 +Index	Yes	Current of a stack/string
803	Repeat	StrMaxCellVol	40138 +Index	Yes	Maximum cell voltage of a stack/string
803	Repeat	StrMinCellVol	40139 +Index	Yes	Minimum cell voltage of a stack/string
803	Repeat	StrCellVolLoc	40140 +Index	No	Location of min/max cell voltages of a stack/string
803	Repeat	StrMaxModTmp	40141 +Index	Yes	Maximum module temperature of a stack/string
803	Repeat	StrMinModTemp	40142 +Index	Yes	Minimum module temperature of a stack/string
803	Repeat	StrModTmpLoc	40143 +Index	No	Location of min/max module temperatures of a stack/string
803	Repeat	StrEvt1	40144 +Index	No	Alarms warnings and status bit field of a stack/string



The term Index in the Repeating block addresses used in the above table refers to a calculation of $\text{Index} = \text{Stack Index} * \text{Length of Repeating block}$. By definition, the 803 Repeating block is 16 Modbus registers in length.

5.5.1.5. Configurable Modbus

The Modbus communication interface has been augmented with a new range of Modbus points. These points allow the mapping of BMS registers into read/write Modbus operations. The mapping of BMS registers to Modbus is accomplished by two different approaches.

1. Mapping of up to 256 individual BMS registers to a set of Modbus points
2. The bulk mapping of BMS register instances (i.e. cell voltages) into a set of Modbus points. Up to 16 different bulk maps can be configured.

Both Modbus read and write operations are supported for the individual BMS register points. This flexibility allows a greater range of Battery Management System data not expressed in the SunSpec Storage models to be accessed over Modbus.



The Battery Management System data that is associated with its safe operation can

not be written to over Modbus when the Battery Management System has its factory configuration locked.

The access to these configurable Modbus points is controlled by the *unit identifier* used in the Modbus TCP protocol. The *unit identifier* selects between the original SunSpec data models and the configurable Modbus points in the following table. All data is accessed as holding registers in each selected region. The start address of each region of Modbus points is shown in the following table.

Table 27. Data Access Based on Modbus Unit Identifier

Unit Identifier	Data Accessed	Start Address
0	No Modbus points	N/A
1	Original SunSpec data models (e.g. Common,801,802,803)	40000
2	Configurable Modbus data points	0
3-255	No Modbus points	N/A

The configurable Modbus points are further split into different address regions. There are two different types of address regions.

1. 256 BMS registers accessible read/write Modbus points
2. 16 sets of read only bulk map Modbus points

The bulk map regions of configurable Modbus points allow mapping of arrays of similar data measurements, such as cell voltages or temperatures, without having to configure each register address. The following table lists the different address regions.

Table 28. Configurable Modbus Holding Register Addresses

Modbus Region ID	Holding Register Address Range	Configurable Data Accessed
0	0x0000 - 0x03FF	Configurable Modbus points
1	0x0400 - 0x0B7F	Configurable bulk map region 1
2	0x0B80 - 0x12FF	Configurable bulk map region 2
3	0x1300 - 0x1A7F	Configurable bulk map region 3
...
15	0x6D00 - 0x747F	Configurable bulk map region 15
16	0x7480 - 0x7BFF	Configurable bulk map region 16

The Modbus Region ID is used in the following configuration section to identify which regions of the configurable Modbus correspond to the BMS register configuration.

Configuration

The following BMS registers are used to configure the Configurable Modbus points and bulk map points. The *Modbus Region ID* is used from the prior Modbus holding register [table](#) to identify which different Modbus region the configuration applies to.

Table 29. Configurable Modbus Configuration Registers

BMS Register	Description	Modbus Region ID
sc_modbus_map[0:255].address	Specifies the address of the BMS address to access	0
sc_modbus_map[0:255].command	Specifies if the access is read-only (0) or read/write (1) for the corresponding address	0
sc_modbus_bulk_map[0:15].baseaddress	Specifies the base address of set of BMS register instances to access as a bulk map	1 to 16
sc_modbus_bulk_map[0:15].baseenableaddress	Specifies the base address of set of BMS register instances that are used to determine each corresponding bulk instance is installed	1 to 16

5.5.1.6. Accessing MESA Models

MESA models are located contiguously in the Modbus address space starting at a base address of 40000. The Common Model is always located first in this space. The End Model is always last and is used to denote the end of MESA Modbus registers. Each model located between the Common Model and the End Model has a numeric identifier as well as a length. A handy tool that can be used to explore the MESA Modbus registers for Nuvation Energy BMS is modpoll.exe. It is available for free download at <http://www.modbusdriver.com/modpoll.html>.

Using modpoll.exe, the Common Model can be polled from a using the following command (assuming the device has an IP address of 192.168.1.21)

Polling example with BMS IP address of 192.168.1.21

```
modpoll.exe -m tcp -0 -r 40000 -c 70 192.168.1.21

modpoll 3.4 - FieldTalk(tm) Modbus(R) Master Simulator
Copyright (c) 2002-2013 proconX Pty Ltd
Visit http://www.modbusdriver.com for Modbus libraries and tools.

Protocol configuration: MODBUS/TCP
Slave configuration...: address = 1, start reference = 40000 (PDU), count = 70
Communication.....: 192.168.1.21, port 502, t/o 1.00 s, poll rate 1000 ms
Data type.....: 16-bit register, output (holding) register table

-- Polling slave... (Ctrl-C to stop)
[40000]: 21365
[40001]: 28243
[40002]: 1
[40003]: 66
.
.
.
[40068]: 4660
[40069]: -32768
```

As another example, the complete S802 model for a system with one stack could be polled using the

following command:

Example with BMS IP address of 192.168.1.21

```
modpoll.exe -m tcp -0 -r 40094 -c 22 192.168.1.21

modpoll 3.4 - FieldTalk(tm) Modbus(R) Master Simulator
Copyright (c) 2002-2013 proconX Pty Ltd
Visit http://www.modbusdriver.com for Modbus libraries and tools.

Protocol configuration: MODBUS/TCP
Slave configuration...: address = 1, start reference = 40094 (PDU), count = 22
Communication.....: 192.168.1.21, port 502, t/o 1.00 s, poll rate 1000 ms
Data type.....: 16-bit register, output (holding) register table

-- Polling slave... (Ctrl-C to stop)
[40094]: 802
[40095]: 20
.
.
.
[40114]: -2
[40115]: -32768
```

6. Instructions for Stack Servicing



The order of these steps must be followed in order to maximize the life of the components (the contactors in particular).

In order to service the stack (including the battery itself), perform the following steps:

1. Allow the battery to come to rest (no current).
 - This may involve sending commands to the power conversion system.
2. Using the Operator Interface, disconnect the stack by clicking the **Disconnect** button.
 - Refer to the [Section 5.3.1.8, "Nuvation Energy BMS Status"](#) for instructions on connecting/disconnecting a stack.
 - This initiates the disconnection sequence.
 - Wait for the connection state to show **Stack Disconnected**.
3. Put the Service Disconnect switch in the **Lock Out** position and insert a lock-out / tag-out.

The battery stack can now be serviced. To bring the stack back into operation, perform the following steps:

1. Remove the lock-out / tag-out and put the Service Disconnect switch in the **Operating** position.
2. Address any faults if necessary (using the Operator Interface).
 - All faults must be cleared for Stack Switchgear to close contactors.
3. Using the Operator Interface, connect the stack by clicking the **Connect** button.
 - Refer to the [Section 5.3.1.8, "Nuvation Energy BMS Status"](#) for instructions on connecting/disconnecting a stack.
 - This initiates the connection sequence.
 - Wait for the connection state to show **Connected**.

The stack is now connected to the DC bus.



The battery stack terminals are always energized and should be handled as such.

Although the DC bus terminals are disconnected from the battery by the Stack Switchgear unit's contactors, the DC bus can still be energized by other components on the DC bus (e.g. power conversion system or other stacks). The DC bus terminals should always be treated as though they were energized.

A simple voltage check (i.e. across the positive and negative terminals) is not always sufficient, *especially* with grounded battery stacks. It is recommended to also check for voltage between each conductor and ground.

Appendix A: Battery Topology Terminology

Energy storage systems are hierarchical in nature. Nuvation Energy has adopted the following definitions for battery pack topology:

Cell

A Cell is the smallest unit of energy storage distinguishable by the Battery Management System. One Cell, as defined from the perspective of the BMS, may actually consist of one or more electrochemical cells connected in parallel. This subtlety is reflected in the nomenclature for completeness. For example, a "1p" Cell refers to a single electrochemical cell, while a "2p" Cell refers to two electrochemical cells connected together in parallel. From the perspective of the BMS, these topologies appear identical except for the capacity of the Cells.

Group

A Group is a set of Cells connected in series and managed together. For example, 12 "1p" Cells in series are referred to as a "12s1p" Group, while 16 "2p" Cells in series are referred to as a "16s2p" Group. Grouping of Cells is highly application-specific and is defined in how BMS hardware interfaces are physically wired up to Cells.

Stack

A Stack is one or more Groups connected in series. For example, five "14s2p" Groups connected in series could be described as a "5g14s2p" Stack. However, it is far more common to describe it as a "70s2p" Stack.

Bank

A Bank is one or more stacks connected in parallel. For example, three "70s2p" Stacks connected in parallel are referred to as a "3x70s2p" Bank.

Pack

A Pack is one or more Banks connected in series.

Appendix B: Best Practices

This section describes important concepts which need special attention to achieve a reliable installation.

Excess Cable Management

During the first prototype system build, it is possible to encounter cable lengths that are too long for your system. Leaving the excess cable length unmanaged can result in a messy system installation.

If reducing the cable length is not feasible or if there is no time to physically modify the lengths, a common solution is to wrap the excess cable length in a coil and fasten the wire loop in the cabinet. This basic tactic has the undesirable effect of creating an air-core transformer which will couple EMI into the cable extremely well.

The best solution to cable length management is to bundle the excess length in a figure-8 pattern. This prevents the bundle from turning into an air-core transformer since the direction of current in one side of the figure-8 turns opposite to the current in the other side. It is recommended to use the figure-8 method if physically reducing the cable length is not possible.

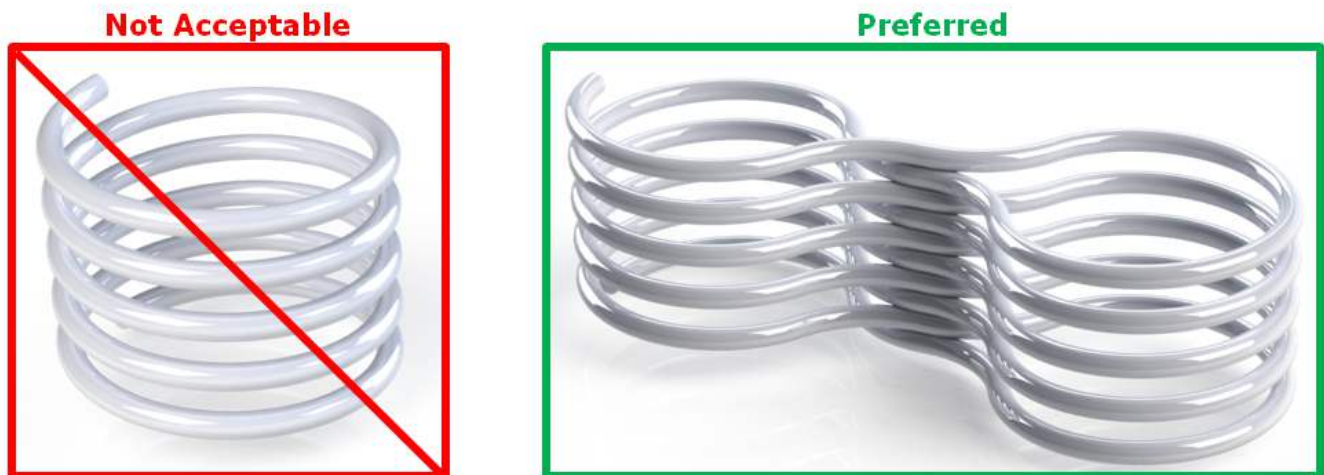


Figure 48. Excess Cable Management Examples

Appendix C: Ordering Information

G5 Stack Switchgear

This section provides orderable part numbers for Nuvation Energy's offerings of G5 Stack Switchgear units and mounting accessories.

Table 30. G5 Stack Switchgear Unit Ordering Information

Part Number	Product Name	Compatible Fuse Rating
NUVG5-SSG-1500-100-x	G5 Stack Switchgear, 1500 V, 100 A	200 A
NUVG5-SSG-1500-200-x	G5 Stack Switchgear, 1500 V, 200 A	250 A, 315 A, 350 A
NUVG5-SSG-1500-300-x	G5 Stack Switchgear, 1500 V, 300 A	350 A, 400 A, 450 A, 500 A

* x = fuse rating code.

Fuse Rating Code

The fuse rating code is denoted by the x at the end of the product part number. The G5 Stack Switchgear fuse rating is determined by the application power profile, which is based on continuous power, cycle duration, and cycle frequency.

A Nuvation Energy Application Engineer will assist with determining a suitable fuse rating when an order is placed.

Table 31. Fuse rating and code

Fuse Rating	Code
200 A	1
250 A	2
315 A	3
350 A	4
400 A	5
450 A	6
500 A	7

For e.g., a NUVG5-SSG-1500-100-1 is a "1500 V DC, 100 A" G5 Stack Switchgear, with a 200 A fuse rating.

Mounting Bracket

By default, the G5 Stack Switchgear ships with a NUVP-SSG-SB bracket for shelf-mounting.

The following mounting bracket options are available upon request.

Table 32. Mounting Bracket Ordering Information

Part Number	Product Name
NUVP-SSG-SB	Part, Stack Switchgear, Brackets for shelf-mounting
NUVP-SSG-RB-19	Part, Stack Switchgear, Front-securing Brackets for 19" Rack

G5 Cell Interface

Product part numbers for ordering a Cell Interface are listed in [Table 33, "Cell Interface Ordering Information"](#).

Table 33. Cell Interface Ordering Information

Part Number	Product Name
NUVG5-CI-24	G5 Cell Interface - 24 channel
NUVG5-CI-24-KIT	G5 Cell Interface - 24 channel, Starter Kit*

* The Starter Kit will include the module and cables to get you started quickly.

Appendix D: Mating Connectors

G5 Stack Switchgear Connectors

Power and Fan Connector



Molex 39-01-2105	
Manufacturer	Molex
Housing	39-01-2105
Housing material	Nylon UL94V-0
Circuits	10
Crimp terminal	39-00-0074
Wire gauge range	AWG18-24 stranded

Table 34. Power and Fan Connector Pin Assignment

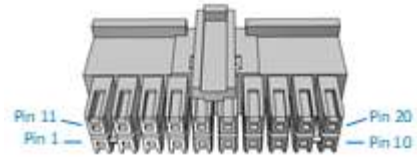
Pin	Connection	Description	Connected to Device
1	AC_IN_N	AC Power In, Neutral	External AC power source
2	AC_FAN_OUT_N	AC Fan Power Out, Neutral	Battery rack AC cooling fans
3	AC_EARTH	AC Earth; connected internally to Pin 8 ¹	AC Ground connection
4	DC_PWR_NEG	DC Power In, Negative	External DC power source
5	DC_FAN_NEG	DC Fan Power Out, Negative	Battery rack DC cooling fans
6	AC_IN_L	AC Power In, Line	External AC power source ³
7	AC_FAN_OUT_L	AC Fan Power Out, Line	Battery rack AC cooling fans
8	AC_EARTH	AC Earth; connected internally to Pin 3 ¹	AC Ground connection
9	DC_PWR_POS	DC Power In, Positive	External DC power source ²
10	DC_FAN_POS	DC Fan Power Out, Positive	Battery rack DC cooling fans

¹Also connected internally to G5 Stack Switchgear chassis

²Powers the G5 Stack Switchgear and the external DC fans

³Powers the external AC fans, and can power the G5 Stack Switchgear if the external DC power source is unavailable

I/O Connector



Samtec IPD1-10-D-K	
Manufacturer	Samtec Incorporated
Housing	IPD1-10-D-K
Housing material	Nylon UL94V-0
Circuits	20
Crimp terminal	CC79L-2024-01-L
Wire gauge range	AWG20-24 stranded

Table 35. I/O Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	COM_CHAIN	Negative reference for chained G5 Stack Switchgear	Next G5 Stack Switchgear COM in the chain
2	ENABLE#_CHAIN	Connected internally to Pin 14	Next G5 Stack Switchgear Enable input in the chain
3	SHUTDOWN#_COM	Signal return for Shutdown input	External equipment
4	ENABLE#_COM	Signal return for Enable input	External equipment
5	DISCONNECT#	Connect to COM_IO to open contactors	External equipment
6	DISCONNECT#_COM_IO	Signal return for Disconnect input	External equipment
7	GPO_ISO1_A	Digital Output 1	External equipment
8	GPO_ISO0_A	Digital Output 0	External equipment
9	GPI_ISO1_COM_IO	Signal return for GPI_ISO1_K input	External equipment
10	GPI_ISO0_COM_IO	Signal return for GPI_ISO0_K input	External equipment
11	COM	Signal return from G5 Stack Switchgear	Next G5 Stack Switchgear COM in the chain
12	SHUTDOWN#_CHAIN	Connected internally to Pin 13	Next G5 Stack Switchgear Shutdown input in the chain
13	SHUTDOWN#	Momentary to COM to invoke shutdown; Hold to COM to force shutdown	External equipment
14	ENABLE#	Momentary to COM to enable G5 Stack Switchgear; Hold to COM to defeat Shutdown	External equipment
15	DISCONNECT#_CHAIN	Connected internally to Pin 16	Next G5 Stack Switchgear Disconnect input in the chain
16	COM_IO_CHAIN	Negative isolated reference for chained G5 Stack Switchgear	Next G5 Stack Switchgear COM_IO in the chain
17	GPO_ISO1_B	Digital Output 1	External equipment
18	GPO_ISO0_B	Digital Output 0	External equipment

Pin	Connection	Description	Connected to Device
19	GPI_ISO1_K	Input detector 1	External equipment
20	GPI_ISO0_K	Input detector 0	External equipment

Disconnect Input

This feature allows an external dry-contact switch to notify the G5 Stack Switchgear to disconnect the battery from the DC bus. The signal can be daisy-chained to adjacent G5 Stack Switchgear units that also share the same DC bus.

The Disconnect input requires the signal to be asserted for a minimum of 500ms when the G5 Stack Switchgear is configured for normal disconnect mode. When configured for fast disconnect mode, the G5 Stack Switchgear instantly reacts to the input.

In the unlikely event the G5 Stack Switchgear is unresponsive, asserting the Disconnect Input for 10 seconds will override the software to disconnect the battery from the DC Bus using a hardware-only circuit.

Linkbus Connector

The Linkbus jack is a standard RJ45 Cat5e rated jack.

Table 36. Linkbus Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	No Connect	No Connection	No Connection
2	No Connect	No Connection	No Connection
3	No Connect	No Connection	No Connection
4	No Connect	No Connection	No Connection
5	No Connect	No Connection	No Connection
6	No Connect	No Connection	No Connection
7	IMA	Link Bus differential pair negative	First Cell Interface module in the Link Bus chain
8	IPA	Link Bus differential pair positive	First Cell Interface module in the Link Bus chain

Ethernet Connector

The Ethernet jack is a standard RJ45 Cat5e rated jack.

Table 37. Ethernet Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	TD_P	Transmit differential pair positive	External equipment
2	TD_N	Transmit differential pair negative	External equipment
3	RD_P	Receive differential pair positive	External equipment

Pin	Connection	Description	Connected to Device
4	NUL45	Unused; connected to Pin 5 and terminated	External equipment
5	NUL45	Unused; connected to Pin 4 and terminated	External equipment
6	RD_N	Receive differential pair, negative	External equipment
7	NUL_78	Unused; connected to Pin 8 and terminated	External equipment
8	NUL_78	Unused; connected to Pin 7 and terminated	External equipment

Battery and DC Bus High Current Connectors

The 4 high current posts accept an M10-1.5 Stainless-Steel bolt which is used to secure the high current wire lug. G5 Stack Switchgear includes 16 mm long bolt and split lock-washer. The bolt must be tightened to 60 to 80 in-lbs.

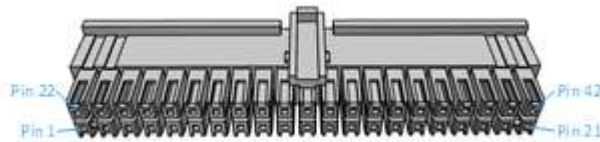
The provided cable insulation boots must be used to insulate each high current post. The red boots are used for *Battery+* and *DC Bus+* positive connections; the black boots are used for *Battery-* and *DC Bus-* negative connections. Maximum cable O.D. (including insulation thickness) is 0.8in [20.3mm]. Wire crimp lug must not extend beyond the center of the M10 clearance hole by 1.3in [33mm].

Earth Bonding Connector

The equipment Earth bonding post accepts an M8-1.25 Zinc-plated bolt which is used to secure the Earth wire lug. G5 Stack Switchgear includes 16mm long bolt and 2 external-toothed lock-washers where one washer is placed between the G5 Stack Switchgear and the grounding lug and the other washer is placed between the grounding lug and the bolt head. The bolt must be tightened to 130 in-lbs. Refer to NFPA 70, Table 250.122 for suitable wire size based on the G5 Stack Switchgear unit's current rating.

G5 Cell Interface Connectors

Cell Voltage and Temperature Connector



Samtec IPD1-21-D-K	
Manufacturer	Samtec Incorporated
Housing	IPD1-21-D-K
Housing material	Nylon UL94V-0
Circuits	42
Crimp terminal	CC79L-2024-01-L
Wire gauge range	AWG20-24 stranded

Table 38. Cell Voltage and Temperature Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	CELL23+	Cell 23 voltage sense	Connect to positive terminal of Cell 23
2	CELL24+	Cell 24 voltage sense	Connect to positive terminal of Cell 24
3	<i>Reserved – Do not populate</i>		
4	TEMP1	External temperature probe input 1	10 kΩ NTC Thermistor #1
5	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #1
6	TEMP2	External temperature probe input 2	10 kΩ NTC Thermistor #2
7	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #2
8	TEMP3	External temperature probe input 3	10 kΩ NTC Thermistor #3
9	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #3
10	TEMP4	External temperature probe input 4	10 kΩ NTC Thermistor #4
11	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #4
12	TEMP5	External temperature probe input 5	10 kΩ NTC Thermistor #5
13	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #5
14	TEMP6	External temperature probe input 6	10 kΩ NTC Thermistor #6
15	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #6
16	TEMP7	External temperature probe input 7	10 kΩ NTC Thermistor #7
17	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #7
18	TEMP8	External temperature probe input 8	10 kΩ NTC Thermistor #8
19	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #8
20	CI_REF1-	Bottom reference of G5 Cell Interface	Connect to negative terminal of the lowest cell (Cell 1)

Pin	Connection	Description	Connected to Device
21	CELL1+	Cell 1 voltage sense	Connect to positive terminal of the lowest cell (Cell 1)
22	CELL22+	Cell 22 voltage sense	Connect to positive terminal of Cell 22
23	CELL21+	Cell 21 voltage sense	Connect to positive terminal of Cell 21
24	CELL20+	Cell 20 voltage sense	Connect to positive terminal of Cell 20
25	CELL19+	Cell 19 voltage sense	Connect to positive terminal of Cell 19
26	CELL18+	Cell 18 voltage sense	Connect to positive terminal of Cell 18
27	CELL17+	Cell 17 voltage sense	Connect to positive terminal of Cell 17
28	CELL16+	Cell 16 voltage sense	Connect to positive terminal of Cell 16
29	CELL15+	Cell 15 voltage sense	Connect to positive terminal of Cell 15
30	CELL14+	Cell 14 voltage sense	Connect to positive terminal of Cell 14
31	CELL13+	Cell 13 voltage sense	Connect to positive terminal of Cell 13
32	CELL12+	Cell 12 voltage sense	Connect to positive terminal of Cell 12
33	CELL11+	Cell 11 voltage sense	Connect to positive terminal of Cell 11
34	CELL10+	Cell 10 voltage sense	Connect to positive terminal of Cell 10
35	CELL9+	Cell 9 voltage sense	Connect to positive terminal of Cell 9
36	CELL8+	Cell 8 voltage sense	Connect to positive terminal of Cell 8
37	CELL7+	Cell 7 voltage sense	Connect to positive terminal of Cell 7
38	CELL6+	Cell 6 voltage sense	Connect to positive terminal of Cell 6
39	CELL5+	Cell 5 voltage sense	Connect to positive terminal of Cell 5
40	CELL4+	Cell 4 voltage sense	Connect to positive terminal of Cell 4
41	CELL3+	Cell 3 voltage sense	Connect to positive terminal of Cell 3
42	CELL2+	Cell 2 voltage sense	Connect to positive terminal of Cell 2

Link In Connector

The Link In jack is a standard RJ45 Cat5e rated jack.

Table 39. Link In Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	No Connect	No Connection	No Connection
2	No Connect	No Connection	No Connection
3	No Connect	No Connection	No Connection
4	No Connect	No Connection	No Connection
5	No Connect	No Connection	No Connection
6	No Connect	No Connection	No Connection
7	IMA	Link Bus differential pair negative	Previous G5 Cell Interface in the Link Bus chain or the G5 Stack Switchgear

Pin	Connection	Description	Connected to Device
8	IPA	Link Bus differential pair positive	Previous G5 Cell Interface in the Link Bus chain or the G5 Stack Switchgear

Link Out Connector

The Link Out jack is a standard RJ45 Cat5e rated jack.

Table 40. Link Out Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	No Connect	No Connection	No Connection
2	No Connect	No Connection	No Connection
3	No Connect	No Connection	No Connection
4	No Connect	No Connection	No Connection
5	No Connect	No Connection	No Connection
6	No Connect	No Connection	No Connection
7	IMA	Link Bus differential pair negative	Subsequent G5 Cell Interface module in the Link Bus chain
8	IPA	Link Bus differential pair positive	Subsequent G5 Cell Interface module in the Link Bus chain

From time to time Nuvation Energy will make updates to products in response to changes in available technologies, client requests, emerging energy storage standards, and other industry requirements. The product specifications in this document, therefore, are subject to change without notice.

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