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Nuvation Energy High-Voltage BMS

Product Manual

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BMS Software Version: Curie Update 1

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

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 High-Voltage BMS: Product Manual* is a comprehensive manual, providing:

- Details about all the features offered by your Nuvation Energy 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 Curie Update 1 software release (Firmware version 4.106.1, Operator Interface version 0.56.1). 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. 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.

3. System Overview

The Nuvation Energy High-Voltage BMS provides cell-level and stack-level control for battery stacks up to 1250 VDC. The UL 1973 Recognized BMS modules in each stack ensure safe battery operation and significantly reduce the effort of certifying the energy storage solution to meet UL 1973 and UL 9540. While the Stack Switchgear does not yet have UL 1973 recognition, it has been designed to enable UL 1973 certification of the battery stack. For more information, please contact support@nuvationenergy.com

Figure 1. High-Voltage BMS

A single Nuvation Energy Stack Switchgear unit manages each stack and connects it to the DC bus of the energy storage system. The Nuvation Energy Stack Switchgear, is a pre-configured assembly that incorporates the major functions of Nuvation Energy High-Voltage BMS into a rack-mountable unit which includes stack monitoring, electrical disconnects, pre-charging, current sensing, fuses, and a safety relay for E-Stop. It also includes supporting components like power supplies, indicator LEDs, and external-facing connectors.

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

The Stack Switchgear and Cell Interface modules operate together as a complete system called the High-Voltage BMS. Available units/modules are listed below.

Table 1. Stack Switchgear and Cell Interface Modules

Model	Unit/Module Name
NUVSSG-1250	Stack Switchgear, 1250 V
NUV100-CI-12-1	Cell Interface - 12 channel
NUV100-CI-16-1	Cell Interface - 16 channel
NUV100-CI-4M12-1	Cell Interface - 12 V 4 channel

Generally, a single battery stack uses one Stack Switchgear and one or more Cell Interface modules. A breakdown of a single battery stack is shown in Figure 2

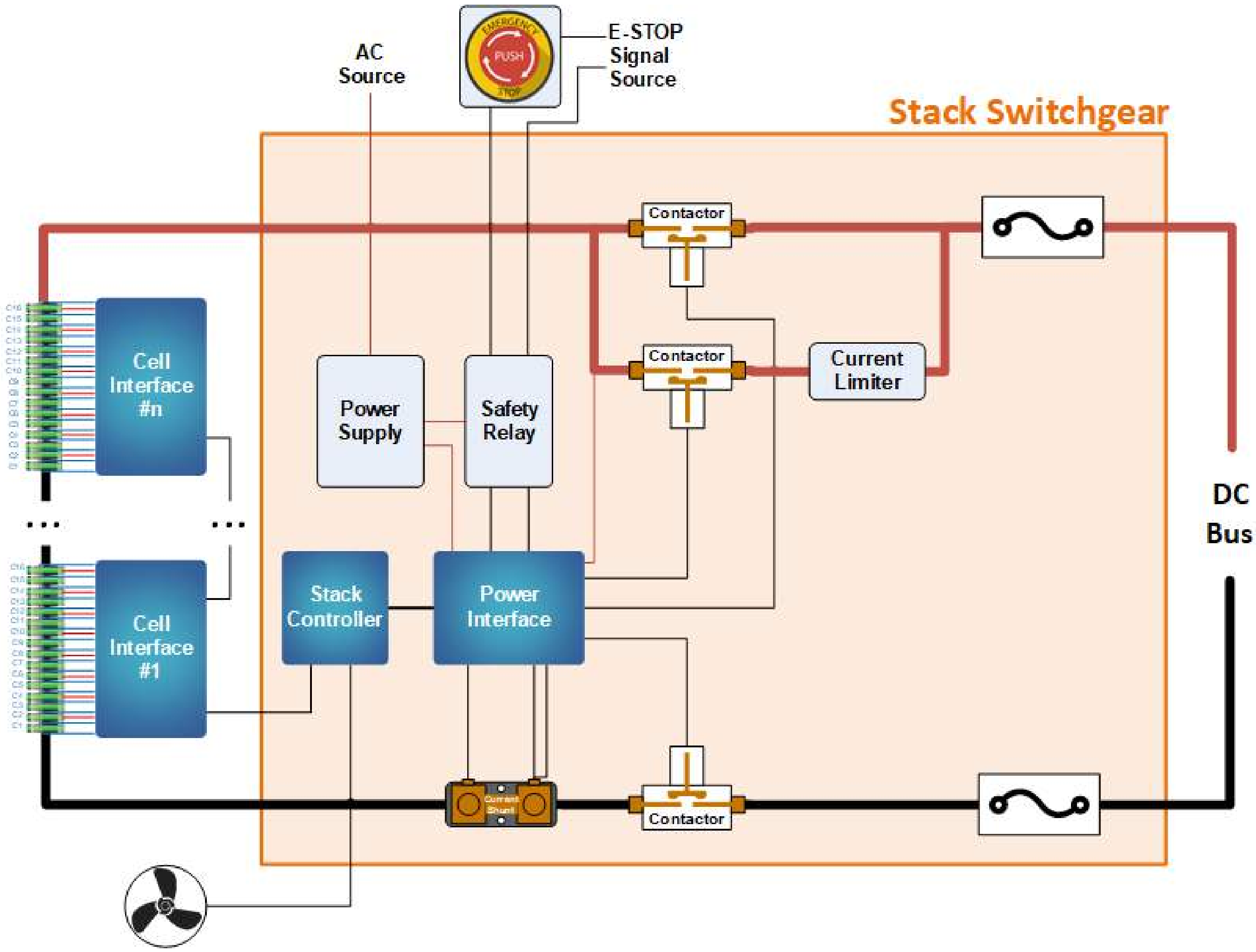


Figure 2. High-Voltage BMS single system diagram

In a multi-stack High-Voltage BMS configuration, as shown in Figure 3, each Stack Switchgear unit is responsible for monitoring the state and safety of one battery stack. All Stack Switchgear units connected to a single common DC bus in the system may be managed by a single Nuvation Energy Multi-Stack Controller, where an Operator Interface provides a unified view and central control of the multi-stack system.

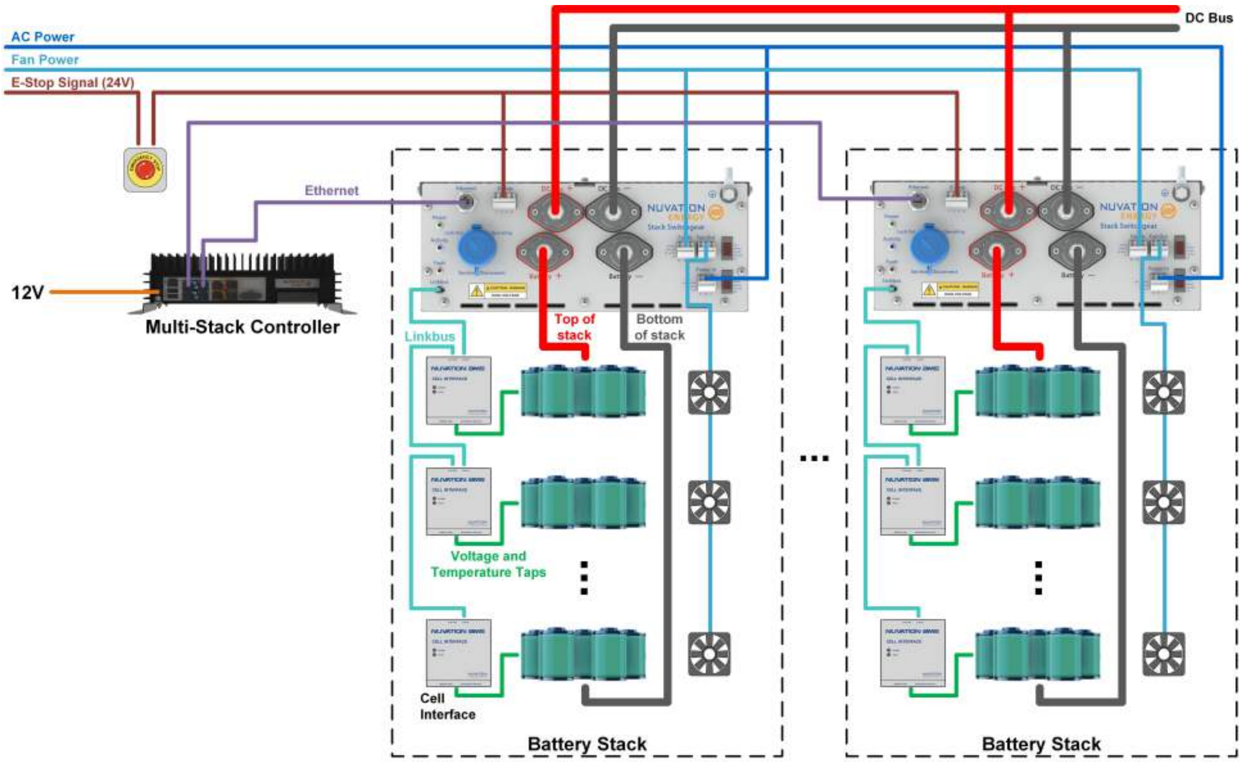


Figure 3. High-Voltage BMS multi-stack diagram

3.1. Stack Switchgear

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

The 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 Stack Switchgear Unit

The external interfaces to this unit are:

- Battery Stack and DC Bus connectors
- 10/100 Base-T Ethernet RJ45 jack (Modbus-TCP)
- Link Bus connector
- E-stop connector
- Fan control connectors with breaker switch
- Power In connector with breaker switch
- Status LEDs (Power, Activity, and Fault)
- Earth bonding connection (grounding stud)

The Stack Switchgear (NUVSSG-1250) supports 1250 VDC. There are multiple options for current rating (from 100 A to 350 A) and fuse rating (from 200 A to 500 A). The Stack Switchgear fuse rating is determined by the application power profile which is based on continuous power, cycle duration, and cycle frequency.

For ordering details, please refer to Stack Switchgear Ordering Information.

3.1.1. Features

The Nuvation Energy Stack Switchgear internally includes the following major hardware components:

- Nuvation Energy High-Voltage Stack Controller
- Nuvation Energy High-Voltage Power Interface
- Current measuring shunt
- Three high-voltage DC contactors
- Pre-charge circuit
- Two fuses (short-circuit protection)
- Safety relay (for E-Stop)

The following subsections describe the components in more detail.

3.1.1.1. Stack Controller and Power Interface

The Stack Switchgear contains a single Nuvation Energy High-Voltage Stack Controller and Nuvation Energy High-Voltage Power Interface.

The Stack Controller has a central MCU which handles processes and decision-making required by the battery management system. The Power Interface contains a redundant MCU to handle processes and decision-making required to control the high-current contactors.

The Stack Controller and Power Interface are UL-recognized components, for use in UL 1973 stationary battery energy storage systems. For more information on the capabilities of the Stack Controller and Power Interface please refer to the datasheets available online at https://www.nuvationenergy.com/technical-resources.

3.1.1.2. Current Measuring Shunt

A precision current shunt in series with the negative side of the stack is used to measure the stack charging/discharging current. Current measurement is performed by the Power Interface.

3.1.1.3. DC Contactors

High-voltage contactors are used by the BMS to connect the battery stack to the DC bus. There are contactors on both the positive and negative sides of the stack. Nuvation Energy BMS opens the contactors either by request of an external controller or in fault conditions. A third high-voltage contactor is used in the pre-charge circuit (see Section 3.1.1.4).

Contactors with auxiliary switch feedback are used so the BMS can raise a fault when it detects contactor failure during opening or closing. Note that the expected lifespan of a contactor is impacted significantly each time it connects or disconnects under load.

3.1.1.4. Pre-Charge Circuit

The Stack Switchgear has a pre-charge circuit to ensure safe connection of its battery stack to the DC bus. The pre-charge circuit temporarily connects the stack to the DC bus through a power resistor. This resistor allows a smaller current (proportional to the difference in voltage between the stack and the DC bus) to flow between the stack and the DC bus. After a 5-second pre-charge timeout, if the measured current is below a safe threshold, the BMS bypasses the pre-charge circuit by connecting the stack directly to the DC bus.

This ensures the battery stack will not connect to the DC bus when an unsafe voltage mismatch is present. By default, the Stack Switchgear is configured with a 150 Ω, 300 W power resistor, suitable for a DC bus capacitance of 15 mF at 1000 V and 10 mF at 1250 V. As a custom request, the pre-charge resistor can be sized specific to the end application.

3.1.1.5. Fuses

There are multiple options for current rating and fuse rating. The Stack Switchgear fuse rating is determined by the application power profile which is based on continuous power, cycle duration, and cycle frequency.

Inline fuses are used on both the positive and negative connections and are sized according to the Stack Switchgear variant. The fuses interrupt a short circuit event; two of them are used to provide redundancy and to permit use of the Stack Switchgear with an ungrounded battery stack.

The following are the current rating and fuse rating options available for the Stack Switchgear (NUVSSG-1250).

Table 2. Stack Switchgear (NUVSSG-1250) current rating options

Current Rating
100 A
200 A
300 A
350 A

Table 3. Stack Switchgear (NUVSSG-1250) fuse rating options

Fuse Rating	Interrupt Current Rating
200 A	100 kA
250 A	100 kA
315 A	100 kA
350 A	100 kA
400 A	100 kA
450 A	100 kA
500 A	100 kA

3.1.1.6. Safety Relay (for E-Stop)

The Stack Switchgear has an internal safety relay for monitoring an external E-Stop signal. A safety relay is used to ensure the relay cannot fail shorted.

This relay meets the requirements of the following standards: EN 954-1, EN 60204-1, VDE 0113-1 and IEC 60204-1. It also has approvals from UL, cUL, CCC and TUV. For more information about the E-Stop functionality, see Section 4.2.6.

3.2. 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 Stack Switchgear, one or more Cell Interface modules are used to convert and relay cell voltage and temperature measurements digitally to the Stack Switchgear. When using multiple Cell Interface modules, the same Cell Interface variant must be used—i.e. all NUV100-CI-12-1, or all NUV100-CI-16-1, or all NUV100-CI-4M12-1. The firmware does not support a mixed chain of different Cell Interface variants.

The following are variants of the Nuvation Energy Cell Interface:

- The NUV100-CI-12-1, Cell Interface - 12 channel can monitor up to 12 series-connected cells
- The NUV100-CI-16-1, Cell Interface - 16 channel can monitor up to 16 series-connected cells
- The NUV100-CI-4M12-1, Cell Interface - 12 V 4 channel can monitor up to 4 series-connected 12V lead-acid cells. Note that cell balancing is not supported in Cell Interface - 12 V 4 channel.

Figure 5. Nuvation Energy Cell Interface Module

The external interfaces to this module are:

- Battery cells connector
- Temperature sensors connector
- 2 Link Bus connectors
- 2 Indicator LEDs

The 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. Installation Instructions

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

4.1. Stack Switchgear Mechanical Installation

4.1.1. Dimensions and Weight

The Stack Switchgear is 4U (rack-units) tall.

The unit weighs 23 kg [50.7 lbs].

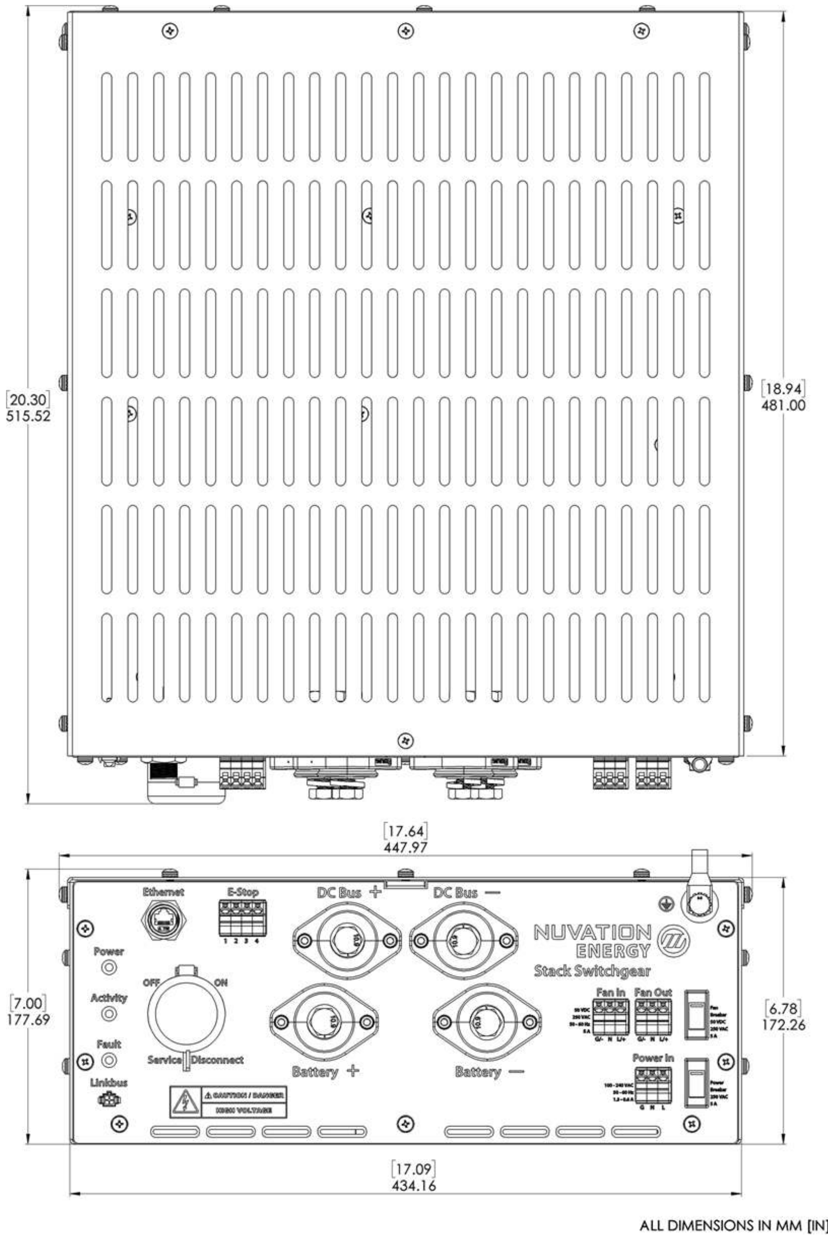


Figure 6. Stack Switchgear Dimensions

4.1.2. Installation Location and Position

The Stack Switchgear is rated to operate in the temperature range of 10 °C to 40 °C. It designed for indoor applications.

The 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. Depending on the desired application, brackets can be ordered with part numbers listed in Stack Switchgear Ordering Information.

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

4.1.2.1. Mounting Clearances

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

4.1.3. Mounting Instructions

For rack and shelf options, the installation can be done by one person. For 2-post options, the installation requires a minimum of two people.

Fasteners for attaching the brackets to the Stack Switchgear unit (M5 x 8 mm) are included with any mounting bracket order. If fasteners other than the provided hardware is used, the screws cannot extend into the 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 of 6.35 mm.

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

4.1.3.1. Front-securing Rack-Mount, 19"

> 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/).

For front-securing 19" rack installations (i.e. using the NUVP-SSG-RB-19)

1. Install the side-support angle brackets (not included) on the rack at the desired location.
2. Install the brackets on the Stack Switchgear.
3. Place the Stack Switchgear onto the installed side-support angle brackets. Ensure the Stack Switchgear is in a horizontal orientation with the vent-slots pointing up to the sky.
4. Secure the Stack Switchgear to the rail of the rack using the brackets installed.

Figure 7. Rack-mount, 19", front-securing

4.1.3.2. 2-Post Rack-Mount, 19" And 23"

For 2-post rack installations (i.e. using the NUVP-SSG-RB-19-2P or NUVP-SSG-RB-23-2P)

1. Install one pair of brackets (i.e. both front or both rear brackets) on the posts at the desired location.
2. Install the other pair of brackets on the Stack Switchgear.
3. Have one person support the Stack Switchgear in the desired position. Ensure the Stack Switchgear is in a horizontal orientation with the vent-slots pointing up to the sky.
4. Attach the Stack Switchgear (with brackets installed) to the posts.

Figure 8. Rack-mount, 2-post, 19"

Figure 9. Rack-mount, 2-post, 23"

4.1.3.3. Shelf-Mount

For shelf installations (i.e. using the NUVP-SSG-SB)

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

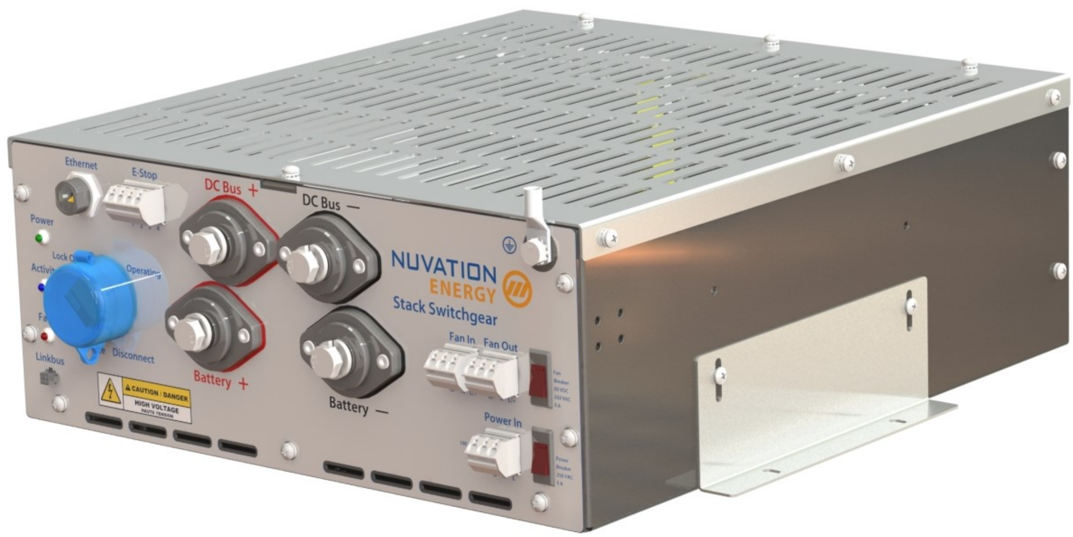


Figure 10. Shelf-mount

4.2. Stack Switchgear Electrical Connections

Before making any connections, ensure that the service disconnect in Figure 11 is in the **OFF** position.

The 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 Cell Interface modules and/or using a different battery topology will result in undesirable Stack Switchgear behavior.

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

4.2.1. Getting Started

- Step 1: Ensure system is de-energized
- Step 2: Ground the Stack Switchgear
- Step 3: Connect Power In
- Step 4: Connect Fan Control
- Step 5: Connect E-Stop
- Step 6: Connect to external PC
- Step 7: Connect Cell Interface Link bus
- Step 8: Connect Battery Stack and DC Bus

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

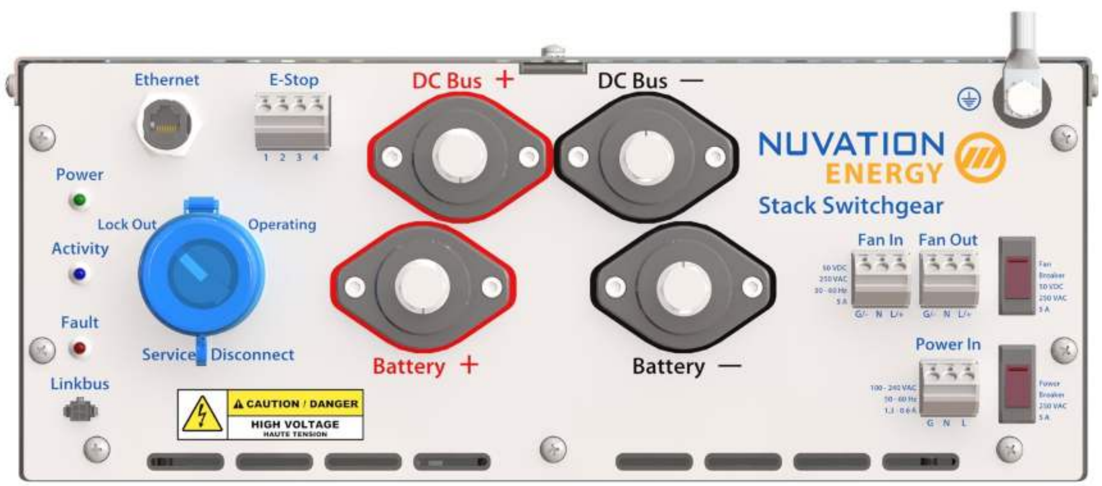


Figure 11. Stack Switchgear external interfaces

4.2.2. Ensure system is de-energized

Ensure that the service disconnect switch, input power breaker, and the fan power breaker are in the **OFF** position.

Service Disconnect

The manual service disconnect switch is accessible on the front of the 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 **OFF** position and lock-out/tag-out the switch by locking the cover.

Figure 12. 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.

Fan Power

An inline breaker provides the ability to turn off fan control for the Stack Switchgear. Ensure the breaker is in the **OFF** position.

Figure 13. Fan Power Breaker

Power In

An inline breaker provides the ability to turn off input power for the Stack Switchgear. Ensure the breaker is in the **OFF** position.

Figure 14. Power In Breaker

Verify system is de-energized

Using a multimeter check the Battery Stack and the DC Bus terminals respectively to verify that the system is de-energized. Be aware that battery itself cannot be de-energized and in some situations, it may not be possible to de-energize the DC bus.

4.2.3. Grounding the Stack Switchgear

Figure 15. Grounding stud

The 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 4.

Table 4. Minimum grounding wire size

Stack Switchgear Current Rating (A)	Grounding Wire (AWG)	
	Copper	Aluminum
100	8	6
200	6	4
300	4	2
350	3	1

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

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].

4.2.4. Connect Power In

The Stack Switchgear requires 100 V to 240 V AC power to be supplied from an external source. Power is connected via feed-through connectors labeled 'Power In' on the front panel, as shown in Table 5.

To install a conductor

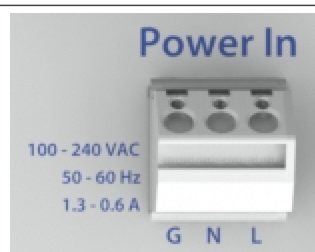
Insert a tool (such as a small flat screwdriver) into the rectangular opening at the top of the connector. This allows the conductor to freely enter into the circular opening at the front of the connector. Remove the tool to secure the conductor in place. For stranded wires, the use of ferrules is recommended.

> When the Stack Switchgear option for external 24 V DC (no internal AC to DC converter) is selected, the positive is at pin 2 and the negative is at pin 3 (pin 1 can be left unconnected). For available Stack Switchgear options, refer to Stack Switchgear Ordering Information.

An inline breaker provides the ability to turn off input power for the Stack Switchgear. It also protects the system by tripping if the input current exceeds 5 A. For specifications of this input, see Stack Switchgear.

> For the breaker’s safety mechanism to work as expected, the input power wiring must also be rated to at least 5 A.

Table 5. Power In Connector Pin Assignment



Pin	Name	Description	Connected to Device
1	G	Ground	External power source
2	N	Neutral	External power source
3	L	Line	External power source

Input power should be de-energized during installation; this usually involves turning off a breaker at a panel.

4.2.5. Connect Fan Control

Fan control enables the 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 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 Stack Switchgear as described in Section 4.2.4.

The signals are connected via feed-through connectors on the front panel, as shown in Table 6.

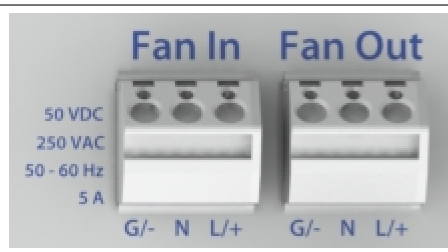
To install a conductor

Insert a tool (such as a small flat screwdriver) into the rectangular opening at the top of the connector. This allows the conductor to freely enter into the circular opening at the front of the connector. Remove the tool to secure the conductor in place. For stranded wires, the use of ferrules is recommended.

An inline breaker provides the ability to turn off fan control for the Stack Switchgear. It also protects the system by tripping if the amperage exceeds 5 A. For specifications of this input, see Stack Switchgear.

> For the breaker's safety mechanism to work as expected, the fan control wiring must also be rated to at least 5 A.

Table 6. Fan Control Connector Pin Assignment



Pin	Name	Description		Connected to Device
		AC	DC	
Fan Input				
1	G/-	Ground	Negative	External power source
2	N	Neutral	NC	External power source
3	L/+	Line	Positive	External power source
Fan Output				
1	G/-	Ground	Negative	External fan system
2	N	Neutral	NC	External fan system
3	L/+	Line	Positive	External fan system

Figure 16 provides the internal wiring implementation of the fan control parts shown above.

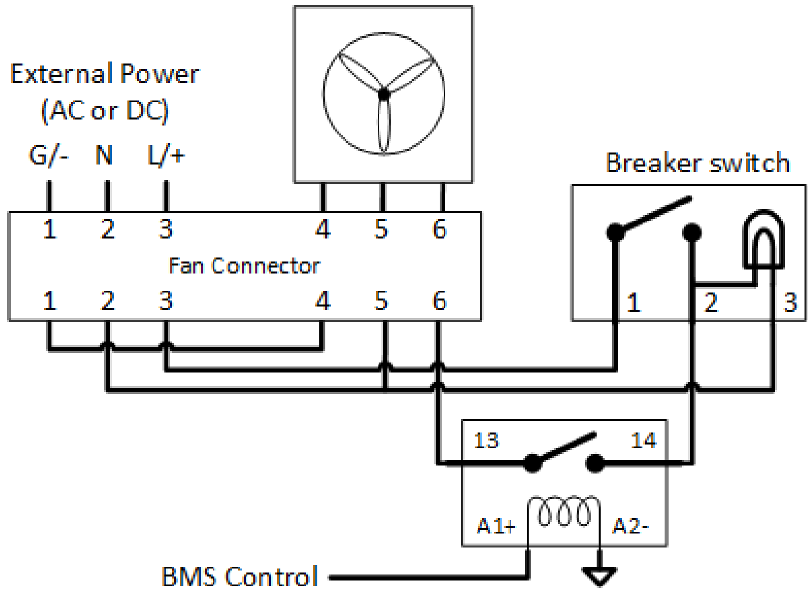


Figure 16. Battery cooling fan control wiring diagram

Fan power should be de-energized during installation; this usually involves turning off a breaker at a panel.

4.2.6. Connect E-Stop

This feature allows a 24 V DC E-Stop signal, provided either by the internal power supply (shown in Figure 17) or by a source external to the Nuvation Energy system (shown in Figure 18), to trigger a BMS fault and disconnect the stack using an internal safety relay. In this event, the BMS will also enter a fault state.

Internally, the E-Stop input is connected to the safety relay coils while the E-Stop output is connected to the internal 24 V DC power supply. One Stack Switchgear unit's E-Stop output is capable of driving the E-Stop inputs for up to two Stack Switchgear units (i.e. one other Stack Switchgear unit in addition to itself); this allows the two Stack Switchgear units to share an E-Stop circuit. For applications requiring more than two Stack Switchgear units on the same E-Stop circuit, an external 24 V DC power source must be used.

For specifications of this input, see Stack Switchgear.

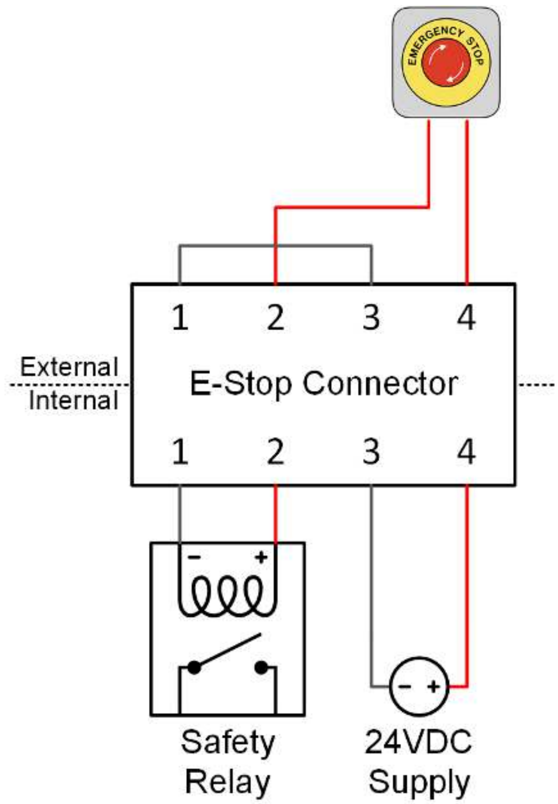


Figure 17. E-Stop circuit (internal supply)

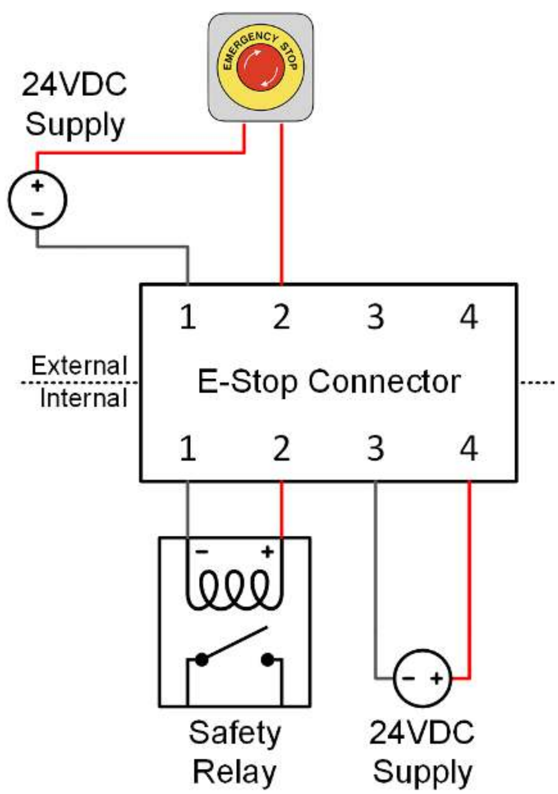


Figure 18. E-Stop circuit (external supply)

The signals are connected via feed-through connectors on the front panel, as shown in Table 7.

To install a conductor

Insert a tool (such as a small flat screwdriver) into the rectangular opening at the top of the connector. This allows the conductor to freely enter into the circular opening at the front of the connector. Remove the tool to secure the conductor in place. For stranded wires, the use of ferrules is recommended.

Table 7. E-Stop Connector Pin Assignment

Pin	Name	Description	Connected to Device
1	E-Stop In-	E-Stop Input (Return)	External E-Stop Circuitry
2	E-Stop In+	E-Stop Input (24 V DC)	External E-Stop Circuitry
3	E-Stop Out-	E-Stop Output (Return)	External E-Stop Circuitry
4	E-Stop Out+	E-Stop Output (24 V DC)	External E-Stop Circuitry

4.2.7. Connect Ethernet

Figure 19. Ethernet Connector

The Ethernet connector is a standard RJ45 Ethernet jack. It may be used to connect the 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.

4.2.8. Connect Link Bus

The Link Bus connector provides power and communication to the Cell Interface modules. The amount of current supplied by this connector is the sum of current consumed by all Cell Interface modules in the system.

Typically, the Link Bus is connected to the Cell Interface module which measures the most negative cell, with each subsequent Cell Interface module measuring increasingly positive cells. Although any order of the 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 Cell Interface modules are not already connected to the battery (e.g. battery cell connection, temperature sensors, and Link Bus cables between the Cell Interface modules), this can be done now. For instructions on connecting the Cell Interface modules to the battery, refer to Section 4.4.

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

4.2.9. 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.

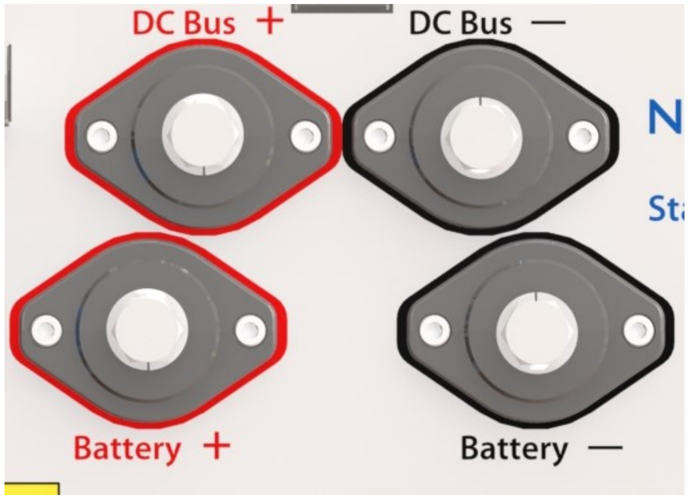
> The Stack Switchgear is configured for a specific battery topology based on the details provided to Nuvation Energy during order fulfillment. Failure to use the same number of Cell Interface modules and/or using a different battery topology will result in undesirable Stack Switchgear behavior. Please contact support@nuvationenergy.com if there is a change in the system design that would require a Stack Switchgear configuration update.

The front panel of the 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 8. 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 NUVSSG-1250-350 installation capable of up to 400 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

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. Cell Interface Mechanical Installation

4.3.1. Dimensions and Weight

The overall dimensions of the Cell Interface are 104.4 mm × 121.58 mm × 40.6 mm.

The standard Cell Interface (i.e. with bulkhead) weighs approximately 450 g.

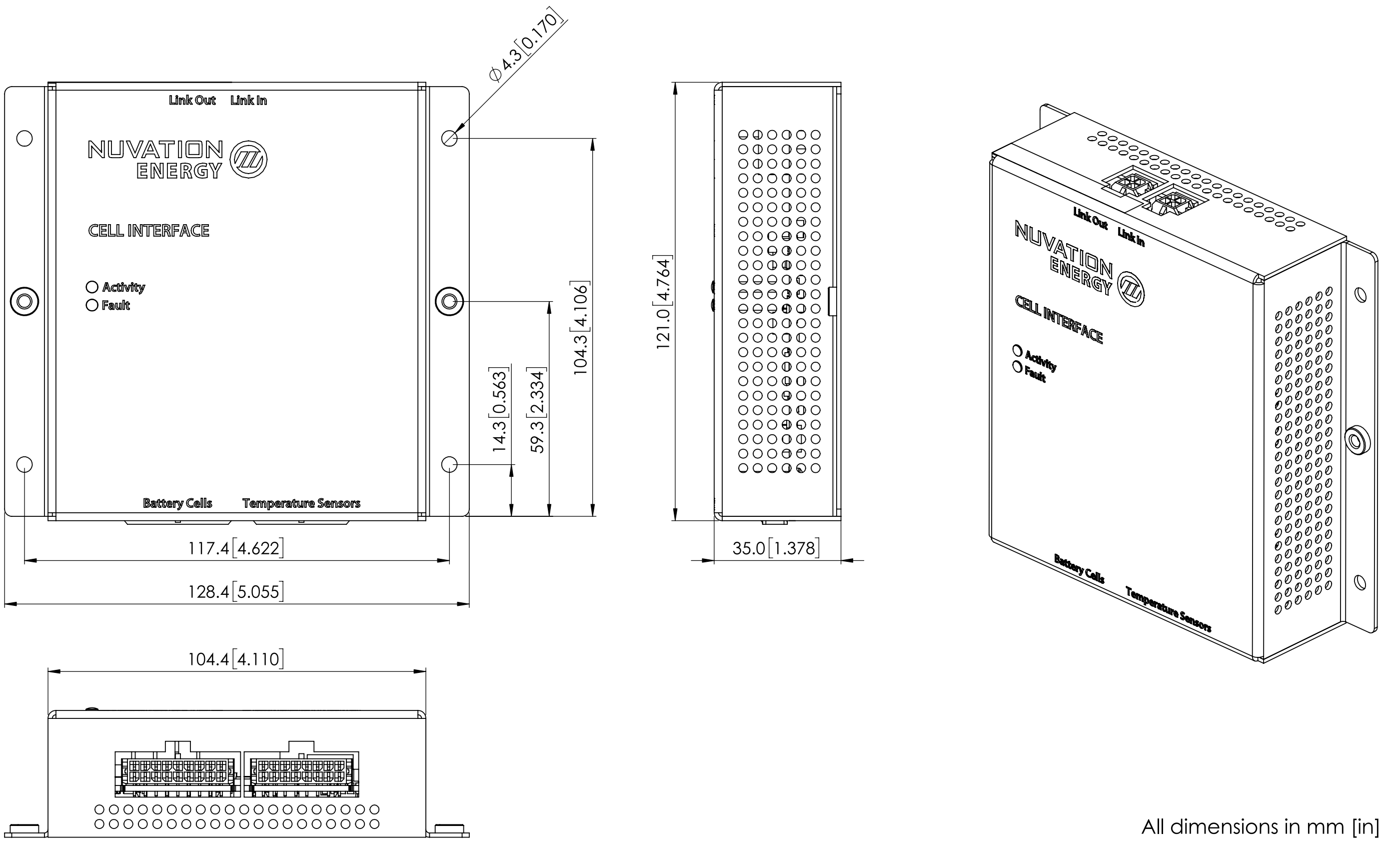


Figure 20. Mechanical Drawing of Cell Interface with Bulkhead Enclosure

4.3.1.1. DIN rail mounting Kit

For applications requiring DIN rail mounting, the Cell Interface Mounting Bracket (Bulkhead-to-DIN) (sold separately) may be used. This kit includes a metal plate and the necessary hardware to securely mount the bulkhead enclosure of the Cell Interface to EN50022-compliant DIN rails.

The Mounting Bracket kit assembly adds an extra 14.2 mm to the overall width of the Cell Interface module, bringing it from 104.4 mm to 118.6 mm. The kit assembly holds the module approximately 7 mm away from the inside lip of the DIN rail.

The Mounting Bracket offsets the Cell Interface module from the center of the DIN rail approximately 30 mm upwards as shown in Figure 21.

A Cell Interface with the Mounting Bracket weighs approximately 540 g.

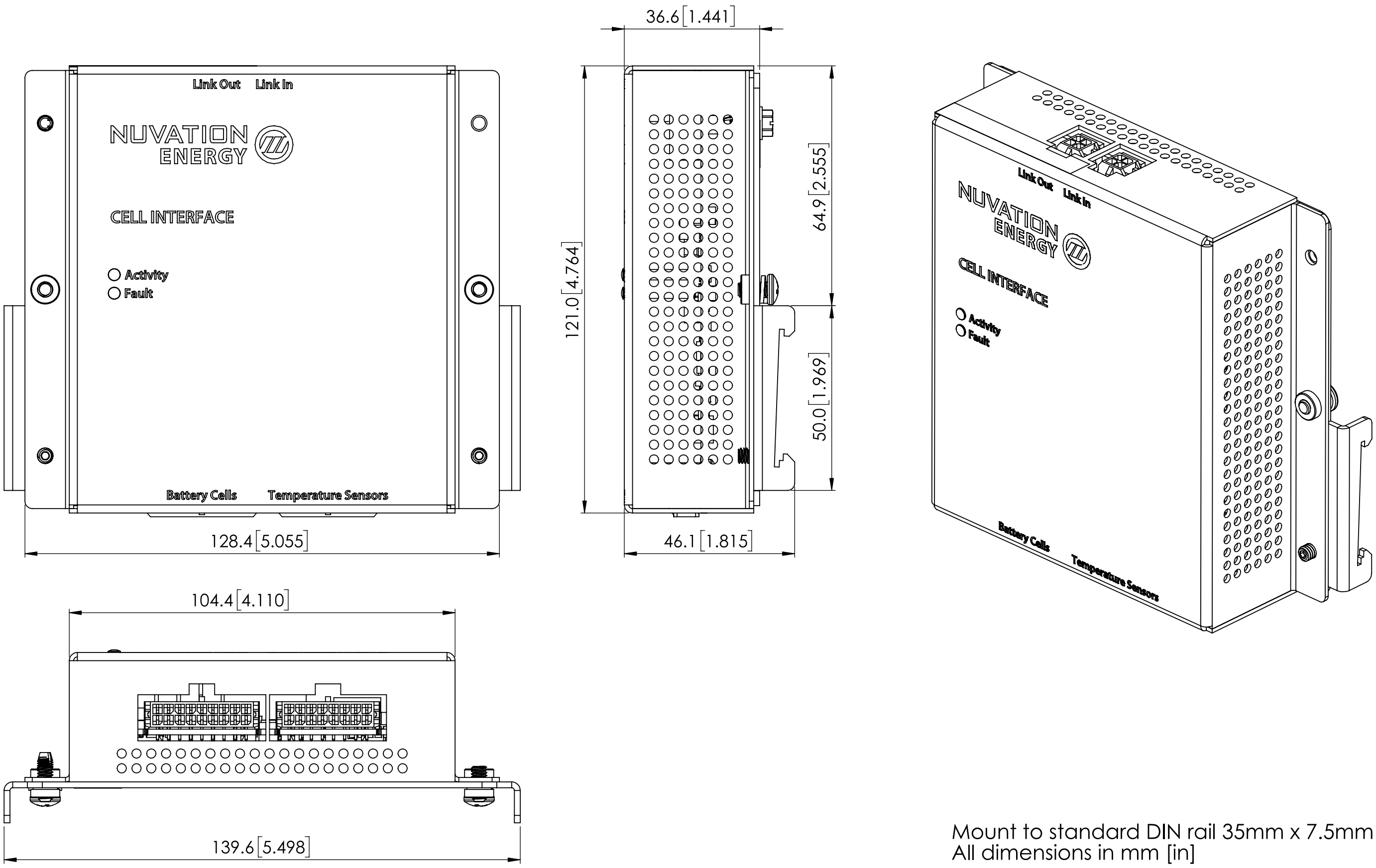


Figure 21. Mechanical Drawing of Cell Interface with Cell Interface Mounting Bracket (Bulkhead-to-DIN)

4.3.2. Installation Location and Position

Figure 22. Nuvation Energy Cell Interface Module

The Cell Interface is available in a bulkhead-mountable enclosure which has five metal walls, leaving the back of the unit fully exposed. It is designed to mount to a metal bulkhead panel such that the panel covers the exposed back.

The Cell Interface is rated to operate in the temperature range of -10 °C to 60 °C. It is designed for indoor use.

The Cell Interface should be mounted against a flat surface with the 'Link In' and 'Link Out' ports 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.

4.3.2.1. Mounting Clearances

The NUV100-CI-12-1 and NUV100-CI-16-1 variants produce up to 24 W and 32 W, respectively, during cell balancing. A portion of this heat is transferred to the bulkhead.

Extra space should be provided around the module to allow for sufficient heat dissipation as well as easy installation and maintenance.

If mounting a `Cell Interface, PCB assembly only (no enclosure)`, note that the Cell Interface contains high-voltage signals reaching as high as 1250 V DC. Care must be taken when mounting the PCB into a metal enclosure to ensure that the metal walls remain a safe distance from the exposed conductor on the PCB. Using 1250 V DC as an example, the metal walls of the enclosure must be at least 4.2 mm from the nearest exposed conductor and must not touch the PCB or any component on the PCB, including the connector housings.

4.3.3. Mounting Instructions

Ensure appropriate fasteners (not included) are used to mount the 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 Cell Interface.

4.4. Cell Interface Electrical Connections

The 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.

4.4.1. Getting Started

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

1. 1x Battery Cells cable
2. 1x Thermistor cable
3. 1x Link Bus cable

These cables are available for purchase as a kit.

Figure 23. Example Cell Interface kit (NUV100-CI-16-KIT-2)

The instructions below are for applications using cable harnesses purchased from Nuvation Energy. To build custom cables, refer to Section 8.2 for connector pin-out and specifications.

Connection sequence

- Step 1: Connect Temperature cable for temperature measurement of the cells
- Step 2: Connect Battery Cells cable to battery voltage sense leads
- Step 3: Connect Link Bus cable to BMS module(s)

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.

4.4.2. Connect Temperature Cable

The 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 Stack Switchgear behavior. Please contact support@nuvationenergy.com if there is a change requiring a 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.

Figure 24. 2 Thermistor cable (NUVW-A18A12-020)

Figure 25. 7 Thermistor cable (NUVW-A19A12-020)

2 to 7 thermistors are supported to accommodate systems requiring Nuvation Energy BMS to meet functional safety requirements.

Cable Isolation

Because the sensors are referenced to the `CELL0` or `BLOCK0` input on the 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 Cell Interface modules in the system

The thermistors must 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.

Thermal Consistency

For safety certified systems, there is an additional constraint on thermal consistency for all temperature measurements for each Cell Interface. The constraint is described in detail in the Sensor Fault Detection section within the Nuvation Energy BMS: Safety Manual (available on request).

4.4.2.1. Connection Procedure

Connect to Surface

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

Connect to Cell Interface

'Temperature' cable connects to the 'Temperature Sensors' port at the bottom of the Cell Interface.

4.4.3. Connect Battery Cells Cable

The Battery Cells cable provides cell voltage input and a means for balancing the cells.

Power Requirements

There is no minimum cell voltage requirement when powering the Cell Interface module from the Link Bus.

However, if powering the Cell Interface - 12 channel module from the cells (i.e. not powering from the Link Bus), a minimum of 11V must be present between the most negative and most positive cells.

Similarly, if powering the Cell Interface - 16 channel module or the Cell Interface - 12 V 4 channel module from the cells (i.e. not powering from the Link Bus), the cells are connected as two groups and a minimum of 11 V must be present between the most negative and most positive cells of each group.

4.4.3.1. Connection Procedure

> The Stack Switchgear is pre-configured to expect a defined battery topology, based on the information provided to Nuvation Energy during order fulfillment. Connecting a differing battery topology will result in undesirable Stack Switchgear behavior. Please contact support@nuvationenergy.com if there is a change in battery topology requiring a Stack Switchgear configuration update.

Connect to Cells

Connect the cables wires to the battery voltage sense leads. The individual wires are labelled to help with identifying the connections. Verify the cell voltages present on the connector are correct. While the Cell Interface module is tolerant of most wiring errors, incorrect connections may cause the cells to discharge.

Refer to the wiring examples below for the specific Cell Interface module used.

Connect to Cell Interface

'Battery Cells' cable connects to the 'Battery Cells' port at the bottom of the Cell Interface.

4.4.3.1.1. Battery Cell Connector for Cell Interface - 12 channel

Figure 26. Battery Cells cable (NUVW-A08Z12-020) for Cell Interface - 12 channel

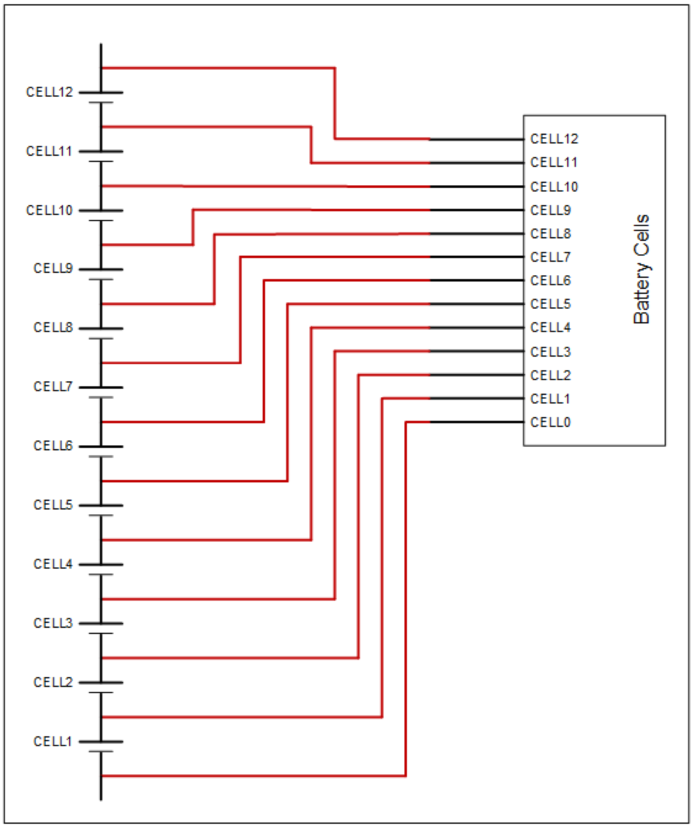


Figure 27. Example wiring 12 cells in a Cell Interface - 12 channel

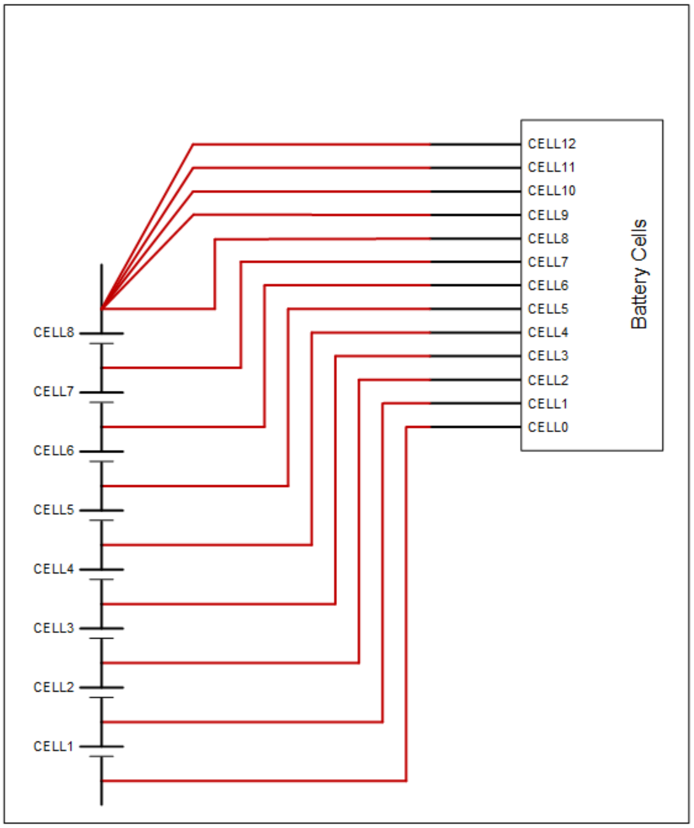


Figure 28. Example wiring 8 cells in a Cell Interface - 12 channel

4.4.3.1.2. Battery Cell Connector for Cell Interface - 16 channel

Figure 29. Battery Cells cable (NUVW-A09Z12-020) for Cell Interface - 16 channel

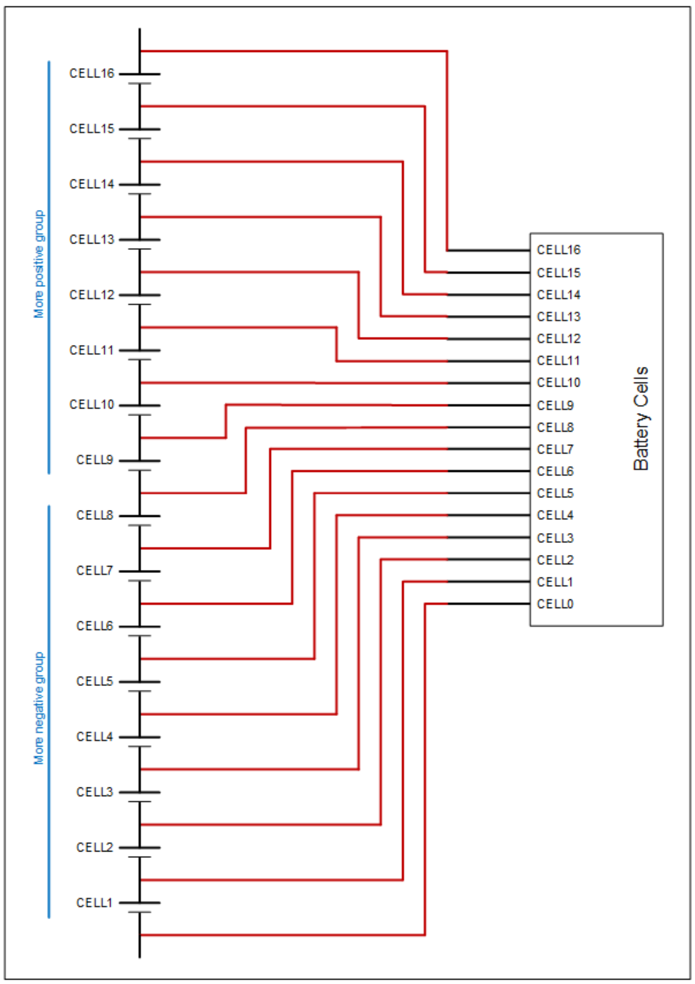


Figure 30. Example wiring 16 cells in a Cell Interface - 16 channel

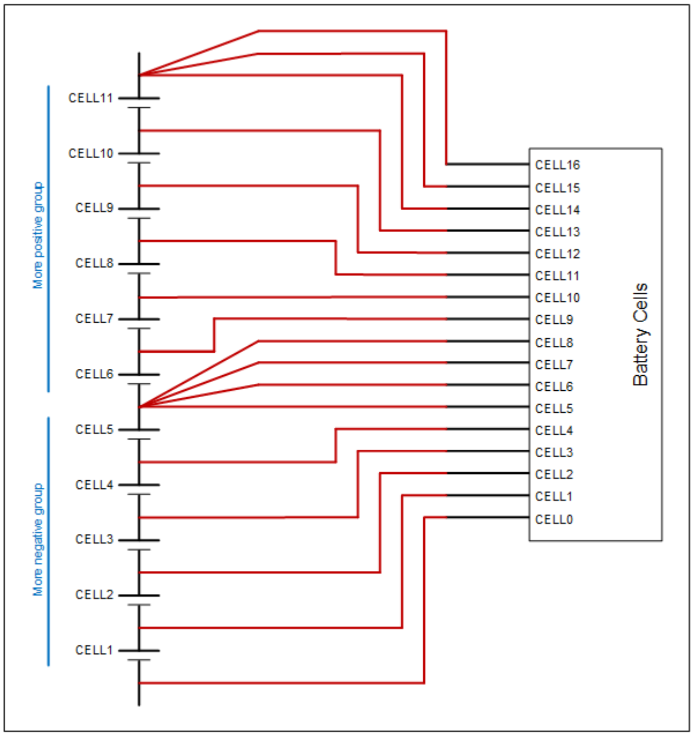


Figure 31. Example wiring 11 cells in a Cell Interface - 16 channel

4.4.3.1.3. Battery Cell Connector for Cell Interface - 12 V 4 channel

Balancing is not supported by the Cell Interface - 12 V 4 channel variant.

Figure 32. Battery Cells cable (NUVW-A10Z12-020) for Cell Interface - 12 V 4 channel

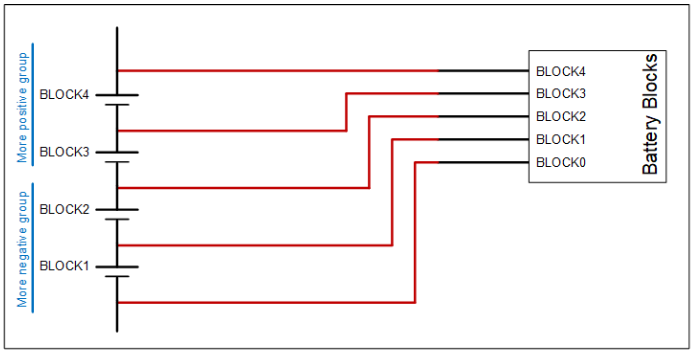


Figure 33. Example wiring 4 blocks in a Cell Interface - 12 V 4 channel

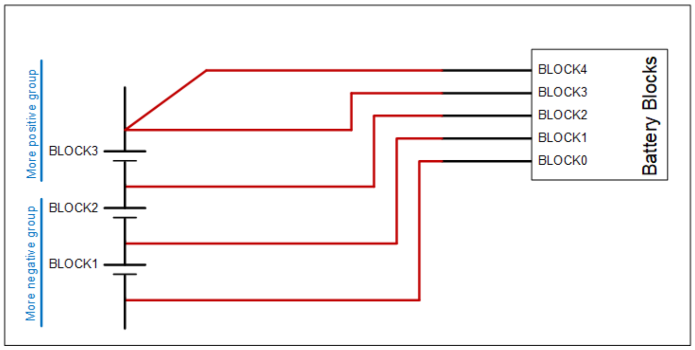


Figure 34. Example wiring 3 blocks in a Cell Interface - 12 V 4 channel

4.4.4. Connect the Link Bus Cable

Figure 35. Link Bus cable (NUVW-A01X03-010)

The Link Bus cable is used to connect Cell Interface modules in a daisy chain (called the Link Bus chain) by connecting the 'Link In' of one Cell Interface to the 'Link Out' of the next 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 and a power source to subsequent Cell Interface modules in the Link Bus chain. The amount of current supplied by this connector is the sum of current consumed by all subsequent Cell Interface modules in the Link Bus chain.

Connection Procedure

1. Connect one end of the cable to the 'Link Out' connector on the Stack Switchgear.
2. Connect the other end of the Link Bus cable to the 'Link In' connector on the Cell Interface.
3. For multiple Cell Interface modules, use additional Link Bus cables to connect the 'Link Out' on the current Cell Interface to the 'Link In' of the next Cell Interface in the chain.
4. The 'Link Out' of the last Cell Interface module in the Link Bus chain is to be left unconnected.

4.5. First Power-up

Once the Stack Switchgear is connected to the battery (including the Cell Interface modules chain), it can be powered (internal power and fan power). The two breakers can be put in the closed (non-tripped) position. The power LED (green) should turn ON.

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.

The service disconnect switch can be put in the **ON** position.

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. The faults are described in the Section 10.1. Once all faults are cleared, the Stack Switchgear is able to connect the battery to the DC bus.

4.5.1. Status LEDs

When the Stack Switchgear is powered up, the status LEDs provide an indication of the functional status. A more detailed status may be accessible via the Operator Interface.

4.5.1.1. Stack Switchgear

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

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).

Figure 36. Power LED

Activity LED

The **ACTIVITY** LED (blue) indicates that the Stack Switchgear is communicating with the Multi-Stack Controller or an external controller and is receiving a heartbeat signal.

Figure 37. Activity LED

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.

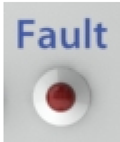


Figure 38. Fault LED

4.5.1.2. Cell Interface

The 2 status LEDs on the face of the Cell Interface indicate the functional status of the module.

Activity

This LED indicates that the Cell Interface module has received a communication packet over the Link Bus.

Fault

This LED is not used in normal operations. It is available to support on-site troubleshooting.

5. Setting up the Operator Interface

5.1. Install the Operator Interface

The Nuvation Energy BMS Operator Interface is used to access the Nuvation Energy BMS. The latest Operator Interface release is available online at: https://ncloud.nuvationenergy.com. You may create an account to download the software package.

1. Download the `High-Voltage BMS` package
2. Extract the contents of the package to a suitable location on your computer.
3. Releases follow a naming convention similar to `nuvation-hv-bms-babbage-18.08.1.zip`. The package should be extracted to a folder with the same name to avoid overwriting other releases or files present in the same directory.

Browser Compatibility

The 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.

5.2. Connect to the Operator Interface

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

Identify the battery management system IP

By default, Stack Switchgear is configured with a static IP address of `192.168.1.21`, unless noted otherwise on a label on the 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 39. 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 at 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 Nuvation Energy BMS and select `Properties`
3. Click `Internet Protocol Version 4 (TCP/IPv4)` and click `Properties`

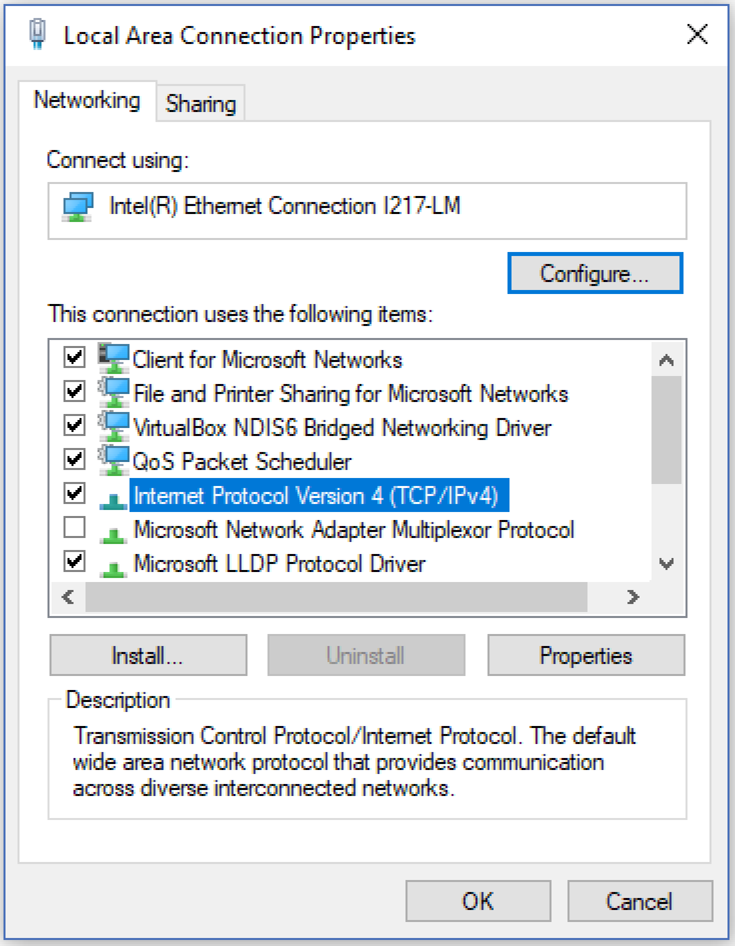


Figure 40. Network Adapter Properties on Windows.

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 battery management system 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 battery management system and the Host ID should be 1.
     - For example, if the battery management system IP address is `192.168.1.21`, the gateway address would be `192.168.1.1`

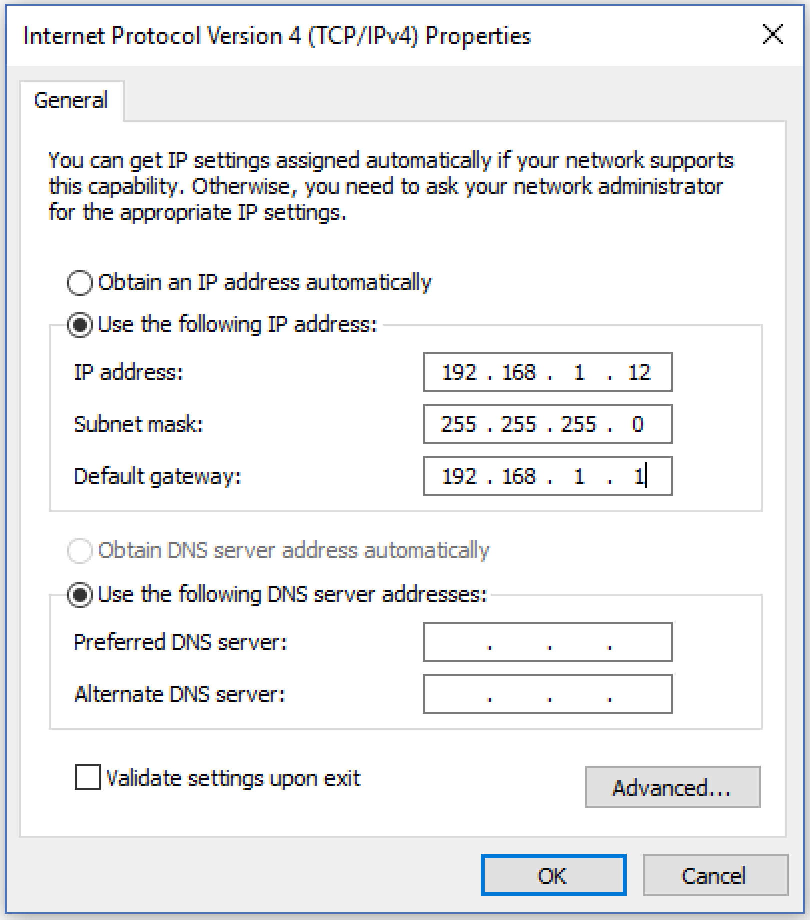


Figure 41. Network Adapter Settings on Windows

5. Ensure your computer is on the same network as your 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.

6. Using the Operator Interface

6.1. 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.

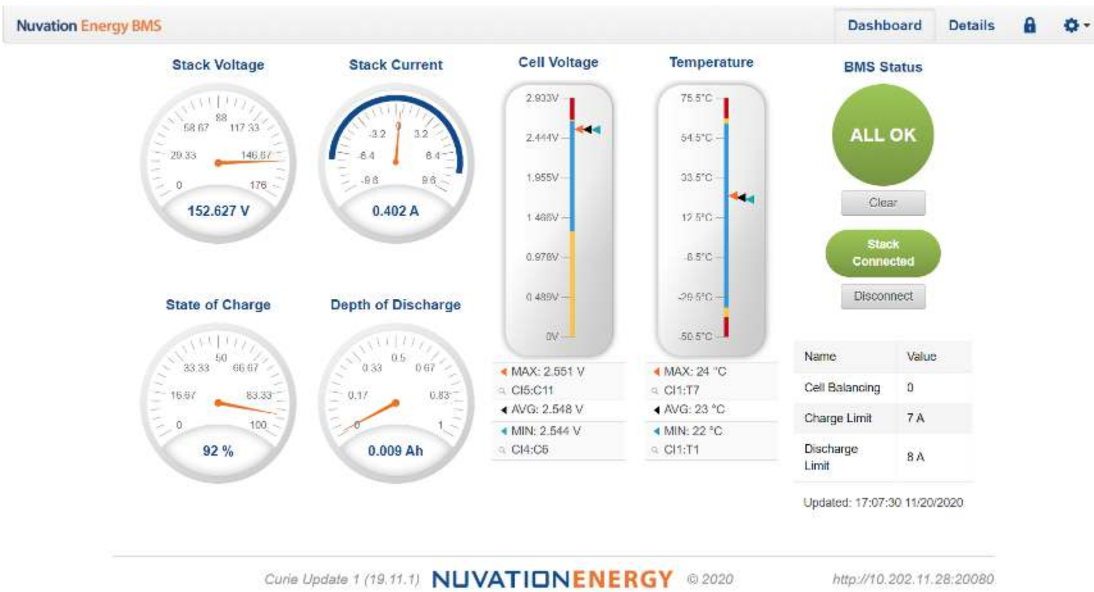


Figure 42. Nuvation Energy BMS Operator Interface Dashboard screenshot

6.1.1. 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.

6.1.2. Stack Voltage

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

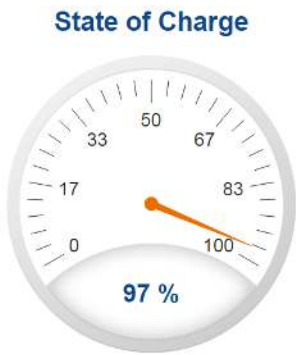
6.1.3. Stack Current

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.

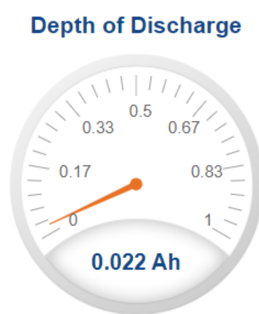
6.1.4. State-of-Charge

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%.



6.1.5. 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.



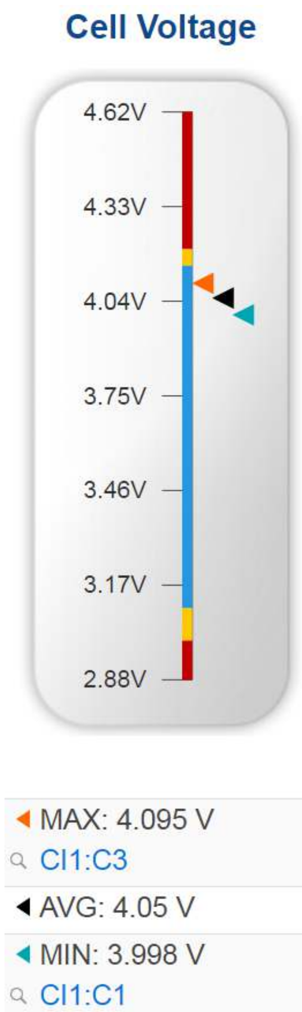
6.1.6. Cell Voltage

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.



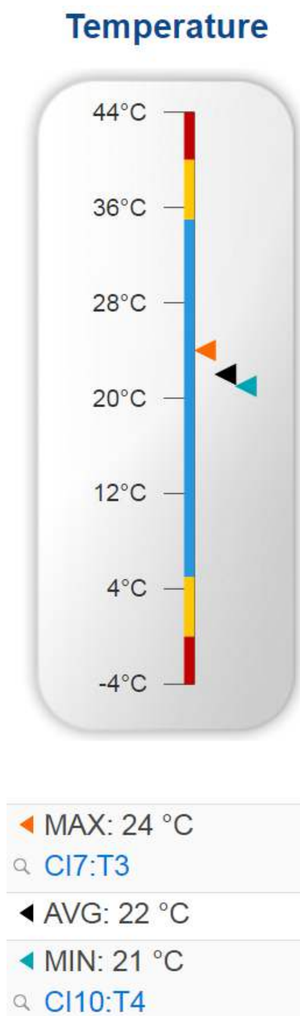
6.1.7. Temperature

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.



6.1.8. 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.

6.1.8.1. Operation Status

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

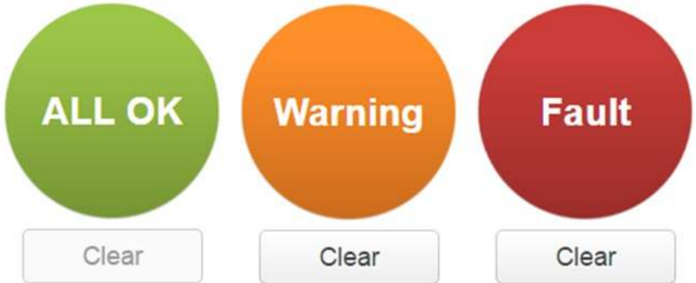


Figure 43. Three possible Nuvation Energy BMS operation states

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.

6.1.8.2. Connection State

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

Figure 44. Three possible connection states

`Stack Disconnected` in a red oval indicates 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.

6.1.8.3. 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.

6.1.8.4. 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 6.4.2 for more details.

6.2. 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.

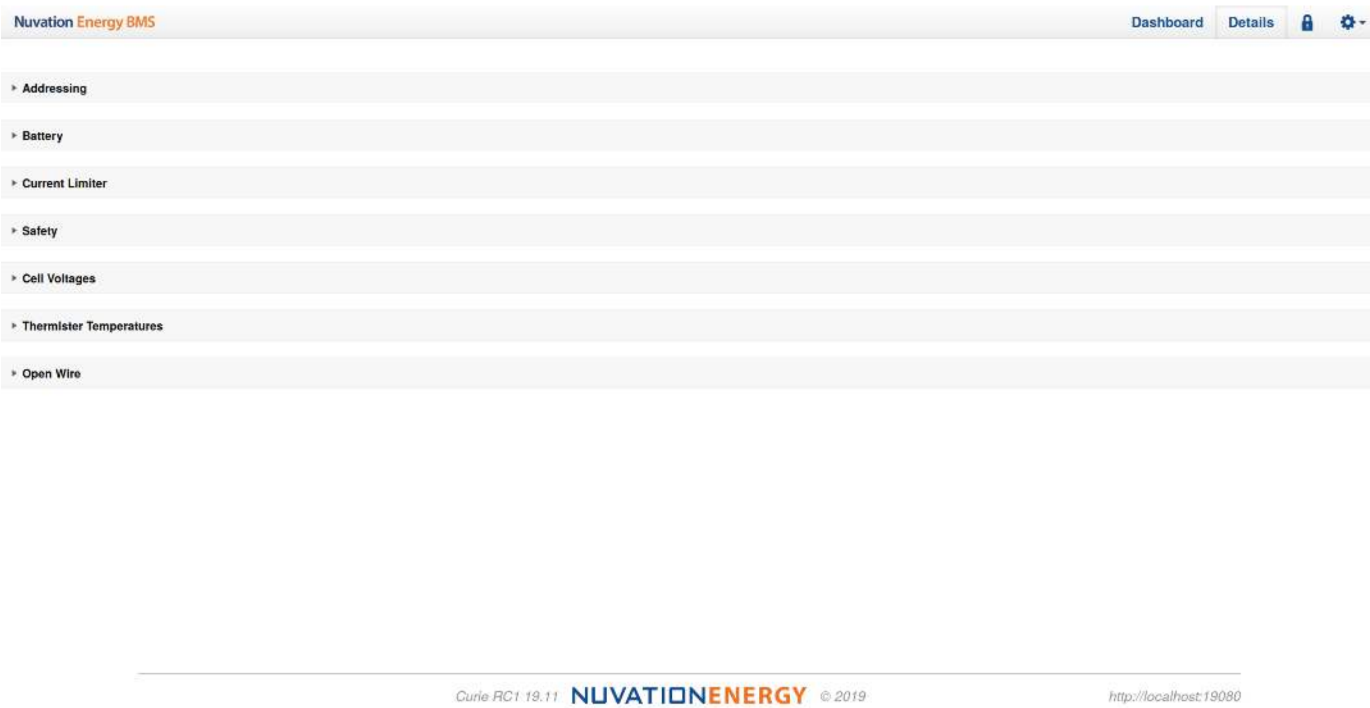


Figure 45. Nuvation Energy BMS Operator Interface Details tab screenshot

6.2.1. 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 46. Addressing accordion in Details Tab

6.2.2. Battery

The Battery accordion contains values on the overall battery stack. This information is identical to the values shown in the radial gauges and bar gauges on the Dashboard.

▾ Battery

Last update: Fri Nov 29 2019 12:44:04 GMT-0500 (Eastern Standard Time)

Register Name	Value
Stack Voltage	1000.000 V
State of Charge	0.67 %
Stack Current	0.729 A
Depth of Discharge	0.15 Ah
Average Cell Voltage	3.216 V
Maximum Cell Voltage	3.26 V
Minimum Cell Voltage	3.096 V
Average Temperature	26 C
Maximum Temperature	28 C
Maximum Temperature	25 C

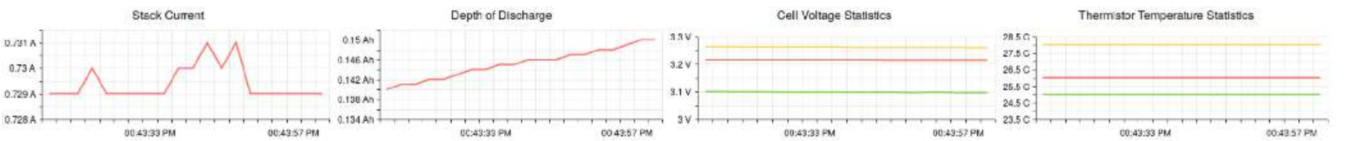


Figure 47. Battery accordion in Details Tab

6.2.3. Current Limiter

The Current Limiter accordion contains 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 Information Table on the Dashboard.

▾ Current Limiter

Last update: Fri Nov 29 2019 12:45:02 GMT-0500 (Eastern Standard Time)

Register Name	Value
Charge Limit	0.75 A
Discharge Limit	0.75 A
Balancing Count	0

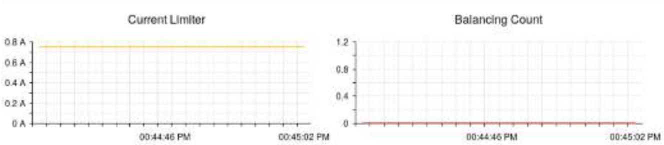
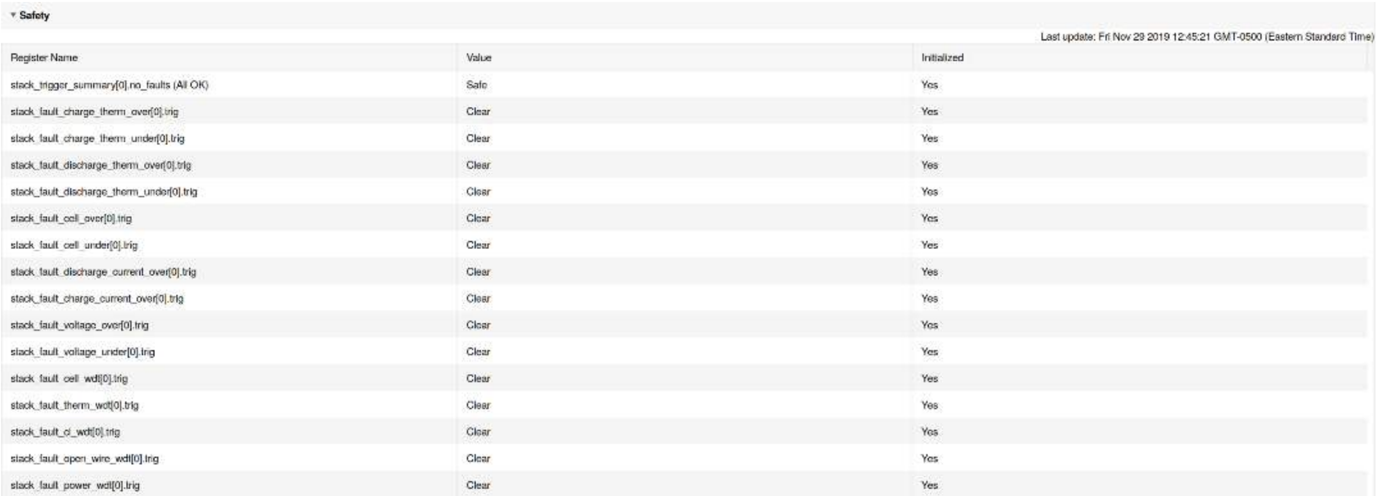


Figure 48. Current Limiter accordion in Details Tab

6.2.4. 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 or warning is shown as `Tripped`. In normal operation, all warnings and faults should be clear and the battery stack can be charged and discharged.



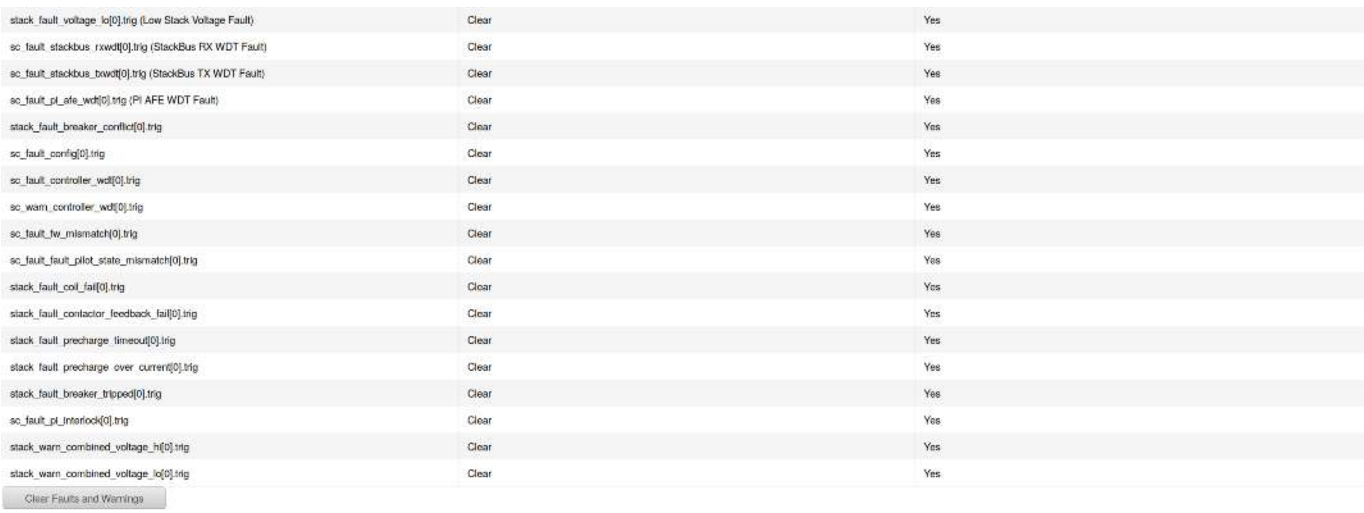
▾ Safety

Last update: Fri Nov 29 2019 12:45:21 GMT-0500 (Eastern Standard Time)

Register Name	Value	Initialized
stack_trigger_summary[0].no_faults (All OK)	Safe	Yes
stack_fault_charge_therm_over[0].trig	Clear	Yes
stack_fault_charge_therm_under[0].trig	Clear	Yes
stack_fault_discharge_therm_over[0].trig	Clear	Yes
stack_fault_discharge_therm_under[0].trig	Clear	Yes
stack_fault_cell_over[0].trig	Clear	Yes
stack_fault_cell_under[0].trig	Clear	Yes
stack_fault_discharge_current_over[0].trig	Clear	Yes
stack_fault_charge_current_over[0].trig	Clear	Yes
stack_fault_voltage_over[0].trig	Clear	Yes
stack_fault_voltage_under[0].trig	Clear	Yes
stack_fault_cell_wdt[0].trig	Clear	Yes
stack_fault_therm_wdt[0].trig	Clear	Yes
stack_fault_cl_wdt[0].trig	Clear	Yes
stack_fault_open_wire_wdt[0].trig	Clear	Yes
stack_fault_power_wdt[0].trig	Clear	Yes

Figure 49. 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_fault_voltage_lo[0].trig (Low Stack Voltage Fault)	Clear	Yes
sc_fault_stackbus_rxwdt[0].trig (StackBus RX WDT Fault)	Clear	Yes
sc_fault_stackbus_txwdt[0].trig (StackBus TX WDT Fault)	Clear	Yes
sc_fault_pl_afe_wdt[0].trig (PI AFE WDT Fault)	Clear	Yes
stack_fault_breaker_conflict[0].trig	Clear	Yes
sc_fault_config[0].trig	Clear	Yes
sc_fault_controller_wdt[0].trig	Clear	Yes
sc_warn_controller_wdt[0].trig	Clear	Yes
sc_fault_fw_mismatch[0].trig	Clear	Yes
sc_fault_fault_pilot_state_mismatch[0].trig	Clear	Yes
stack_fault_coil_fail[0].trig	Clear	Yes
stack_fault_contactor_feedback_fail[0].trig	Clear	Yes
stack_fault_precharge_timeout[0].trig	Clear	Yes
stack_fault_precharge_over_current[0].trig	Clear	Yes
stack_fault_breaker_tripped[0].trig	Clear	Yes
sc_fault_pl_interlock[0].trig	Clear	Yes
stack_warn_combined_voltage_hi[0].trig	Clear	Yes
stack_warn_combined_voltage_lo[0].trig	Clear	Yes

Clear Faults and Warnings

Figure 50. Bottom of Safety accordion in Details Tab

6.2.5. 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.

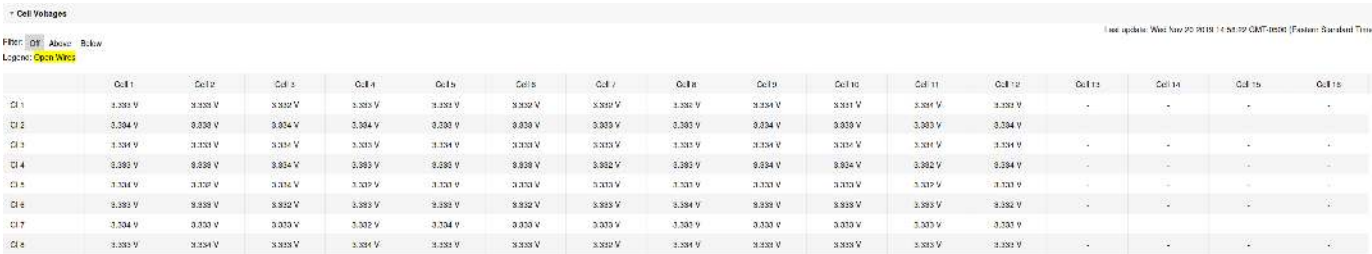


Figure 51. Cell Voltages accordion in Details Tab

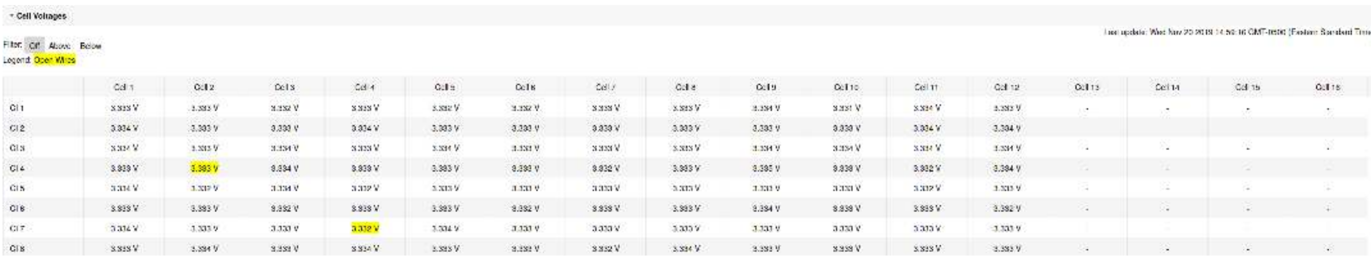
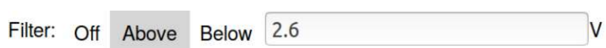


Figure 52. Cell Voltages with open wires accordion in Details Tab

6.2.5.1. Filtering

You can filter the display to cells with voltages above or below a value you specify.



6.2.6. 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

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

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	-	-
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 53. Thermistor accordion in Details Tab

6.2.6.1. Filtering

You can filter the display to cells with temperatures above or below a value you specify.

6.2.7. 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.

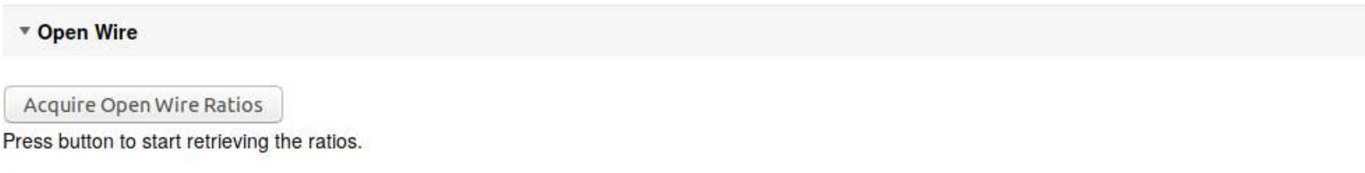


Figure 54. Open Wire accordion in Details Tab

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

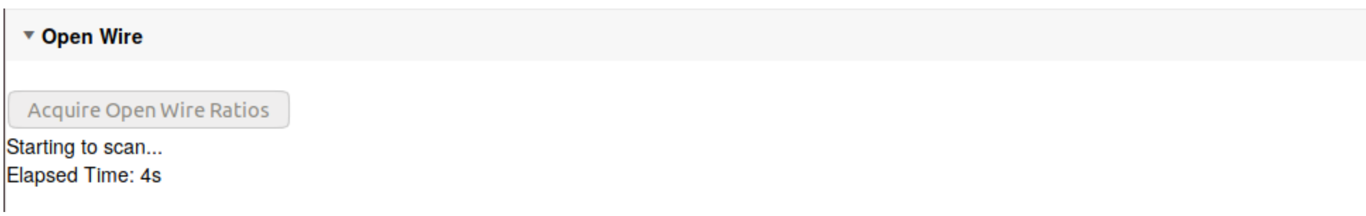


Figure 55. Open Wire acquiring accordion in Details Tab

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.

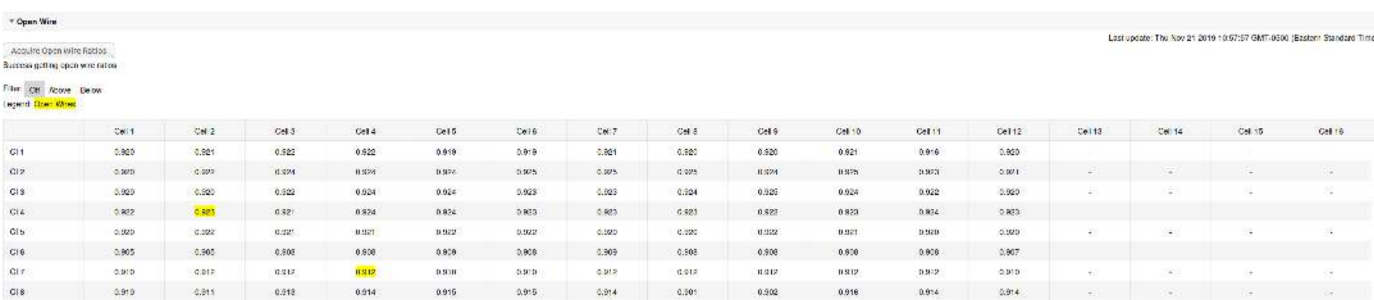


Figure 56. Open Wire diagnostics accordion in Details Tab

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.

Depending on whether you are using 12 or 16 channel battery management system modules or monobloc battery management system modules, they will display different diagnostics information.

6.2.7.1. Filtering

Use the filter to show only ratios of Voltage that are above or below the specified value.

6.3. 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

6.3.1. 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.

> It is possible to edit registers on multiple stacks using this interface, which can result in unintended behavior. It is recommended to only edit registers that start with `pack_` or `gbc_` using this interface. Use the stack-level Operator Interface to make edits to a connected stack.

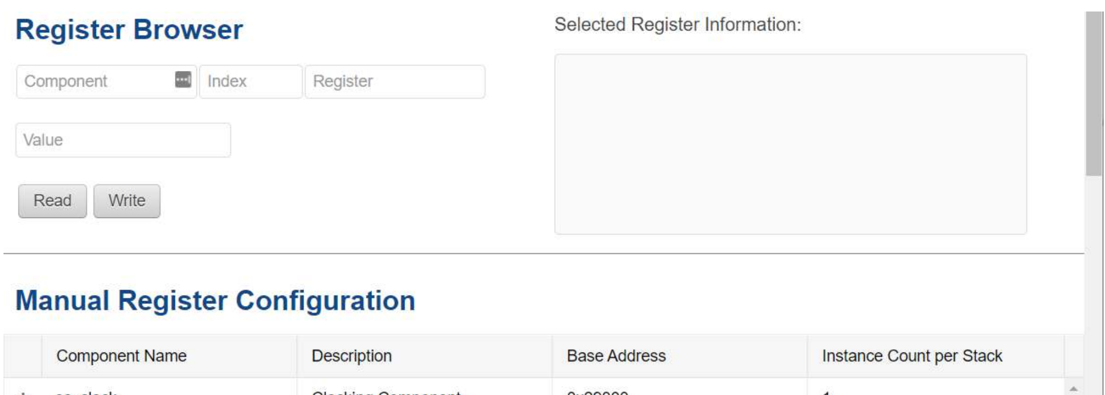


Figure 57. Register Browser

6.3.2. Service

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

6.3.2.1. 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 Stack Switchgear 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.

6.3.2.2. 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`

6.3.2.3. 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.

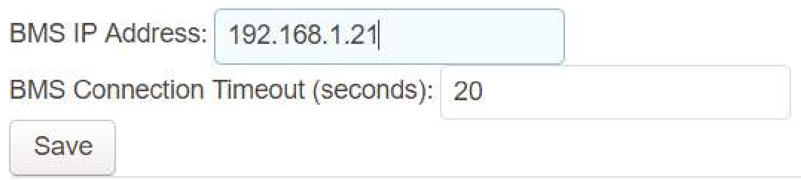
6.3.3. Connection

The connection screen 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:

1. Re-open the Nuvation-Energy-Operator-Interface.html file in your web browser
2. Wait for the connection message to time out

3. From the menu, select Connection to bring up the IP address configuration page
4. Enter the IP address of Nuvation Energy BMS you wish to connect to
5. Enter a Connection Timeout – `20` is the recommended seconds



6. Click the Save button. The page will refresh and try to connect to this new IP

> 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. The Operator Interface can be opened in separate browser tabs and the connection information changed after the interface loads. However, please note that if either instance is refreshed, that tab will use the most recently set IP address.

6.3.4. 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 Stack Switchgear 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 Stack Switchgear.

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

Figure 58. Operator Interface Locked indicator

Figure 59. Operator Interface Unlocked indicator

6.3.4.1. 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.

6.3.4.2. 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.

6.3.5. 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.

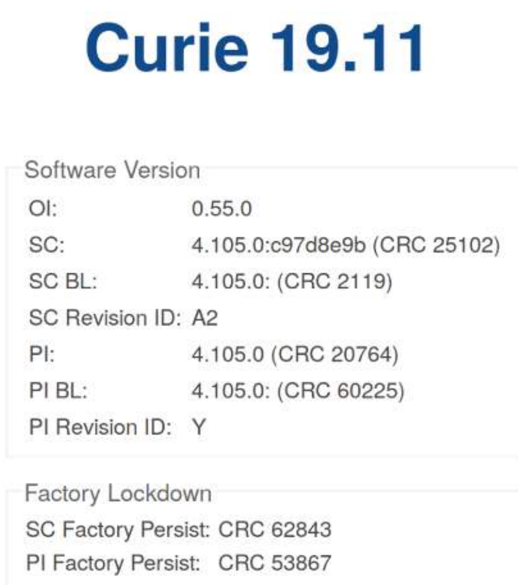


Figure 60. Sample About screen

Not all information is displayed unless the BMS is factory locked. Additional information for identifying the configuration and images is provided to ensure the correct version of firmware and configuration is being used as specified at the factory.

6.4. 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.

If the network connection speed is slow, it is possible to see the 'Exiting Lockout' banner appear briefly during normal operation. Network speed does not impact the state of the BMS and so this is not an issue.

6.4.1. Service Lockout Indication

> In normal operating scenarios the Stack Switchgear should never be in service lockout. In the un-likely scenario that the Stack Switchgear is in service lockout, please contact support@nuvationenergy.com.

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

Figure 61. Operator Interface Service Lockout indicator

Figure 62. Operator Interface Exiting Service Lockout indicator

Figure 63. Operator Interface Entering Service Lockout indicator

6.4.2. 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.

Figure 64. Multi-Stack Operator Interface Communication lost indicator

7. Communication Protocols

7.1. 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.

7.1.1. 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).

7.1.2. 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.

7.1.2.1. 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. A full description of the Common Model can be found in the SunSpec specification bundle.

7.1.2.2. 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.

7.1.2.3. 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.

7.1.2.4. 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.

7.1.2.5. End Model

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

7.1.3. 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.

7.1.3.1. 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 16 bits, partial read accesses are not allowed. A Modbus read/write error is returned on such an access.

7.1.3.2. 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.

7.1.3.3. 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 9. 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 10. 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)
802	CycleCt	Cycle Count
802	WMaxDisChaRte	NamePlate Max Discharge Rate
802	SoH	State of Health (reported in 803 model per string)
802	BatReqPCSSt	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

7.1.3.4. 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.

7.1.4. 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).

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

7.1.4.1. 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 11. 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 12. 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.

7.1.4.2. 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 13. 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	BMaxModTmpLoc	40126	No	Module/String location for minimum module temperature
803	Fixed	BTotDCCur	40127	Yes	Total DC current of the battery system
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

Model	Block	Point Name	Address	Scale Factor	Purpose
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 `Index = Stack Index * Length of Repeating block`. By definition, the 803 Repeating block is 16 Modbus registers in length.

7.1.5. 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
```

8. External Interfaces

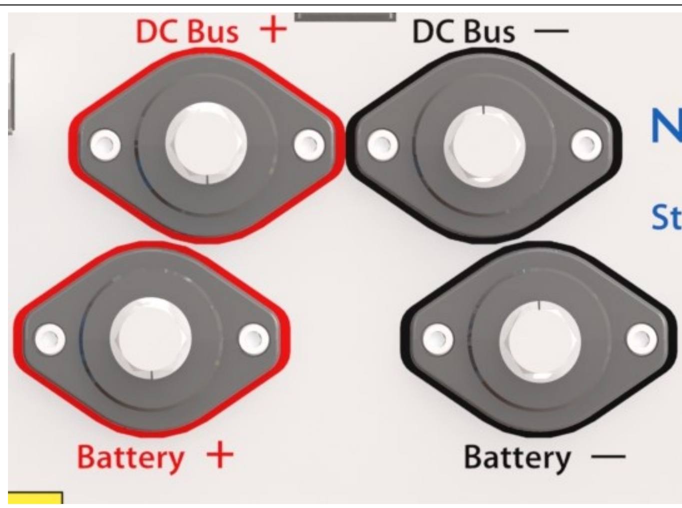
8.1. Stack Switchgear

8.1.1. Battery Stack and DC Bus

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 14. 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

8.1.2. Ethernet

The Ethernet jack is a standard RJ45 Cat5e rated jack.

Table 15. 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
4	NUL45	Unused; connected to Pin 5 and terminated	External Equipment
5	NUL45	Unused; connected to Pin 4 and terminated	External Equipment

Pin	Connection	Description	Connected to Device
6	RD_N	Receive differential pair negative	External Equipment
7	NUL78	Unused; connected to Pin 8 and terminated	External Equipment
8	NUL78	Unused; connected to Pin 7 and terminated	External Equipment

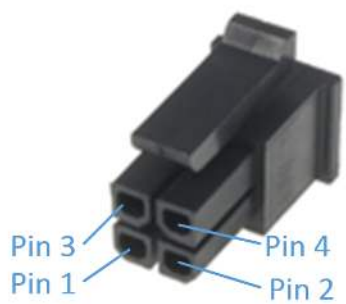
8.1.3. Link Bus

Supported Wire Diameter: 22 AWG - 12 AWG

Table 16. Link Bus Connector Pin Assignment

Pin	Name	Description	Connected to Device
1	VBUS	DC power from Stack Switchgear	Cell Interface
2	COM	Power return from Stack Switchgear	Cell Interface
3	IPA	Link Bus differential pair plus	Cell Interface
4	IMA	Link Bus differential pair minus	Cell Interface

Table 17. Link Bus: Molex Micro-Fit 3.0 Connector



Molex 43025-0400	
Manufacturer	Molex Incorporated
Housing	43025-0400
Housing material	Nylon UL94V-0
Circuits	4
Crimp terminal	43030-0002
Wire gauge range	AWG20–24 stranded

8.1.4. E-Stop

Supported Wire Diameter: 22 AWG - 12 AWG

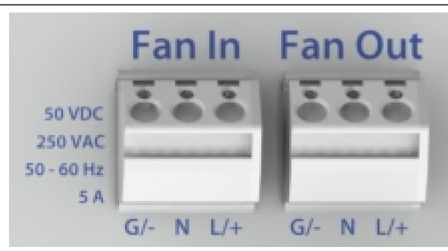
Table 18. E-Stop Connector Pin Assignment

Pin	Name	Description	Connected to Device
1	E-Stop In-	E-Stop Input (Return)	External E-Stop Circuitry
2	E-Stop In+	E-Stop Input (24 V DC)	External E-Stop Circuitry
3	E-Stop Out-	E-Stop Output (Return)	External E-Stop Circuitry
4	E-Stop Out+	E-Stop Output (24 V DC)	External E-Stop Circuitry

8.1.5. Fan Control

Supported Wire Diameter: 22 AWG - 12 AWG

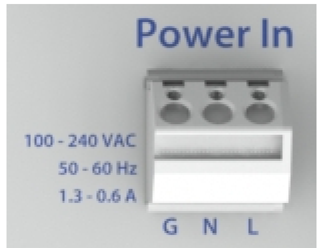
Table 19. Fan Control Connector Pin Assignment



Pin	Name	Description		Connected to Device
		AC	DC	
		Fan Input		
1	G/-	Ground	Negative	External power source
2	N	Neutral	NC	External power source
3	L/+	Line	Positive	External power source
		Fan Output		
1	G/-	Ground	Negative	External fan system
2	N	Neutral	NC	External fan system
3	L/+	Line	Positive	External fan system

8.1.6. Power In

Table 20. Power In Connector Pin Assignment



Pin	Name	Description	Connected to Device
1	G	Ground	External power source
2	N	Neutral	External power source
3	L	Line	External power source

8.2. Cell Interface

8.2.1. Battery Cells

The Battery Cells connector provides cell voltage input and a means for balancing the cells. The cable wire should be rated for at least 750 mA to survive worse-case currents.

Pins 8, 16, 17, and 18 are `No Connect` in the Cell Interface - 12 channel model. Pins 2, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16, and 17 are `No Connect` in the Cell Interface - 12 V 4 channel model.

All unused voltage inputs should be tied to the next highest potential voltage sense input. In this way, all pins should be connected with the exception of pins 8, 16, 17 and 18 in the Cell Interface - 12 channel model and pins 2, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16, and 17 in the Cell Interface - 12 V 4 channel model.

> The wiring of the battery cell voltage and temperature sensing should be verified **before** connecting to the Cell Interface modules. The temperature sensing wires must be isolated from the cell voltage sensing leads. 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.

> The Stack Switchgear is pre-configured to expect a defined battery topology, based on the information provided to Nuvation Energy during order fulfillment. Connecting a differing battery topology will result in undesirable Stack Switchgear behavior. Please contact support@nuvationenergy.com if there is a change in battery topology requiring a Stack Switchgear configuration update.

Table 21. Battery Cells: Molex Micro-Fit 3.0 Connector

Molex 43025-1800	
Manufacturer	Molex Incorporated
Housing	43025-1800
Housing material	Nylon UL94V-0
Circuits	18
Crimp terminal	43030-0002
Wire gauge range	AWG20–24 stranded

8.2.1.1. Battery Cell Connector for Cell Interface - 12 channel

Table 22. Cell Interface - 12 channel Battery Cell Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	CELL0	Bottom reference of Cell Interface	Connect to negative terminal of the lowest cell (Cell 1)
2	CELL2	Cell 2 voltage sense	Connect to positive terminal of Cell 2
3	CELL4	Cell 4 voltage sense	Connect to positive terminal of Cell 4
4	CELL6	Cell 6 voltage sense	Connect to positive terminal of Cell 6
5	CELL8	Cell 8 voltage sense	Connect to positive terminal of Cell 8
6	CELL10	Cell 10 voltage sense	Connect to positive terminal of Cell 10
7	CELL12	Cell 12 voltage sense	Connect to positive terminal of Cell 12
8	No Connect	Not Connected	No Connect
9	No Connect	Not Connected	No Connect
10	CELL1	Cell 1 voltage sense	Connect to positive terminal of the lowest cell (Cell 1)
11	CELL3	Cell 3 voltage sense	Connect to positive terminal of Cell 3
12	CELL5	Cell 5 voltage sense	Connect to positive terminal of Cell 5
13	CELL7	Cell 7 voltage sense	Connect to positive terminal of Cell 7
14	CELL9	Cell 9 voltage sense	Connect to positive terminal of Cell 9
15	CELL11	Cell 11 voltage sense	Connect to positive terminal of Cell 11
16	No Connect	Not Connected	No Connect
17	No Connect	Not Connected	No Connect
18	No Connect	Not Connected	No Connect

8.2.1.2. Battery Cell Connector for Cell Interface - 16 channel

Table 23. Cell Interface - 16 channel Battery Cell Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	CELL0	Bottom reference of Cell Interface	Connect to negative terminal of the lowest cell (Cell 1)
2	CELL2	Cell 2 voltage sense	Connect to positive terminal of Cell 2
3	CELL4	Cell 4 voltage sense	Connect to positive terminal of Cell 4
4	CELL6	Cell 6 voltage sense	Connect to positive terminal of Cell 6
5	CELL8	Cell 8 voltage sense	Connect to positive terminal of Cell 8
6	CELL10	Cell 10 voltage sense	Connect to positive terminal of Cell 10
7	CELL12	Cell 12 voltage sense	Connect to positive terminal of Cell 12
8	CELL14	Cell 14 voltage sense	Connect to positive terminal of Cell 14
9	No Connect	Not Connected	No Connect
10	CELL1	Cell 1 voltage sense	Connect to positive terminal of the lowest cell (Cell 1)
11	CELL3	Cell 3 voltage sense	Connect to positive terminal of Cell 3
12	CELL5	Cell 5 voltage sense	Connect to positive terminal of Cell 5
13	CELL7	Cell 7 voltage sense	Connect to positive terminal of Cell 7
14	CELL9	Cell 9 voltage sense	Connect to positive terminal of Cell 9
15	CELL11	Cell 11 voltage sense	Connect to positive terminal of Cell 11

Pin	Connection	Description	Connected to Device
16	CELL13	Cell 13 voltage sense	Connect to positive terminal of Cell 13
17	CELL15	Cell 15 voltage sense	Connect to positive terminal of Cell 15
18	CELL16	Cell 16 voltage sense	Connect to positive terminal of Cell 16

8.2.1.3. Battery Cell Connector for Cell Interface - 12 V 4 channel

Table 24. Cell Interface - 12 V 4 channel Battery Cell Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	BLOCK0	Bottom reference of Cell Interface	Connect to negative terminal of the lowest cell (Cell 1)
2	No Connect	Not Connected	No Connect
3	BLOCK1	Cell 1 voltage sense	Connect to positive terminal of the lowest cell (Cell 1)
4	No Connect	Not Connected	No Connect
5	BLOCK2	Cell 2 voltage sense	Connect to positive terminal of Cell 2
6	No Connect	Not Connected	No Connect
7	BLOCK3	Cell 3 voltage sense	Connect to positive terminal of Cell 3
8	No Connect	Not Connected	No Connect
9	No Connect	Not Connected	No Connect
10	No Connect	Not Connected	No Connect
11	No Connect	Not Connected	No Connect
12	No Connect	Not Connected	No Connect
13	No Connect	Not Connected	No Connect
14	No Connect	Not Connected	No Connect
15	No Connect	Not Connected	No Connect
16	No Connect	Not Connected	No Connect
17	No Connect	Not Connected	No Connect
18	BLOCK4	Cell 4 voltage sense	Connect to positive terminal of Cell 4

8.2.2. Temperature Sensors

The Temperature Sensors connector provides NTC thermistor inputs for temperature measurement of the cells and/or surrounding area. Because the sensors are referenced to the `CELL0` (or `BLOCK0` on CI-4M12) input on the 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 Cell Interface modules in the system. The thermistors must be isolated from the cell voltage terminals in such a way that they will not make an electrical connection to a cell terminal in the event of vibration/failures.

Connect up to eight 10 kΩ NTC thermistors to this connector.

The 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 Stack Switchgear behavior. Please contact support@nuvationenergy.com if there is a change requiring a Stack Switchgear configuration update.

2 to 7 thermistors are supported to accommodate systems requiring Nuvation Energy BMS to meet functional safety requirements.

Table 25. Temperature Sensors: Molex Micro-Fit 3.0 Connector

Molex 43025-1600	
Manufacturer	Molex Incorporated
Housing	43025-1600
Housing material	Nylon UL94V-0
Circuits	16
Crimp terminal	43030-0002
Wire gauge range	AWG20–24 stranded

Table 26. Temperature Sensors Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	VBOT	External Temperature Probe Reference 1	10 kΩ NTC Thermistor
2	VBOT	External Temperature Probe Reference 2	10 kΩ NTC Thermistor
3	VBOT	External Temperature Probe Reference 3	10 kΩ NTC Thermistor
4	VBOT	External Temperature Probe Reference 4	10 kΩ NTC Thermistor
5	VBOT	External Temperature Probe Reference 5	10 kΩ NTC Thermistor

Pin	Connection	Description	Connected to Device
6	VBOT	External Temperature Probe Reference 6	10 kΩ NTC Thermistor
7	VBOT	External Temperature Probe Reference 7	10 kΩ NTC Thermistor
8	VBOT	External Temperature Probe Reference 8	10 kΩ NTC Thermistor
9	TEMP1_R	External Temperature Probe Input 1	10 kΩ NTC Thermistor
10	TEMP2_R	External Temperature Probe Input 2	10 kΩ NTC Thermistor
11	TEMP3_R	External Temperature Probe Input 3	10 kΩ NTC Thermistor
12	TEMP4_R	External Temperature Probe Input 4	10 kΩ NTC Thermistor
13	TEMP5_R	External Temperature Probe Input 5	10 kΩ NTC Thermistor
14	TEMP6_R	External Temperature Probe Input 6	10 kΩ NTC Thermistor
15	TEMP7_R	External Temperature Probe Input 7	10 kΩ NTC Thermistor
16	TEMP8_R	External Temperature Probe Input 8	10 kΩ NTC Thermistor

For safety certified applications there must be at least 2—but no more than 7—thermistors installed per Cell Interface module in a specific pattern. The following table lists the expected pattern of thermistor installation approved for safety certification.

Table 27. Safety Certified Thermistor Installation

Total Thermistors per Cell Interface	TEMP1_R	TEMP2_R	TEMP3_R	TEMP4_R	TEMP5_R	TEMP6_R	TEMP7_R	TEMP8_R
7	Installed	Installed	Installed	Installed	Installed	Installed	Installed	Not Installed
6	Installed	Installed	Installed	Installed	Not Installed	Installed	Installed	Not Installed
5	Installed	Installed	Not Installed	Installed	Not Installed	Installed	Installed	Not Installed
4	Not Installed	Installed	Installed	Installed	Installed	Not Installed	Not Installed	Not Installed
3	Not Installed	Installed	Installed	Installed	Not Installed	Not Installed	Not Installed	Not Installed
2	Not Installed	Installed	Installed	Not Installed	Not Installed	Not Installed	Not Installed	Not Installed

8.2.2.1. Thermal Consistency

For safety certified systems, there is an additional constraint on thermal consistency for all temperature measurements for each Cell Interface. The constraint is described in detail in the Sensor Fault Detection section within the Nuvation Energy BMS: Safety Manual (available on request).

8.2.3. Link In

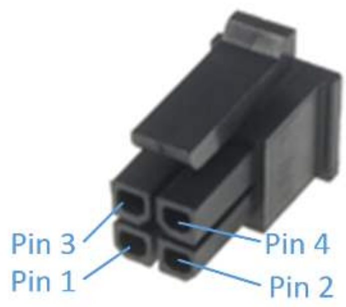
The Stack Switchgear is pre-configured to expect a defined battery topology, based on the information provided to Nuvation Energy during order fulfillment. Connecting a differing battery topology will result in undesirable Stack Switchgear behavior. Please contact support@nuvationenergy.com if there is a change in battery topology requiring a Stack Switchgear configuration update.

This interface is used, with Link Bus cables, to connect each Cell Interface in series to the Cell Interface of the next lowest potential, and the Cell Interface of the lowest potential to the Stack Switchgear. 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 Cell Interface also accepts power from its Link In connector to power itself, as well as subsequent Cell Interface modules in the Link Bus chain (i.e. connected to its Link Out connector). The amount of current sourced into this connector is the sum of current consumed by this Cell Interface and the subsequent Cell Interface modules in the Link Bus chain.

Connect this interface to the Link Out connector on the previous Cell Interface module in the Link Bus chain or to the Link Bus connector on the Stack Switchgear.

Table 28. Link In: Molex Micro-Fit 3.0 Connector



Molex 43025-0400	
Manufacturer	Molex Incorporated
Housing	43025-0400
Housing material	Nylon UL94V-0
Circuits	4
Crimp terminal	43030-0002
Wire gauge range	AWG20–24 stranded

Table 29. Link In Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	VBUS	DC power from the Stack Switchgear, with Fault Pilot Signal	Previous Cell Interface in the Link Bus chain or Stack Switchgear
2	COM	Power return from the Stack Switchgear	Previous Cell Interface in the Link Bus chain or Stack Switchgear
3	IPA	Link Bus differential pair plus	Previous Cell Interface in the Link Bus chain or Stack Switchgear
4	IMA	Link Bus differential pair minus	Previous Cell Interface in the Link Bus chain or Stack Switchgear

8.2.4. Link Out

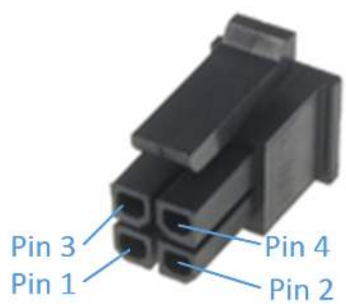
This interface is used to provide a data channel and power source to subsequent Cell Interface modules in the Link Bus chain. The amount of current supplied by this connector is the sum of current consumed by all subsequent Cell Interface modules in the Link Bus chain (up to 25 mA per CI-12 or

31 mA per CI-16/CI-4M12).

The Stack Switchgear is pre-configured to expect a defined battery topology, based on the information provided to Nuvation Energy during order fulfillment. Connecting a differing battery topology will result in undesirable Stack Switchgear behavior. Please contact support@nuvationenergy.com if there is a change in battery topology requiring a Stack Switchgear configuration update.

Connect this interface to the Link In connector on the subsequent Cell Interface module in the Link Bus chain. The Link Out interface of the last Cell Interface module in the Link Bus chain is to be left unconnected.

Table 30. Link Out: Molex Micro-Fit 3.0 Connector



Molex 43025-0400	
Manufacturer	Molex Incorporated
Housing	43025-0400
Housing material	Nylon UL94V-0
Circuits	4
Crimp terminal	43030-0002
Wire gauge range	AWG20–}24 stranded

Table 31. Link Out Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	VBUS	DC power from Stack Switchgear , with Fault Pilot Signal	Subsequent Cell Interface module in the Link Bus chain
2	COM	Power return from Stack Switchgear	Subsequent Cell Interface module in the Link Bus chain
3	IPA	Link Bus differential pair plus	Subsequent Cell Interface module in the Link Bus chain
4	IMA	Link Bus differential pair minus	Subsequent Cell Interface module in the Link Bus chain

9. 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 6.1.8 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 **OFF** 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 **ON** 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 6.1.8 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.

10. Troubleshooting

10.1. Faults and Initialization Issues

During initial setup of a Nuvation Energy BMS, there are two main classes of issues that can be encountered:

1. Initialization issues
2. Triggering of faults

The first class of issues are encountered during initial deployment of a Nuvation Energy BMS, particularly while attempting to power on the Stack Switchgear. When this event occurs, an operator of the Operator Interface can open the Details|Safety accordion (Section 6.2.4). That screen presents a list of fault and warning triggers that may or may not be initialized. This section will provide details on why the faults/warnings could not be initialized. Once all faults/warnings have been initialized, Nuvation Energy BMS has been installed as expected (i.e. all inputs are receiving data). When this occurs the software enters its operational mode.

The second class of issues occurs while Nuvation Energy BMS is operational. One or more faults can be triggered causing Nuvation Energy BMS to exit its operating condition and open all contactors. There are many faults that can be triggered. This section will describe the condition the fault monitors and the meaning when that fault is triggered.

The following sections describe different classes of faults/warnings and issues surrounding any initialization. In general, all warnings have a similar trigger condition as their corresponding fault. The following discussion will focus on the term fault and all descriptions can be applied to the compatible warning.

10.1.1. Cell Voltage Faults

`stack_fault_cell_over`

- Fault that is triggered when an installed cell voltage is above the *over* fault threshold

`stack_fault_cell_hi`

- Fault that is triggered when an installed cell voltage is above the *high* fault threshold

`stack_fault_cell_lo`

- Fault that is triggered when an installed cell voltage is below the *low* fault threshold

`stack_fault_cell_under`

- Fault that is triggered when an installed cell voltage is below the *under* fault threshold

10.1.1.1. Initialization Issues

These faults could fail to initialize through a number of possible conditions such as:

> The 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 Cell Interface modules and/or using a different battery topology could result in initialization issue and other undesirable behavior. Please contact support@nuvationenergy.com if there is a change in the system design that would require a Stack Switchgear configuration update.

1. Missing or misconfigured Cell Interface modules, preventing the software from scanning for the measurements
2. Misconfiguration on the number of Cell Interface modules. Refer to the register `sc_linkbus.cicount` (Note that Low-Voltage BMS is counted as a Cell Interface).
3. Failure in the Link Bus communication. Any interruptions of the bus can prevent the cell voltages from being initialized. Such a failure could happen if:
   - Not all Cell Interface modules are connected
   - Link Bus cables are connected to the wrong port (i.e. Link Out instead of Link In).
   - Link Bus cables are damaged

10.1.2. Stack Voltage Faults

`stack_fault_voltage_over`

- Fault that is triggered when the stack voltage is above the *over* fault threshold.

`stack_fault_voltage_hi`

- Fault that is triggered when the stack voltage is above the *high* fault threshold.

`stack_fault_voltage_lo`

- Fault that is triggered when the stack voltage is below the *low* fault threshold.

`stack_fault_voltage_under`

- Fault that is triggered when the stack voltage is below the *under* fault threshold.

`stack_fault_voltage_sum`

- Fault that is triggered when the absolute difference between the measured stack voltage and sum of all cell voltages in the stack exceeds the fault threshold.

10.1.2.1. Initialization Issues

These faults have the following initialization issues:

Fault	Initialization Issues
stack_fault_voltage_hi stack_fault_voltage_lo	Contact support@nuvationenergy.com. Stack Switchgear unit's internal Power Interface module's AFE is disabled.
stack_fault_voltage_sum	Same issues regarding cell voltage initialization issues (Section 10.1.1.1)

10.1.3. Thermal Faults

`stack_fault_discharge_therm_over`

- Fault that is triggered when any thermistor measurement is above the *over* fault threshold during discharge

`stack_fault_discharge_therm_hi`

- Fault that is triggered when any thermistor measurement is above the *high* fault threshold during discharge

`stack_fault_discharge_therm_lo`

- Fault that is triggered when any thermistor measurement is below the *low* fault threshold during discharge

`stack_fault_discharge_therm_under`

- Fault that is triggered when any thermistor measurement is below the *under* fault threshold during discharge

`stack_fault_charge_therm_over`

- Fault that is triggered when any thermistor measurement is above the *over* fault threshold during charge

`stack_fault_charge_therm_hi`

- Fault that is triggered when any thermistor measurement is above the *high* fault threshold during charge

`stack_fault_charge_therm_lo`

- Fault that is triggered when any thermistor measurement is below the *low* fault threshold during charge

`stack_fault_charge_therm_under`

- Fault that is triggered when any thermistor measurement is below the *under* fault threshold during charge

10.1.3.1. Initialization Issues

All of the temperature measurements are communicated through over the Link Bus using the same mechanism as the cell voltages. Thus, the failures to initialize the temperature measurements are exactly the same. Refer to Section 10.1.1.1 for further details.

10.1.4. Stack Current Faults

`stack_fault_discharge_current_over`

- Fault that is triggered when the stack current is above the *over* discharge fault threshold.

`stack_fault_discharge_current_hi`

- Fault that is triggered when the stack current is above the *high* discharge fault threshold.

`stack_fault_charge_current_hi`

- Fault that is triggered when any stack current is above the *high* charge fault threshold.

`stack_fault_charge_current_under`

- Fault that is triggered when any stack current is above the *over* charge fault threshold.

10.1.4.1. Initialization Issues

The stack current is measured from the Stack Switchgear unit's internal Power Interface module's Analog Front End (AFE). The following issues can contribute to these faults not initializing:

1. Stack Switchgear unit's internal Power Interface module's AFE is not enabled.
    - This may occur if the Stack Switchgear configuration file is incorrectly modified. Contact support@nuvationenergy.com for a valid configuration file for the Stack Switchgear.
2. Communication failure between the Stack Switchgear unit's internal Stack Controller and Power Interface modules

10.1.5. Pre-charge Faults

`stack_fault_precharge_timeout`

- Fault that is triggered at the end of the pre-charge period if the measured current exceeds the maximum pre-charge current

`stack_fault_precharge_over_current`

- Fault that is triggered at any time during the pre-charge connection period if the stack current exceeds the fault threshold

10.1.5.1. Initialization Issues

These faults are directly related to the current faults detailed previously. Refer to Section 10.1.4.1 for details.

10.1.6. Contactor Faults

`stack_fault_coil_fail`

- Fault that is generated when there is a difference between the commanded state of the contactor coil and the observed state read from the hardware. This fault is a consistency check on the drive state of the coil. This fault will trigger when contactors are unconnected or have a short in their circuit. If the fault pilot signal is asserted, this fault will trigger and can not be used to determine if there is a inconsistent contactor drive state.

`stack_fault_contactor_feedback_fail`

- Fault that is generated when there is a mismatch between the contactor state and the contactor feedback signal provided. Note that the feedback is provided through a GPI.

`sc_fault_pi_interlock`

- Fault that is generated when the interlock function of the Stack Switchgear unit's internal Power Interface module has been activated. In the Stack Switchgear unit, this is connected to fuse indicator switches on the main fuses. This fault should only occur if the main fuses have blown.

> The Stack Switchgear unit's e-stop circuit is unrelated to this interlock.

`sc_fault_fault_pilot_state_mismatch`

- Fault that is generated when the fault pilot state set by the Stack Switchgear unit's internal Stack Controller module does not match the detected state on the Stack Switchgear unit's internal Power Interface module

10.1.6.1. Initialization Issues

All of these faults are dependent on the stack bus communication between the Stack Switchgear unit's internal Stack Controller and Power Interface modules The following table summarizes these initialization issues:

Fault	Initialization Issues
`sc_fault_pi_interlock`	Stack Bus failure
`sc_fault_fault_pilot_state_mismatch`	Stack Bus failure
`stack_fault_coil_fail`	Stack Switchgear unit's internal Power Interface module's AFE disabled*
`stack_fault_contactor_feedback_fail`	GPI not configured* Stack Switchgear unit's internal Power Interface module's AFE disabled* Stack Bus failure

* Note that these faults may occur if the Stack Switchgear configuration file is incorrectly modified. Contact support@nuvationenergy.com for a valid configuration file for the Stack Switchgear.

10.1.7. Diagnostics Faults

`stack_fault_cell_open_wire`

- Fault indicating there is an open wire on an installed cell channel
- This can also trip due to misconfigured or incorrectly installed cells

`stack_warn_cell_open_wire`

- Warning triggering on the same data as `stack_fault_cell_open_wire`

`stack_fault_therm_circuit_fail`

- Fault indicating there is a circuit failure on a thermistor channel on a Cell Interface
- This can also trip due to misconfigured or incorrectly installed thermistors

`stack_fault_ci_therm_consistency`

- Fault indicating the difference between thermal readings on a Cell Interface is too large

`sc_fault_ci`

- Fault indicating there was an internal hardware failure on a Cell Interface

`stack_fault_open_shunt`

- Fault indicating the current shunt is open circuit

`stack_fault_short_shunt`

- Fault indicating the current shunt is short circuit

When experiencing difficulty clearing this fault, please refer to Section 10.1.7.1.

10.1.7.1. Known Issues

10.1.7.1.1. Short Shunt Fault on Exiting Service Lockout

Issue

In rare occasions, the `stack_fault_short_shunt` can accidentally trip when powering on the Stack Switchgear. If the contactors remain open and no current has flowed through the batteries, the fault does not indicate a short on the current shunt. Note that this issue only occurs within a minute of powering on the Stack Switchgear and faults that happen outside this window should be investigated further.

Workaround

The operator of the Operator Interface can attempt to clear the fault as described in Section 6.2.4.

10.1.7.1.2. Clearing the Short Shunt Fault Is Not Immediate

Issue

Clearing the `stack_fault_short_shunt` fault might not occur immediately.

Workaround

To determine when the fault can be cleared, read the values of the `stack_short_shunt_detector.voltage_activity_threshold` and `stack_short_shunt_detector.inactivity_envelope` registers. Wait until the value in the inactivity envelope is smaller than the voltage activity threshold. At this point the `stack_fault_short_shunt` fault can be cleared. The maximum time required for the inactivity envelope to fall below the threshold can be determined by reading the `stack_short_shunt_detector.activity_detection_time` register, with the value given in µs.

10.1.7.2. Initialization Issues

The `stack_fault_cell_open_wire`, `stack_fault_therm_circuit_fail`, `stack_fault_ci_therm_consistency`, and `sc_fault_ci` can be uninitialized due to problems with the Link Bus. Refer to Section 10.1.1.1 for further details.

The stack_fault_open_shunt and stack_fault_short_shunt can be uninitialized if the associated algorithms are not enabled, the Stack Switchgear unit's internal Power Interface module's AFE is not enabled, or there is Stack Bus communication errors. This is typically caused by incorrectly modifying the Stack Switchgear factory configuration file. Contact support@nuvationenergy.com for a valid configuration file for the Stack Switchgear.

10.1.8. Breaker Faults

stack_fault_breaker_tripped

- Fault that is triggered to indicate that the breaker has tripped (i.e. opened)

stack_fault_breaker_conflict

- Fault that is triggered to indicate that the breaker state differs from the expected state of the breaker

10.1.8.1. Initialization Issues

Failure to initialize these faults is caused by an invalid configuration of the GPI(s) used to read the breaker state. This is typically caused by incorrectly modifying the Stack Switchgear factory configuration file. Contact support@nuvationenergy.com for a valid configuration file for the Stack Switchgear.

10.1.9. Watchdog Faults

stack_fault_power_wdt

- Fault indicating stack voltage and current data has not been updated periodically

stack_fault_cell_wdt

- Fault indicating all cell data has not been updated periodically for every installed cell

stack_fault_therm_wdt

- Fault indicating all thermistor data has not been updated periodically for every installed thermistor

stack_fault_ci_wdt

- Fault indicating Cell Interface data has not been updated periodically for every installed Cell Interface

stack_fault_open_wire_wdt

- Fault indicating open wire scanning has not been occurring periodically when connected to the DC bus

sc_fault_controller_wdt

- Fault indicating that an external controller to the battery management system was not updating its watchdog timer (via the MESA heartbeat) sc_warn_controller_wdt

- Warning triggered from the same data as sc_fault_controller_wdt

sc_fault_stackbus_rxwdt

- Fault indicating that there was a receive communication failure over the Stack Bus

sc_fault_stackbus_txwdt

- Fault indicating that there was a transmit communication failure over the Stack Bus

sc_fault_pi_afe_wdt

- Fault indicating that there was a communication failure between the AFE and the Stack Switchgear unit's internal Power Interface module

sc_fault_linkbus_wdt

- Fault indicating that there was an internal communication failure relating to Link Bus data. Please contact Nuvation Energy at support@nuvationenergy.com if you are experiencing this fault.

sc_fault_ram_test_wdt

- Fault indicating the internal RAM testing has not been executing periodically

sc_fault_rom_test_wdt

- Fault indicating the internal ROM testing has not been executing periodically

sc_fault_factory_verify_wdt

- Fault indicating the factory registers on the Stack Switchgear unit's internal Stack Controller module have not been periodically validated against non-volatile memory
- Typically disabled

pi_fault_factory_verify_wdt

- Fault indicating the factory registers on the Stack Switchgear unit's internal Power Interface module have not been periodically being validated against non-volatile memory.
- Typically disabled

10.1.9.1. Initialization Issues

The stack_fault_cell_wdt, stack_fault_therm_wdt, stack_fault_ci_wdt, and stack_fault_open_wire_wdt can be uninitialized due to problems with the Link Bus. Refer to Section 10.1.1.1 for further details.

The sc_fault_pi_afe_wdt and stack_fault_power_wdt can be uninitialized due to disabling the Stack Switchgear unit's internal Power Interface module's AFE or a high amount of noise on the DC bus. This is typically caused by incorrectly modifying the Stack Switchgear factory configuration file. Contact support@nuvationenergy.com for a valid configuration file for the Stack Switchgear.

The sc_fault_controller_wdt can be uninitialized if there is no external controller updating the heartbeat. Contact support@nuvationenergy.com to update the configuration file

10.1.10. Miscellaneous Faults

`sc_fault_config`

- Fault indicating that there was an error reading the non-volatile storage of the battery management system configuration. A default configuration is used when this fault occurs and the battery management system will fail to start.

`sc_fault_config_factory`

- Fault indicating that there was an error reading the non-volatile storage of the battery management system factory configuration. This is similar to `sc_fault_config`; refer to that fault for more details.

`sc_fault_config_factory_verify`

- Fault indicating that verification of factory configuration settings against non-volatile storage has failed on the Stack Switchgear unit's internal Stack Controller module This typically means either a setting was changed after saving or non-volatile memory has been corrupted.

`pi_fault_config_factory_verify`

- Fault indicating that verification of factory configuration settings against non-volatile storage has failed on the Stack Switchgear unit's internal Power Interface module This typically means either a factory setting was changed after saving or non-volatile memory has been corrupted.

`sc_fault_fw_mismatch`

- Fault indicating that the internal Stack Controller and Power Interface modules firmware versions are different. Contact support@nuvationenergy.com if this occurs.

`sc_fault_clocks`

- Fault indicating that the internal Stack Controller and Power Interface modules clocks are ticking at different rates. This may indicate an overloaded system or malfunction in the hardware or software. Also if one of the processors resets, this fault can trip since its clock also resets.

`sc_fault_linkbus_power`

- Fault indicating that there was a hardware problem with the Link Bus power or an incorrect power mode in `sc_linkbus.power_mode` Contact support@nuvationenergy.com if this occurs.

10.2. Lost/Forgotten IP Address

If a Nuvation Energy BMS has been configured with a static IP address and it has been forgotten, follow the steps below to recover it.

> Depending on the network interface used on the PC, this process may not work due to differing security and IP configurations. If the only IP discovered is the IP of the PC, the network interface is not suitable and another one will need to be used. This issue is most common with USB to Ethernet dongles.

10.2.1. Wireshark (Windows/Linux)

1. Download/install Wireshark on a PC (https://www.wireshark.org/)
2. Connect the PC directly to the Ethernet port on the Stack Switchgear
3. Start a Wireshark capture on the network interface connected to the Stack Switchgear
4. In the 'filter' field, enter in `arp.isgratuitous` and press enter
5. Either reboot the Stack Switchgear, or unplug/plug the Ethernet cable
6. The device should send a 'Gratuitous ARP' on the Ethernet network. In Wireshark the 'Info' field looks like: Gratuitous ARP for <IP> (Request) where the <IP> is the address for the Stack Switchgear
7. Once that is complete, update the PC network settings to match the Stack Switchgear and connect the Operator Interface.
    - Refer to Section 5.2 for instructions.

10.2.2. Netdiscover (Linux only)

1. Install `netdiscover` on a PC (on Debian based systems use: `sudo apt install netdiscover`)
2. Connect the PC directly to the Ethernet port on the Stack Switchgear
3. Run sudo netdiscover -i <interface> -p where <interface> is the network interface connected to the Stack Switchgear
4. Either reboot the Stack Switchgear, or unplug/plug the Ethernet cable
5. The device address and MAC will show up in `netdiscover` once an ARP packet is sent
6. Once that is complete, update the PC network settings to match the Stack Switchgear and connect the Operator Interface.
    - Refer to Section 5.2 for instructions.

> In the event the IP address cannot be discovered, contact support@nuvationenergy.com for assistance.

Appendix A: Operating Limits

Stack Switchgear

Exceeding the ratings will damage the system.

External Specifications

Symbol	Parameter	Min	Typ	Max	Units
V_{input}	Input Voltage	100	-	240	V AC
P_{input}	Input Power	-	33.7	60	W
f_{input}	Input Frequency	45	50/60	65	Hz
V_{fan_DC}	Cooling Fan DC Voltage	-	-	50	V DC
V_{fan_AC}	Cooling Fan AC Voltage	-	-	250	V AC
I_{fan}	Cooling Fan Current	-	-	5	A DC/AC
$I_{E\text{-}Stop}$	E-Stop Input Current Rating	-	-	9.6	mA DC
$V_{E\text{-}Stop}$	E-Stop Input Voltage Rating	19.2	24	28.8	V DC

Electrical Characteristics

Symbol	Parameter	Min	Typ	Max	Units
	Stack Voltage Specifications				
V_{stack_ov}	Stack Over-Voltage Threshold (triggers contactors to open)	0	Configurable	1250	V DC
V_{stack_uv}	Stack Under-Voltage Threshold (triggers contactors to open)	0	Configurable	-	V DC
	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 Threshold (triggers contactors to open)	-	Configurable	-	°C
T_{ot}	Over-Temperature Threshold (triggers contactors to open)	-	Configurable	-	°C
T_{fan_en}	Fan Enable Temperature Threshold	-	Configurable	-	°C
	Contactor Opening Specifications				
I_{cont_max}	One time contactor maximum breaking current	-	-	1260	A DC

Symbol	Parameter	Continuous	Max*	Units
	Stack Switchgear Configuration: 1250 V DC, 100 A			
$I_{discharge\_oc}$	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
	Stack Switchgear Configuration: 1250 V DC, 200 A			
$I_{discharge\_oc}$	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
	Stack Switchgear Configuration: 1250 V DC, 300 A			
$I_{discharge\_oc}$	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

Symbol	Parameter	Continuous	Max*	Units
	Stack Switchgear Configuration: 1250 V DC, 350 A			
$I_{discharge\_oc}$	Stack Discharging Over-Current (triggers contactors to open)	350	400	A DC
I_{charge_oc}	Stack Charging Over-Current (triggers contactors to open)	350	400	A DC

* The 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 max rating. Sufficient time to allow the system to cool down afterward is required.

Environmental Conditions

Symbol	Parameter	Min	Typ	Max	Units
	Thermal Specifications				
T_a	Operating Temperature	10	25	40	°C
	Storage Temperature	-10	25	40	°C
	Humidity Specifications				
RH	Operating Relative Humidity	5	-	85	%
	Storage Relative Humidity	5	-	85	%
	Shock and Vibration Specifications				
Vertical	Vertical shock/vibration	-	-	10	m/s^2
Longitudinal	Longitudinal shock/vibration	-	-	10	m/s^2
Transverse	Transverse shock/vibration	-	-	10	m/s^2
Pulse vibration	On each axis	-	-	245	m/s^2

The Nuvation Energy Stack Switchgear has been designed to meet the requirements of SAE J2464 (shock) and SAE J2380 (random vibration). For transportation, it is recommended that the Stack Switchgear be shipped in its original packaging via pallet whenever possible.

Standards and Certifications

Standard/Certification		
Stationary Battery Safety	UL Recognized (internal Power Interface and Stack Controller modules)	UL 1973 (file no. MH64071)
Functional Safety	UL Recognized (internal Power Interface and Stack Controller modules)	UL 991 (file no. MH64071) UL 1998 (file no. MH64071)

UL 1973 recognition ensures safe battery operation and significantly reduces the effort of certifying the energy storage solution to meet UL 1973 and UL 9540.

Cell Interface

Exceeding the maximum ratings will damage the Cell Interface module.

Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
		Link In Specifications				
$+V_{BUS}$	Input Voltage	-	9	24	60	V DC
	Input Current, CI-12	+VBUS = 24 V DC, Link Out disconnected	-	-	25.5	mA DC
	Input Current, CI-16 and CI-4M12	+VBUS = 24 V DC, Link Out disconnected	-	-	31.7	mA DC
I_{P_LINK}	Output Current	-	-	-	20	mA DC
I_{N_LINK}	Output Current	-	-	-	20	mA DC
		Link Out Specifications				
$+V_{BUS}$	Output Voltage	-	-	+VBUS	-	V DC
	Output Current per CI-12	+VBUS = 24 V DC	-	-	25.5	mA DC
	Output Current per CI-16 and CI-4M12	+VBUS = 24 V DC	-	-	31.7	mA DC
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	CI-12, CI-16	0	-	5	V DC
$B_{(n)}$ - $B_{(n-1)}$	Input Block Voltage Range	CI-4M12	5	-	20	V DC
V_{sum}	Voltage between C0 and C12	CI-12, +VBUS = 0 V DC	11	-	60	V DC
	Voltage between C0 and C8	CI-16, +VBUS = 0 V DC	11	-	40	V DC
	Voltage between C8 and C16	CI-16, +VBUS = 0 V DC	11	-	40	V DC
	Voltage between B0 and B2	CI-4M12, +VBUS = 0 V DC	11	-	40	V DC
	Voltage between B2 and B4	CI-4M12, +VBUS = 0 V DC	11	-	40	V DC
TME	Total Measurement Error	CI-12, CI-16, +VBUS = 24 V DC	±0.1	±1.2	±1.6	mV DC
	Total Measurement Error	CI-4M12, +VBUS = 24 V DC	±2.0	±8.0	±10.0	mV DC
$I_{(n)}$	Cell Balancing Current (only for CI-12 and CI-16)	C(n) - C(n-1) = 4 V DC	304	307	310	mA DC
V_{bal}	Cell Voltage for Balancing	CI-12 and CI-16	1.1	-	-	V DC
Vins	Internal reinforced insulation rating from Chassis/COM	-	-	-	1250	V DC
		Temperature Sensors Specifications				
$I_{(n)}$	Output Current to Temperature Sensor	-	-	-	300	μA
$R_{t(n)}$	Temperature Sensor Resistance at 25 °C	-	-	10	-	kΩ
$T_{(n)}$	Input Temperature Sensor Voltage Range	Cell 0 or Block 0 = 0 V	0	-	3	V
Vins	Internal reinforced insulation rating from Chassis/COM	-	-	-	1250	V DC

Environmental Conditions

Symbol	Parameter	Min	Typ	Max	Units
	Thermal Specifications				
T_a	Operating Temperature	-10	25	60	°C
	Storage Temperature	-20	25	60	°C
	Humidity Specifications				
RH	Operational RH	5	-	85	%
	Storage RH	5	-	85	%
	Shock and Vibration Specifications				
Vertical	Vertical shock/vibration	-	-	10	m/s^2
Longitudinal	Longitudinal shock/vibration	-	-	10	m/s^2
Transverse	Transverse shock/vibration	-	-	10	m/s^2
Pulse vibration	On each axis	-	-	245	m/s^2

The Cell Interface has been designed to meet the requirements of SAE J2464 (shock) and SAE J2380 (random vibration).

Standards and Certifications

The Cell Interface meets industry standards CISPR 22 Class A and IEC/EN 61000-4-2 for EMC/EMI and ESD respectively. It has been designed to meet EN 60950 high voltage creepage/clearance distances for reinforced insulation rated to 1250 V DC. All components are EU RoHS / China RoHS compliant.

Standard/Certification		
Stationary Battery Safety	UL Recognized	UL 1973 (file no. MH64071)
Functional Safety	UL Recognized	UL 991 (file no. MH64071) UL 1998 (file no. MH64071)

UL 1973 recognition ensures safe battery operation and significantly reduce the effort of certifying the energy storage solution to meet UL 1973 and UL 9540.

Maximum Stack Deployment

Cell Interface modules are deployed as a daisy chain to monitor the cells of a stack. The maximum number of modules that are supported in a stack depend on two metrics:

- the maximum number of modules that can be powered over Link Bus power (if required)
- the required scan rate of the cell voltage measurements

Limits Due to Link Bus Power

Max CI-12	Max CI-16	Max CI-4M12
50	40	40

Limits Due to Cell Voltage Scan Rate

The following are approximate cell voltage scan rates for different lengths of Cell Interface daisy chains where all cells are installed. On the Stack Switchgear, the Measurement Anti-Aliasing Filter is set to OFF.

Table 32. Cell Voltage Scan Rates for CI-16 and CI-4M12

Measurement Anti-Aliasing Filter	Cell Interface Chain Length	Scan Rate [Hz]
Off	1	5.53
Off	5	3.32
Off	10	2.22
Off	15	1.74
Off	20	1.38
Off	25	1.15
Off	30	0.91

Table 33. Cell Voltage Scan Rates for CI-12

Measurement Anti-Aliasing Filter	Cell Interface Chain Length	Scan Rate [Hz]
Off	1	6.01
Off	5	3.94
Off	10	3.03
Off	15	2.59
Off	20	1.97
Off	25	1.63
Off	30	1.44
Off	35	1.30
Off	40	1.08

Appendix B: Ordering Information

Stack Switchgear

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

These options are suffixed to the product part number in the format: `NUVSSG-1250-<current-rating>-<fuse-rating-code>`.

Table 34. Stack Switchgear Unit Ordering Information

Part Number	Product Name	Compatible Fuse Rating
NUVSSG-1250-100-x	Stack Switchgear, 1250 V, 100 A	200 A
NUVSSG-1250-200-x	Stack Switchgear, 1250 V, 200 A	250 A, 315 A, 350 A
NUVSSG-1250-300-x	Stack Switchgear, 1250 V, 300 A	350 A, 400 A, 450 A, 500 A
NUVSSG-1250-350-x	Stack Switchgear, 1250 V, 350 A	400 A, 450 A, 500 A

* x = fuse rating code.

Fuse Rating Code

The `x` in the product part number above denotes the fuse rating code. Refer to the table below for possible values. The 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 after an order is placed.

Table 35. Stack Switchgear (NUVSSG-1250) 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

Mounting Bracket

The following mounting bracket options are available. The Stack Switchgear ships with a `NUVP-SSG-RB-19` by default.

Table 36. Stack Switchgear Mounting Brackets 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
NUVP-SSG-RB-19-2P	Part, Stack Switchgear, Brackets for 2-post 19" Rack

Part Number	Product Name
NUVP-SSG-RB-23-2P	Part, Stack Switchgear, Brackets for 2-post 23" Rack

To attach these brackets to the unit, fasteners (M5 x 8 mm) are included with any mounting bracket order. If fasteners other than the provided hardware is used, the screws cannot extend into the 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 of 6.35 mm.

Cell Interface

Product part numbers for ordering a Cell Interface are listed in Table 37. Accessory kits are listed in Table 38.

Cell Interface kits—which include the Cell Interface module and cables—are available to get you started quickly. Please visit https://nstore.nuvationenergy.com for more details.

Table 37. Cell Interface Ordering Information

Part Number	Product Name
NUV100-CI-12-1	Cell Interface - 12 channel, Bulkhead
NUV100-CI-12-U	Cell Interface - 12 channel, PCB assembly only (no enclosure)
NUV100-CI-12-KIT	Cell Interface Kit - 12 channel
NUV100-CI-16-1	Cell Interface - 16 channel, Bulkhead
NUV100-CI-16-U	Cell Interface - 16 channel, PCB assembly only (no enclosure)
NUV100-CI-16-KIT	Cell Interface Kit - 16 channel
NUV100-CI-4M12-1	Cell Interface - 12 V 4 channel, Bulkhead
NUV100-CI-4M12-U	Cell Interface - 12 V 4 channel, PCB assembly only (no enclosure)
NUV100-CI-4M12-KIT	Cell Interface Kit - 12V 4 channel

If mounting a `Cell Interface, PCB assembly only (no enclosure)`, note that the Cell Interface contains high-voltage signals reaching as high as 1250 V DC. Care must be taken when mounting the PCB into a metal enclosure to ensure that the metal walls remain a safe distance from the exposed conductor on the PCB. Using 1250 V DC as an example, the metal walls of the enclosure must be at least 4.2 mm from the nearest exposed conductor and must not touch the PCB or any component on the PCB, including the connector housings.

Table 38. Cell Interface Accessory Kits Ordering Information

Part Number	Product Name
NUVP-CI-DIN-MB	Cell Interface Mounting Bracket (Bulkhead-to-DIN)

Appendix C: 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.

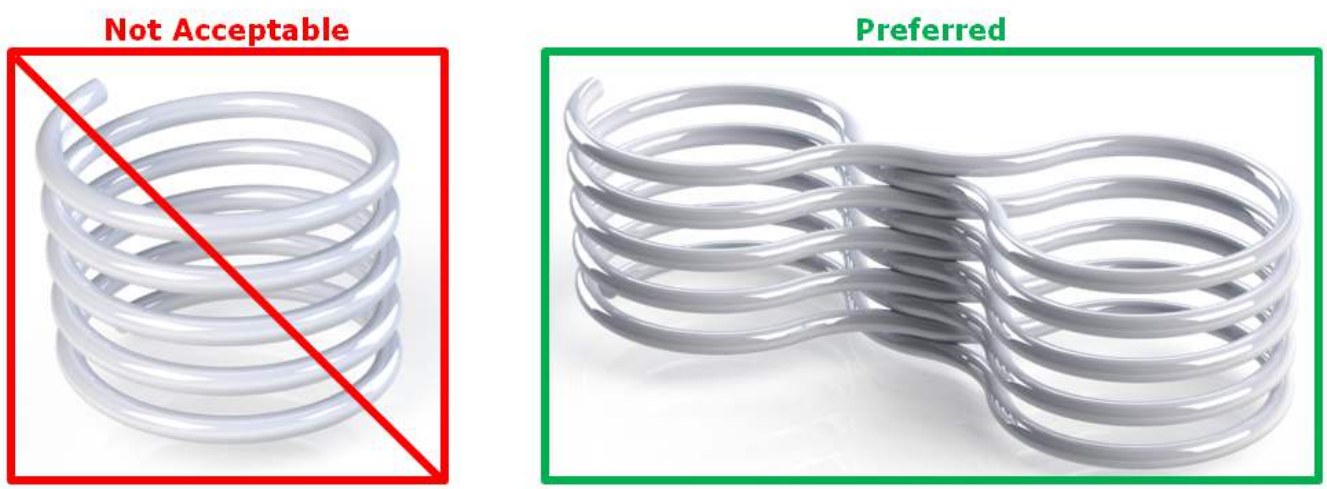


Figure 65. Excess Cable Management Examples

System Noise

High-power inverters generate a lot of system noise, especially on the DC bus. This is due to the industry standards for AC harmonics and EMC on the grid-side which require the DC bus to help filter out the harmful emissions. Unfortunately, that means the battery cells and the High-Voltage BMS experience extreme levels of noise.

The most harmful emissions on the DC bus are between the DC bus and earth. This is due to the slew-rate of the switching devices implemented in the inverter (usually IGBTs). The slew-rate is impacted by many elements, and the emissions can be minimized by carefully grounding the installation so that the return-path for the high-frequency switching noise can be kept small.

The High-Voltage BMS has various faults and informative registers to determine if the system has a high level of noise that is impacting the battery management system.

The communication faults are:

```
sc_fault_linkbus_wdt.trig
sc_fault_stackbus_rxwdt.trig
sc_fault_stackbus_txwdt.trig
sc_fault_pi_afe_wdt.trig
sc_fault_controller_wdt.trig
```

The informative communication error registers are:

```
sc_linkbus_packets.operation_read_errors
sc_linkbus_packets.operation_validate_errors
sc_stackbus.rxerrrate
sc_stackbus.txerrrate
pi_afe.rx_err_rate
pi_afe.tx_err_rate
```

The system controller heartbeat should also be coming through as expected, and can be verified by reading the register:

```
sc_controller_heartbeat.value
```

In a correctly wired system, a communication fault points to elevated system noise that is disrupting communications. If the system grounding scheme cannot be improved, there are still a few techniques within High-Voltage BMS or the battery area to try to decrease the amount of noise.

DC Filtering

A DC filter can be installed between the DC bus and the inverter or between each DC battery stack and the common DC bus in a multi-stack system. Schaffner FN 2200 is an example DC filter which has been known to decrease the amount of harmful emissions on the DC bus. An example filter installation is shown below:

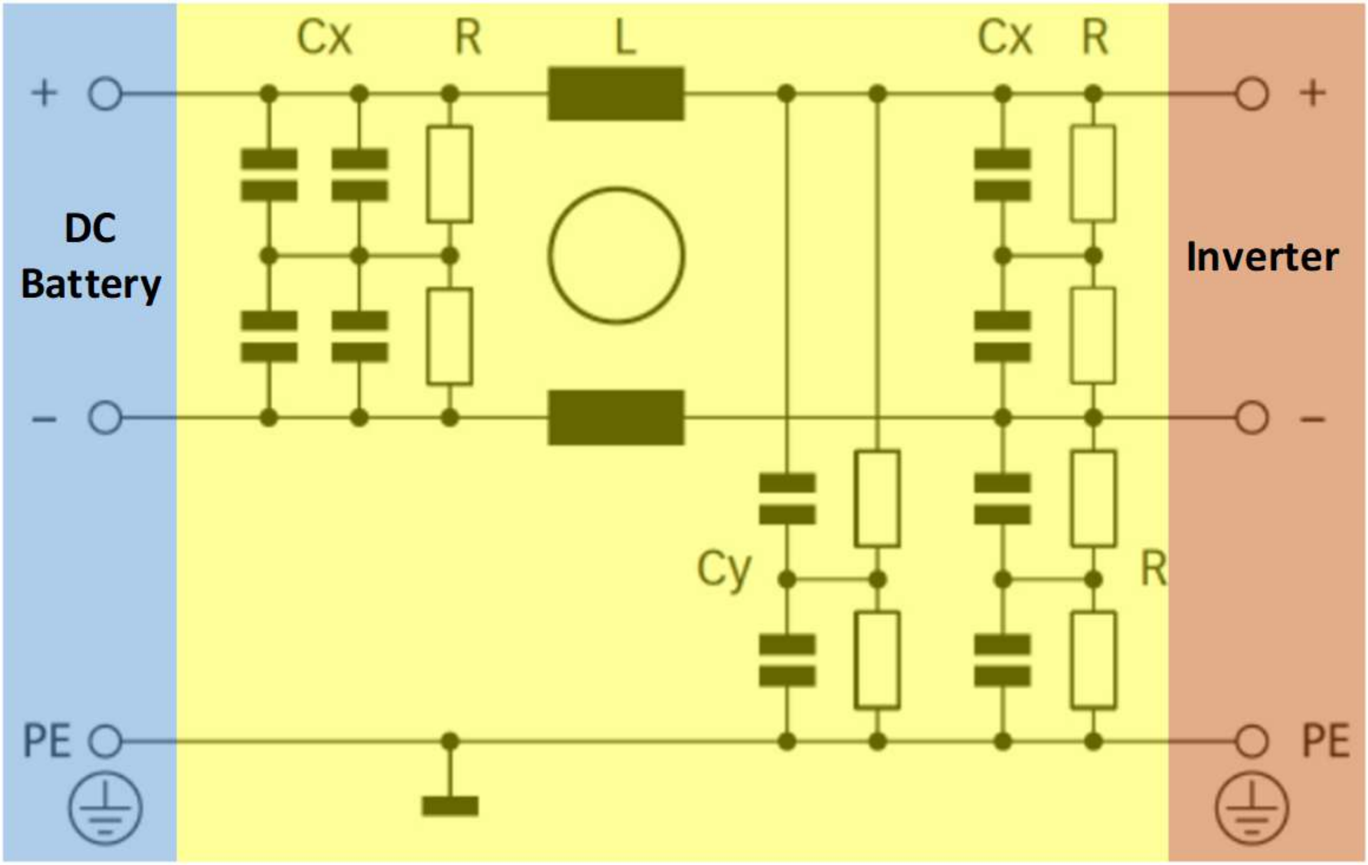


Figure 66. Example DC Filter Schematic

When using DC filters, please be aware that it shunts high-frequency noise to earth. If the inverter is not driving an insulated neutral system, there will be high current pulses flowing in the system earth which can trip ground fault detectors. It might be necessary to install an isolation transformer between the inverter and the grid to remove the high current pulses.

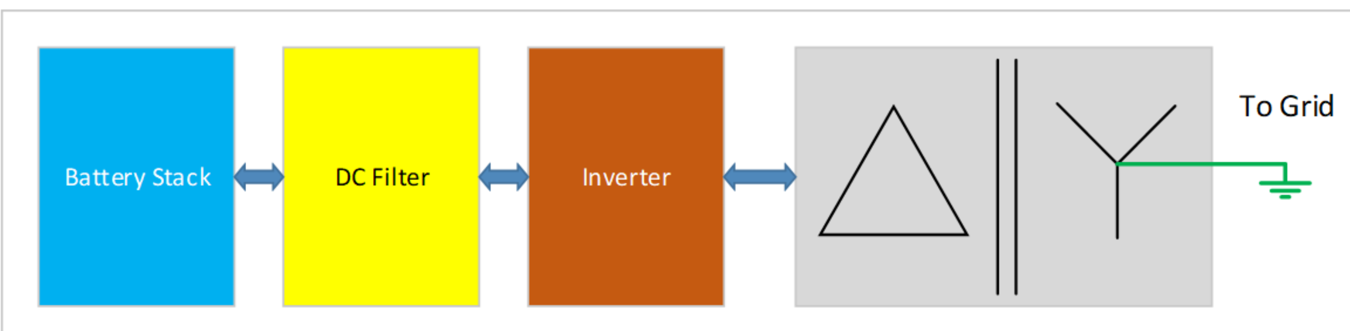


Figure 67. Example Isolation Transformer Installation Diagram

Link Bus Power

While the communication interface between the Stack Switchgear and the Cell Interface is a daisy-chain, the power supplied to the Cell Interface from the Stack Switchgear is a bus. This results in the power twisted pair in the Link Bus cable carrying power up the entire length of the chain. This provides a decent medium to couple system noise into the Link Bus which can result in `sc_linkbus` communication faults.

In systems where the cells can provide the necessary minimum operating voltage to the Cell Interface, Link Bus power can be disabled if the observed impact on performance is acceptable. The power twisted pair must be disconnected in the Link Bus cable, so all Link Out and Link In connectors on the Stack Switchgear and the Cell Interface modules must have pins 1 and 2 unpopulated.

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.

Registers