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Nuvation Energy Stack Switchgear

Product Manual

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Important Safety Information

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.

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.

Continued on next page →

(Continued)

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.

The provided module enclosures are not fire enclosures.

Depending on battery chemistry, there might be a nominal voltage per cell which adds up in series and is always present. There are many different battery chemistries with different current capacities, and so high voltage with high current capacity may be present while connecting Nuvation Energy BMS. You must use proper electrical safety precautions when handling any part of Nuvation Energy BMS.

Neither Nuvation Energy or any of its employees shall be liable for any direct, indirect, incidental, special, exemplary, personal or consequential harm or damages (including, but not limited to, procurement or substitute goods or services; loss of use, data, or profits; or business interruption) however caused and on any theory of liability, whether in contract, strict liability, or tort (including negligence or otherwise) arising in any way out of the use of this product.

1. Introduction

Thank you for choosing Nuvation Energy BMS.

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.

You can take advantage of the highly configurable browser-based user interface and custom-tune Nuvation Energy BMS to your specific target application.

1.1. About this Manual

This *Nuvation Energy Stack Switchgear: Product Manual* provides mounting and wiring to connect your Nuvation Energy Stack Switchgear to your system as well as instructions on using the Nuvation Energy Stack Switchgear.

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

2. System Overview

The Nuvation Energy Stack Switchgear, shown in Figure 1, is a pre-configured assembly that incorporates the major functions of Nuvation Energy battery management system 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.

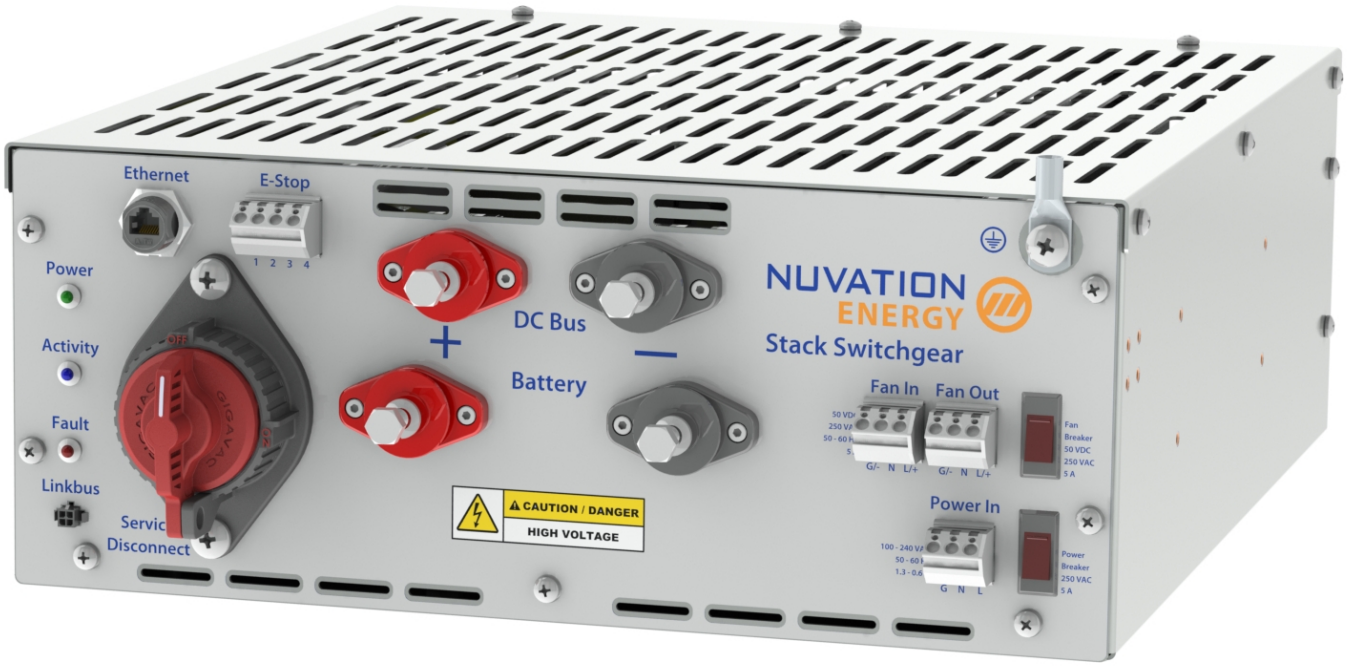


Figure 1. Nuvation Energy Stack Switchgear

There are different amperage configurations available for the base Stack Switchgear unit, listed in Table 1. Orderable part numbers are listed in *Nuvation Energy Stack Switchgear: NUVSSG Datasheet*, available online at https://www.nuvationenergy.com/technical-resources.

Table 1. Nuvation Energy Stack Switchgear variants

Maximum Voltage Rating	Maximum Current Rating
1250 V DC	100 A
	200 A
	300 A

The high-level Stack Switchgear system design 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.

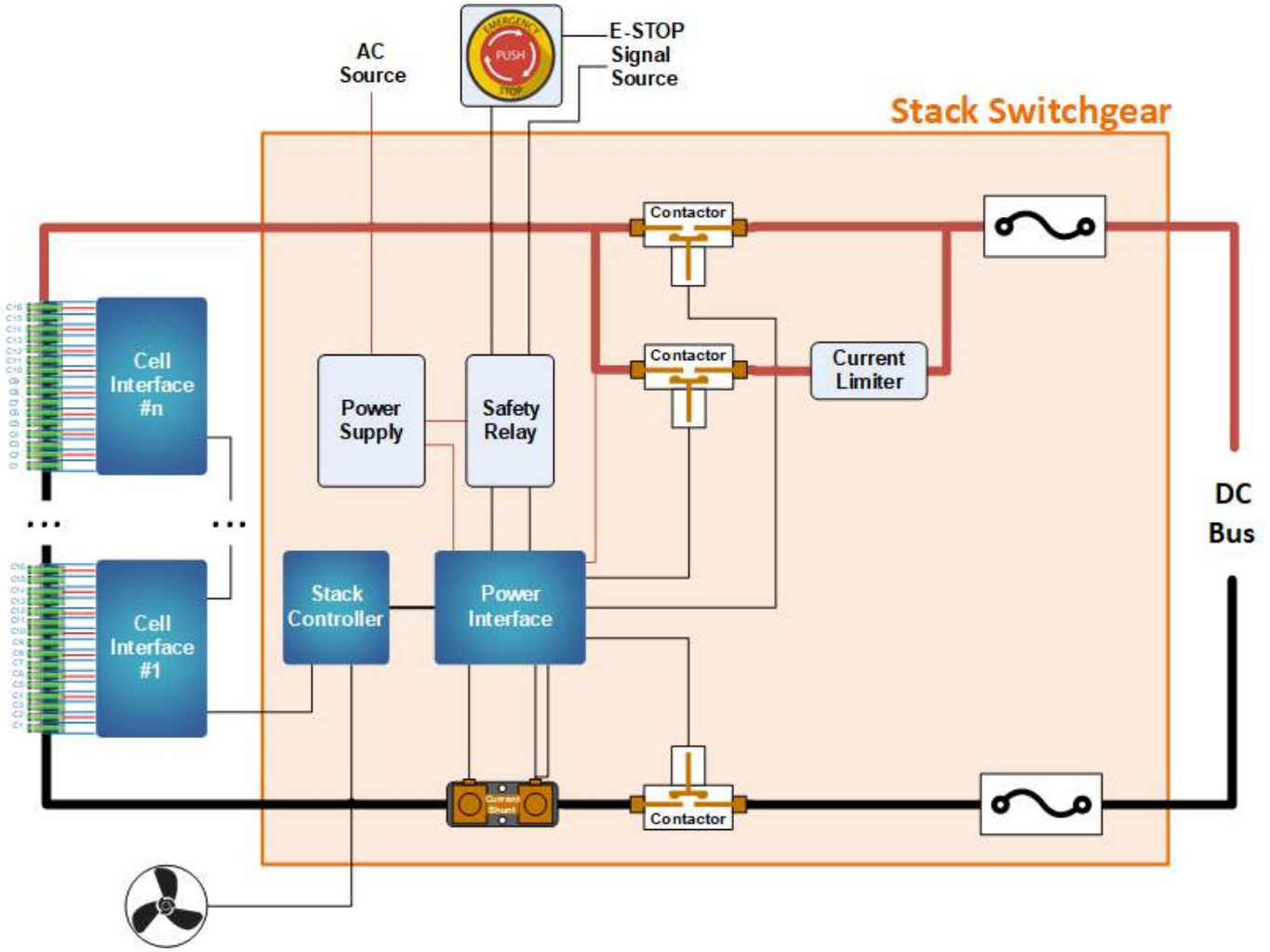


Figure 2. Stack Switchgear system diagram

In a multi-stack 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 connected to a single Nuvation Energy Battery Control Panel, where an Operator Interface provides a unified view and central control of the multi-stack system.

Nuvation Energy Cell Interface and Nuvation Energy Battery Control Panel are sold separately. Datasheets are available online at https://www.nuvationenergy.com/technical-resources.

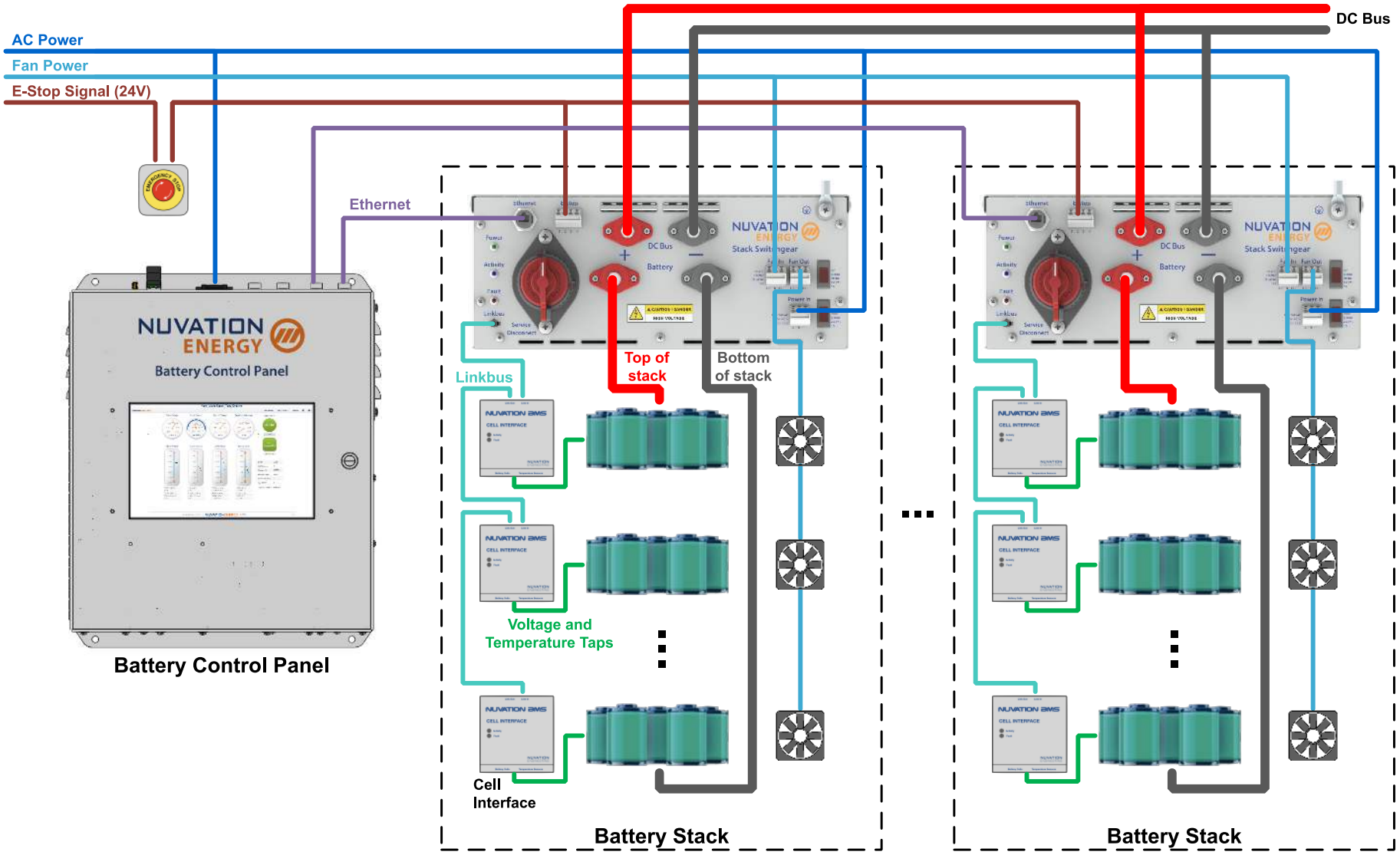


Figure 3. Stack Switchgear multi-stack diagram

2.1. Nuvation Energy Stack Switchgear

2.1.1. Mechanical Overview

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 *Nuvation Energy Stack Switchgear: NUVSSG Datasheet*, available online at https://www.nuvationenergy.com/technical-resources.

The Stack Switchgear is 4U (rack-units) tall. To maintain safe operating temperatures, it is recommended to leave 1U of space above the unit for airflow. Depending on the environment, active airflow, and ambient temperature, some cases may require additional space.

The unit weighs 23 kg [50.7 lbs]. Its overall dimensions, as well as mounting-specific ones, are shown in Section 2.1.1.4. Please refer to https://www.nuvationenergy.com/technical-resources for access to CAD files.

Rack-Mount, 19"

As mentioned above, this is the most common use-case for mounting the Stack Switchgear, shown in Figure 4. The mounting brackets allow for adjusting how far the unit protrudes or receeds from the front of the rack; see Figure 9 for precise dimensions. Also, these brackets are designed to secure the front of the unit with respect to the front of the rack. As such, the following note is important.

Third-party side-support angle brackets are necessary to uphold the weight of the unit, in this mounting application. Some examples include Hammond Manufacturing's RASA22BK3 or RAAB2436BK products; details are available on their website.

Figure 4. Rack-mount, 19"

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

Brackets are available for 2-post open-frame racks. Mounting widths of 19" and 23" are supported, as shown in Figure 5 and Figure 6, respectively.

Note that third-party side-support 2-post-extension brackets are available, *though not necessary*. One example is Hammond Manufacturing's RDAB2U26 product; details are available on their website.

Figure 5. Rack-mount, 2-post, 19"

Figure 6. Rack-mount, 2-post, 23"

Shelf-Mount

A Stack Switchgear may also be mounted to the surface on which it rests, with the aid of shelf-mount brackets, as shown in Figure 7

Figure 7. Shelf-mount

Dimensions

This section provides detailed drawings of the Stack Switchgear and its mounting provisions.

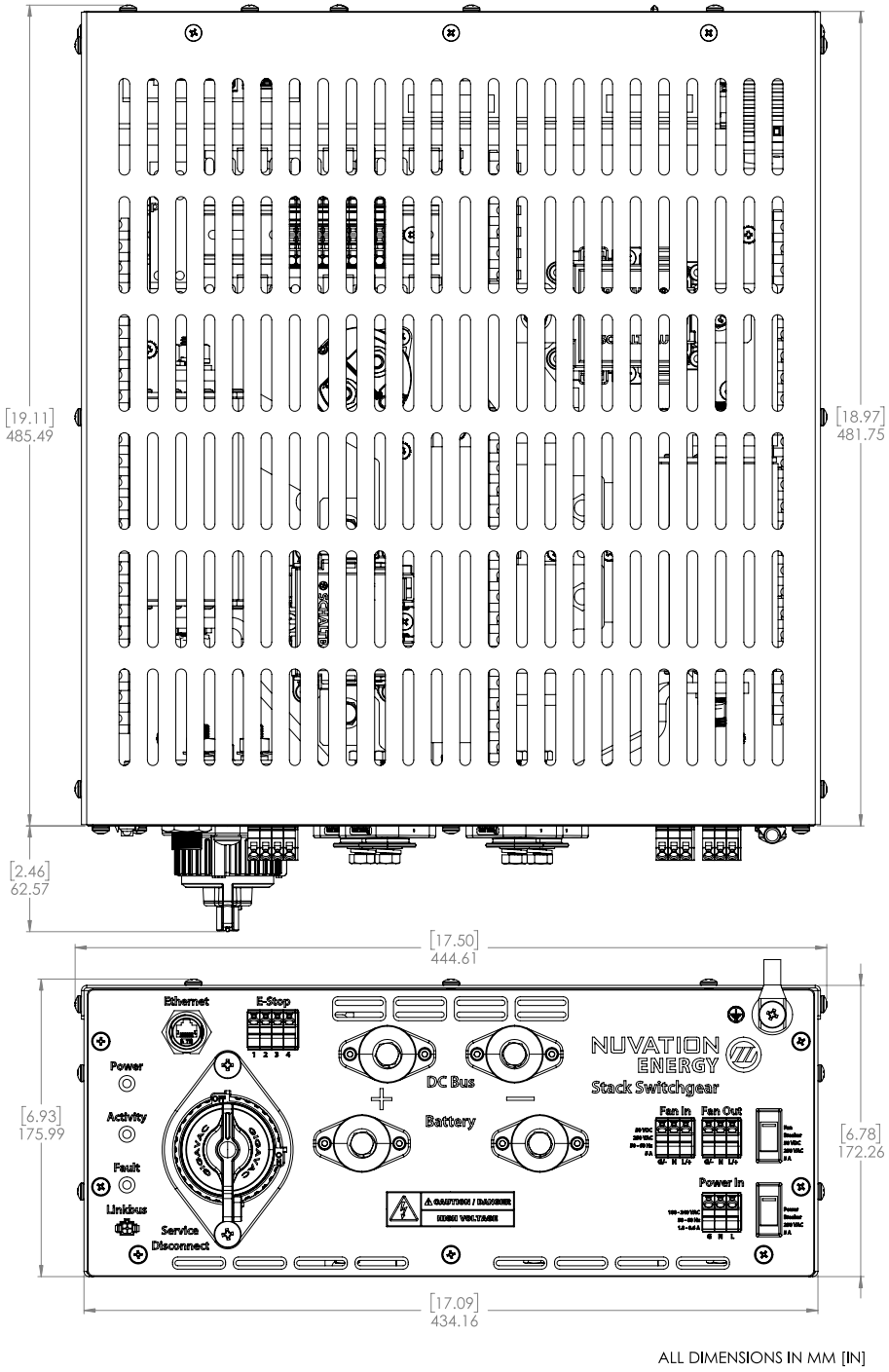


Figure 8. Dimensions, overall

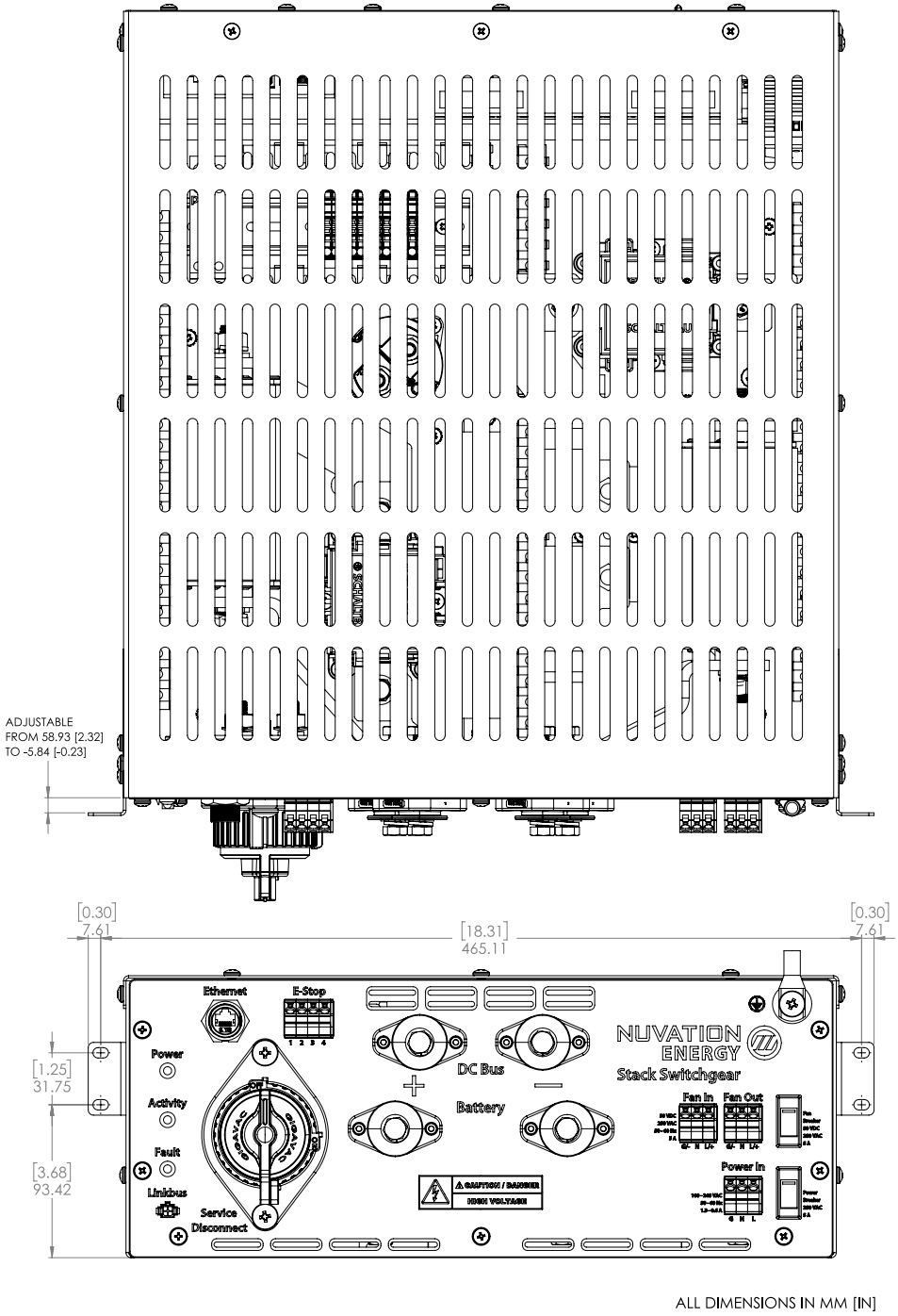


Figure 9. Dimensions, rack-mount, 19"

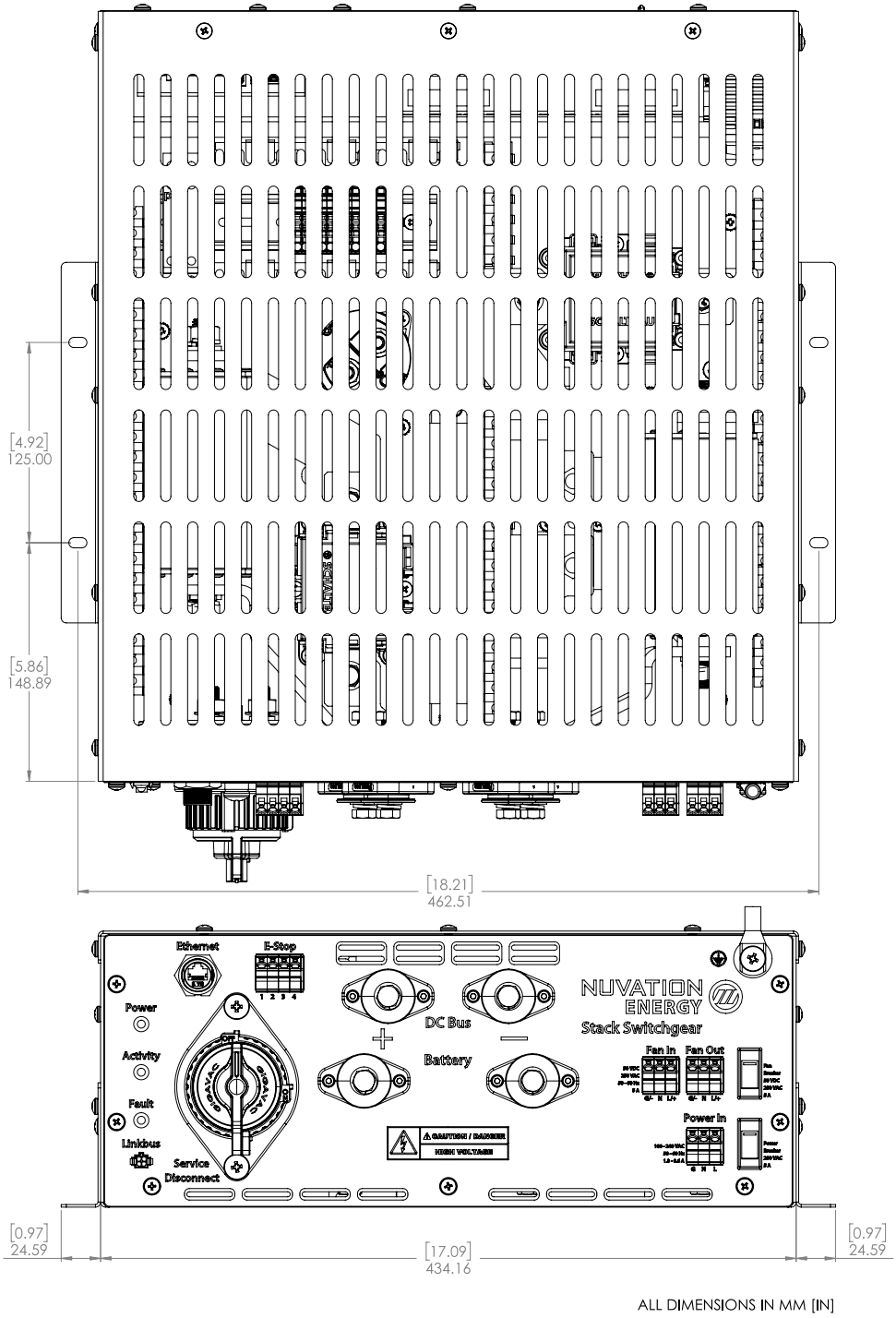


Figure 10. Dimensions, shelf-mount

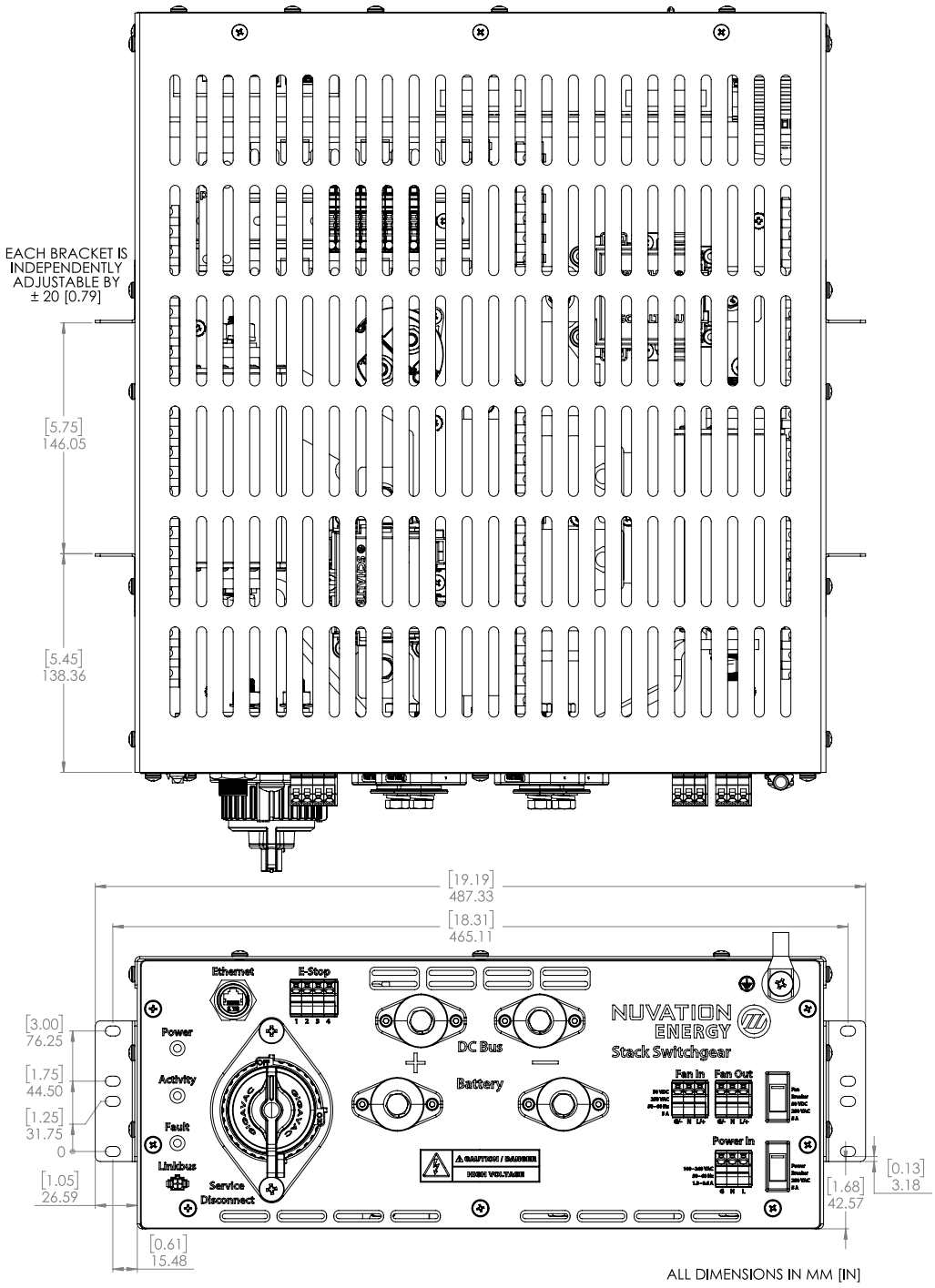


Figure 11. Dimensions, 2-post rack-mount, 19"

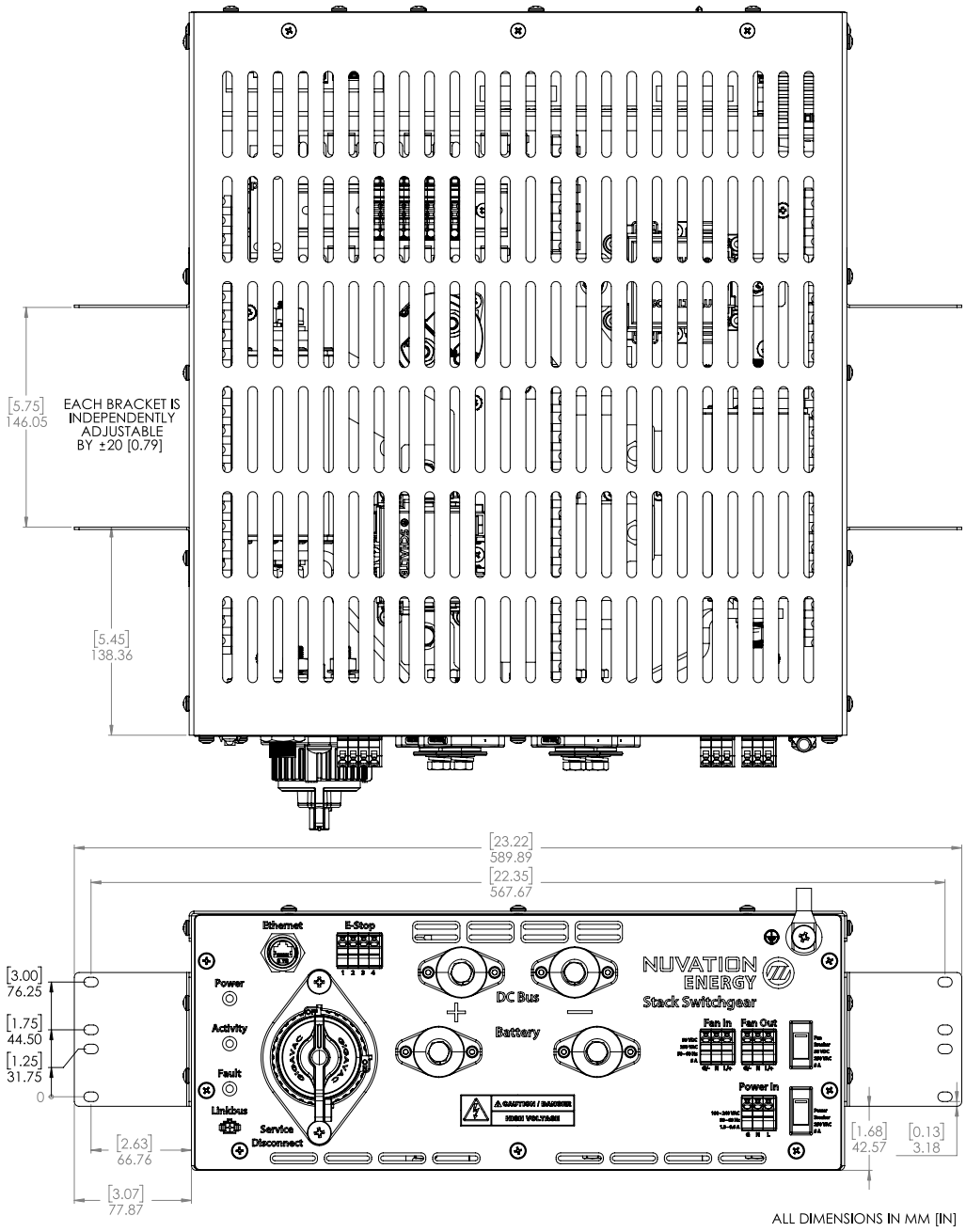


Figure 12. Dimensions, 2-post rack-mount, 23"

2.1.2. Internal Hardware Overview

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 short-circuit fuses
- Safety relay (for E-Stop)

The following subsections describe the components in more detail.

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.

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.

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 2.1.2.4). 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 disconnects under load.

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 an appropriately sized 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 the pre-set 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.

Fuses

Inline fuses are used on both the positive and negative connections and are sized according to the Stack Switchgear variant. See Table 2 for the fuse ratings for each 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. A microswitch is used on each fuse so that the BMS can recognize blown fuses and issue a fault alert.

Table 2. Internal fuse ratings

Stack Switchgear Variant	Fuse Rating	Interrupt Current Rating
1250 V DC, 100 A	200 A	100 kA
1250 V DC, 200 A	315 A	100 kA
1250 V DC, 300 A	450 A	100 kA

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 2.1.3.4.

2.1.3. External Interfaces

The Nuvation Energy Stack Switchgear provides the following external interfaces:

- Ethernet
- Link Bus
- Internal Power
- E-Stop
- Fan Control
- Battery Stack and DC Bus
- Grounding Stud

The following subsections describe each interface in more detail.

Ethernet

The Ethernet connector is a standard RJ45 Ethernet jack. Connect external equipment (such as a network switch or a Nuvation Energy Battery Control Panel) to this connector.

Table 3. Ethernet Connector Pin Assignment

Pin	Name	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
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

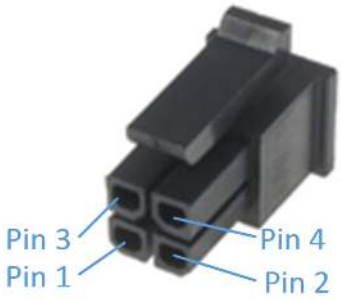
Link Bus

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, this is connected to the Cell Interface module which is measuring 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 be not be as intuitive as the aforementioned order (i.e. order of increasing potential).

Table 4. Link Bus connector pinout

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 5. Link Bus mating 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

Internal Power

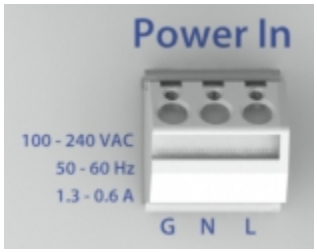
The default Stack Switchgear requires 100 V to 240 V AC power to be supplied from an external source. Power is connected via feed-through connectors on the front panel, as shown in Table 6. To install a conductor, insert a tool (such as a small flat screwdriver) into the rectangular opening at the top of the connector. This allows the conductor to freely enter into the circular opening at the bottom 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 *Nuvation Energy Stack Switchgear: NUVSSG Datasheet*, available online at https://www.nuvationenergy.com/technical-resources.

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 Appendix A.

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

Table 6. Internal power pinout



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

E-Stop

This feature allows a 24 V DC E-Stop signal, provided either by the internal power supply (shown in Figure 13) or by a source external to the Nuvation Energy system (shown in Figure 14), 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 source must be used. For specifications of this input, see Appendix A.

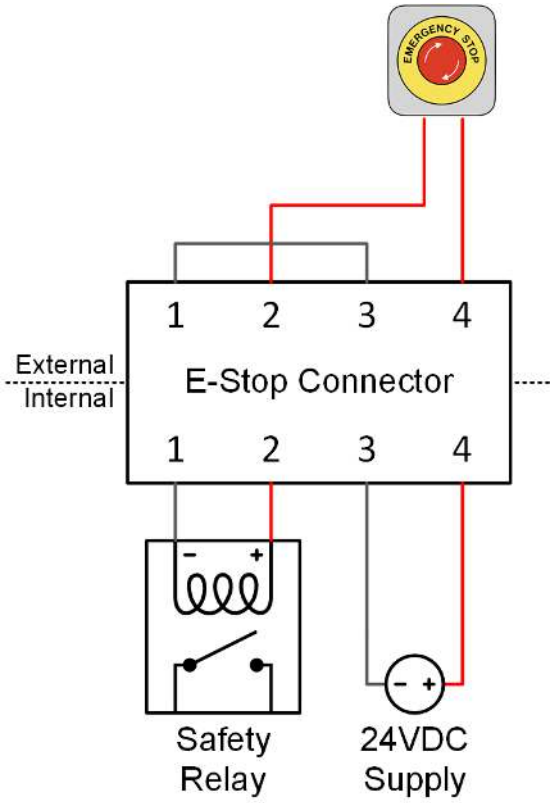


Figure 13. E-Stop circuit (internal supply)

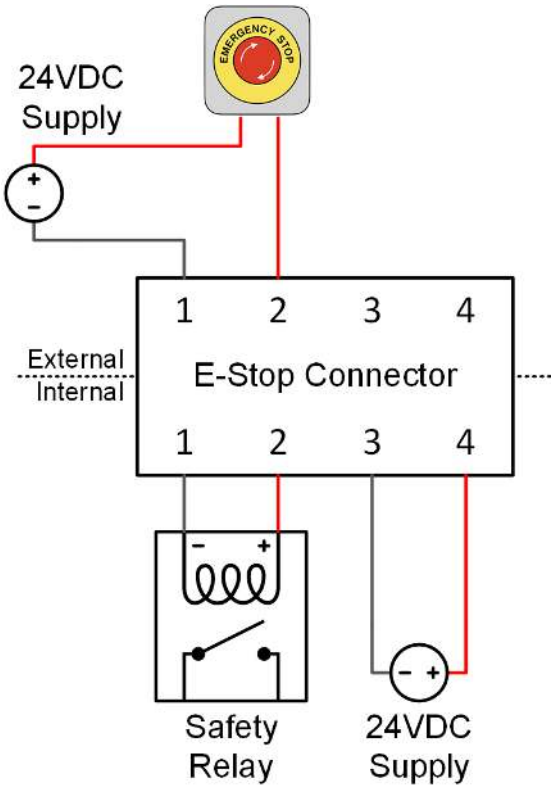


Figure 14. E-Stop circuit (external supply)

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 bottom 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 pinout

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

Fan Control

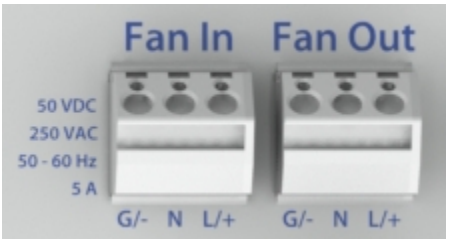
This feature gives the ability for the Stack Switchgear to control external AC or DC fans for cooling the battery cells. The fans are enabled by the BMS when battery cell temperatures exceed configurable thresholds. The power source for the fans must be supplied to the Stack Switchgear. It can be either 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 2.1.3.3.

The signals are connected via feed-through connectors on the front panel, as shown in Table 8. 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 bottom 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 Appendix A.

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

Table 8. Battery cooling fan control pinout



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

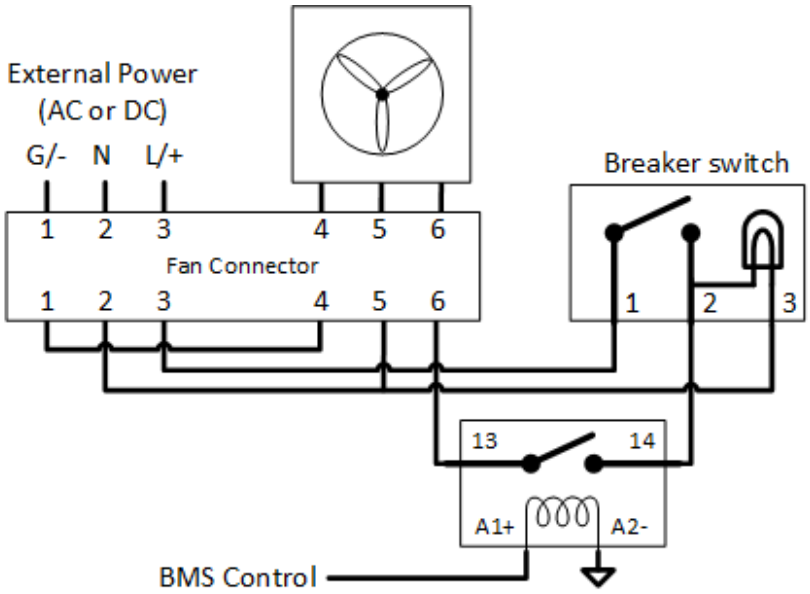
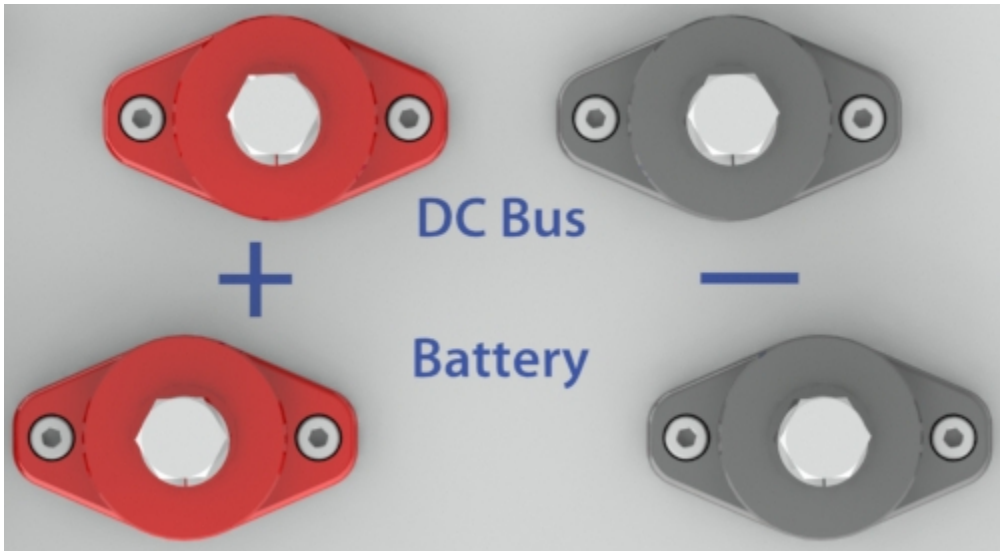


Figure 15. Battery cooling fan control wiring diagram

Battery Stack and DC Bus

The front panel of the Stack Switchgear has four high power connectors, as illustrated by Table 9. 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 M8 screws (included) and are intended for M8 lugs (not included, e.g. Panduit Corp LCMA50-8-L). Flexible snap-on terminal covers are included.

Table 9. High power connections



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

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. Slide the terminal cover onto the terminal

The recommended tightening torque is 5.7 to 6.8 N-m [50 to 60 in-lbs].

Grounding Stud

The SSG 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 overcurrent device in the circuit, as shown in Table 10.

Table 10. Minimum grounding wire size

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

Figure 16. Grounding stud

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 16.

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].

2.2. Nuvation Energy Cell Interface

2.2.1. System Overview

The Nuvation Energy Cell Interface is one of several major components of a Nuvation Energy battery management system. The Cell Interface is the direct link between the battery stack cells and the rest of the battery management system. It facilitates battery monitoring and control functionalities.

In a Stack Switchgear, depending on battery stack size and count, one or more Cell Interface modules are used to convert and relay cell voltage and temperature readings digitally to the Stack Controller. 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.

There are 3 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 - 12V 4 channel can monitor up to 4 series-connected 12V lead-acid cells

A basic system diagram is shown below:

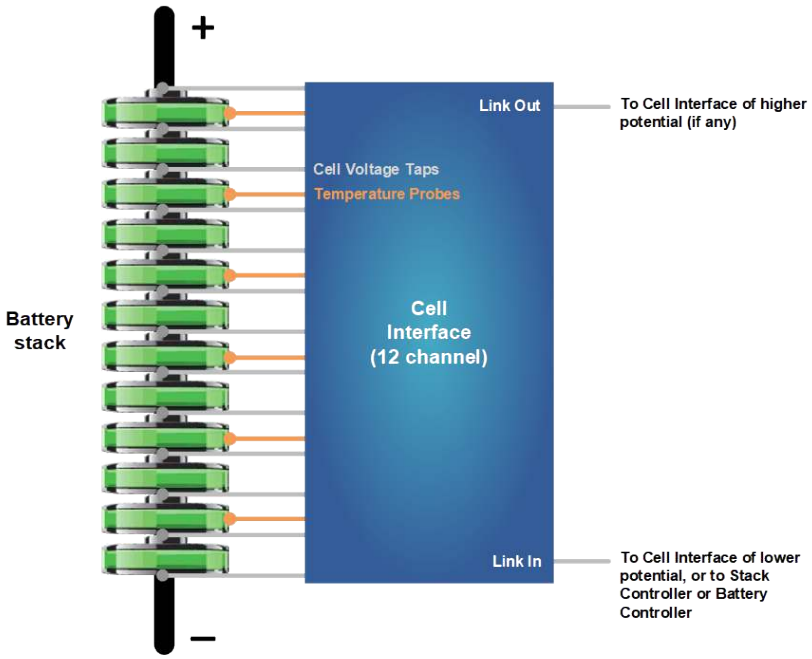


Figure 17. Cell Interface System Diagram

2.2.2. Mechanical Overview

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

The Cell Interface is available in a bulkhead-mountable enclosure as shown in Figure 18. The

enclosure has five metal walls, leaving the bottom of the unit fully exposed. It must be mounted to a metal bulkhead panel such that the panel covers the exposed bottom side.

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 easy installation/maintenance.

The standard Cell Interface, Bulkhead weighs approximately 450 g.

> 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.

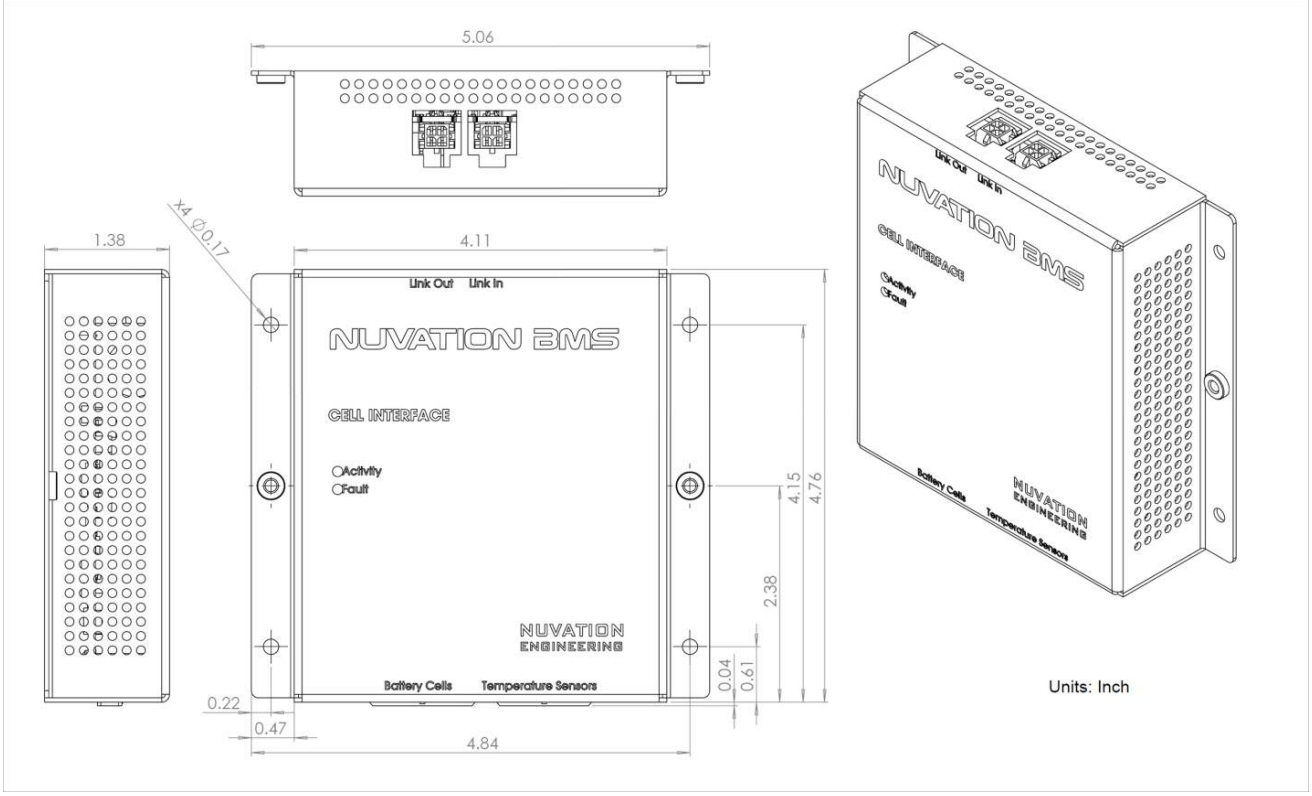


Figure 18. Mechanical Drawing of Cell Interface with Bulkhead Enclosure

Optional DIN rail mounting Kit

For applications requiring DIN rail mounting, the Cell Interface may be ordered with the Cell Interface Mounting Bracket (Bulkhead-to-DIN) kit. This kit is sold separately, and includes a metal plate and the necessary hardware to securely mount the standard Cell Interface module to EN50022-compliant DIN rails, as shown in Figure 19.

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 19.

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

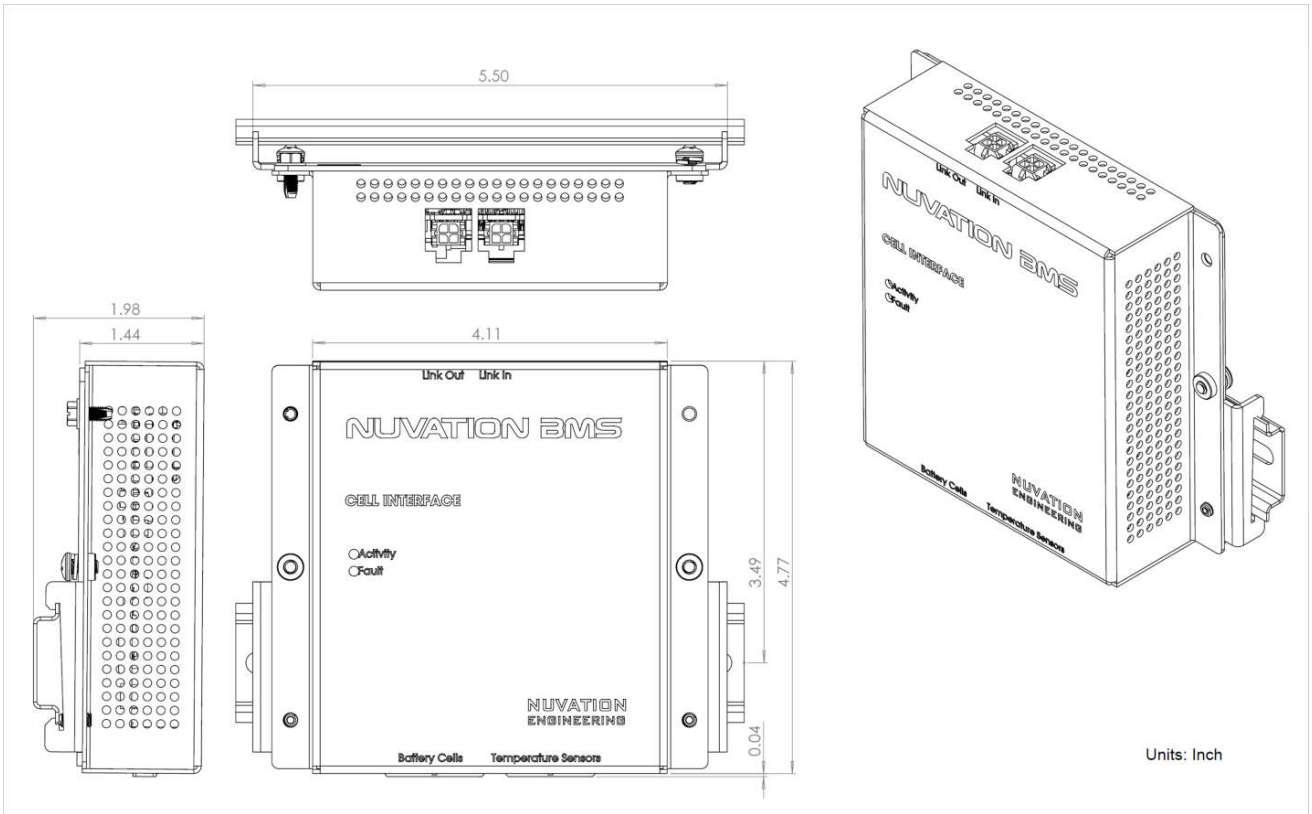


Figure 19. Mechanical Drawing of Cell Interface with Cell Interface Mounting Bracket (Bulkhead-to-DIN)

NRND variant with DIN rail mounting

The older Cell Interface, DIN Mount variant has been discontinued and is NRND (not recommended for new design). New designs should use Cell Interface, Bulkhead variant with the Cell Interface Mounting Bracket (Bulkhead-to-DIN) kit. The information below is provided for the purpose of updating DIN rail mechanical designs.

The clips add an extra 19.6 mm to the overall width of the standard Cell Interface module, bringing it from 104.4 mm to 124 mm. The clips also hold the module approximately 7mm away from the inside lip of the DIN rail. The DIN enclosure vertically centers the module over the DIN rail, as shown in Figure 20.

A Cell Interface with DIN mountable enclosure weighs approximately 540 g.

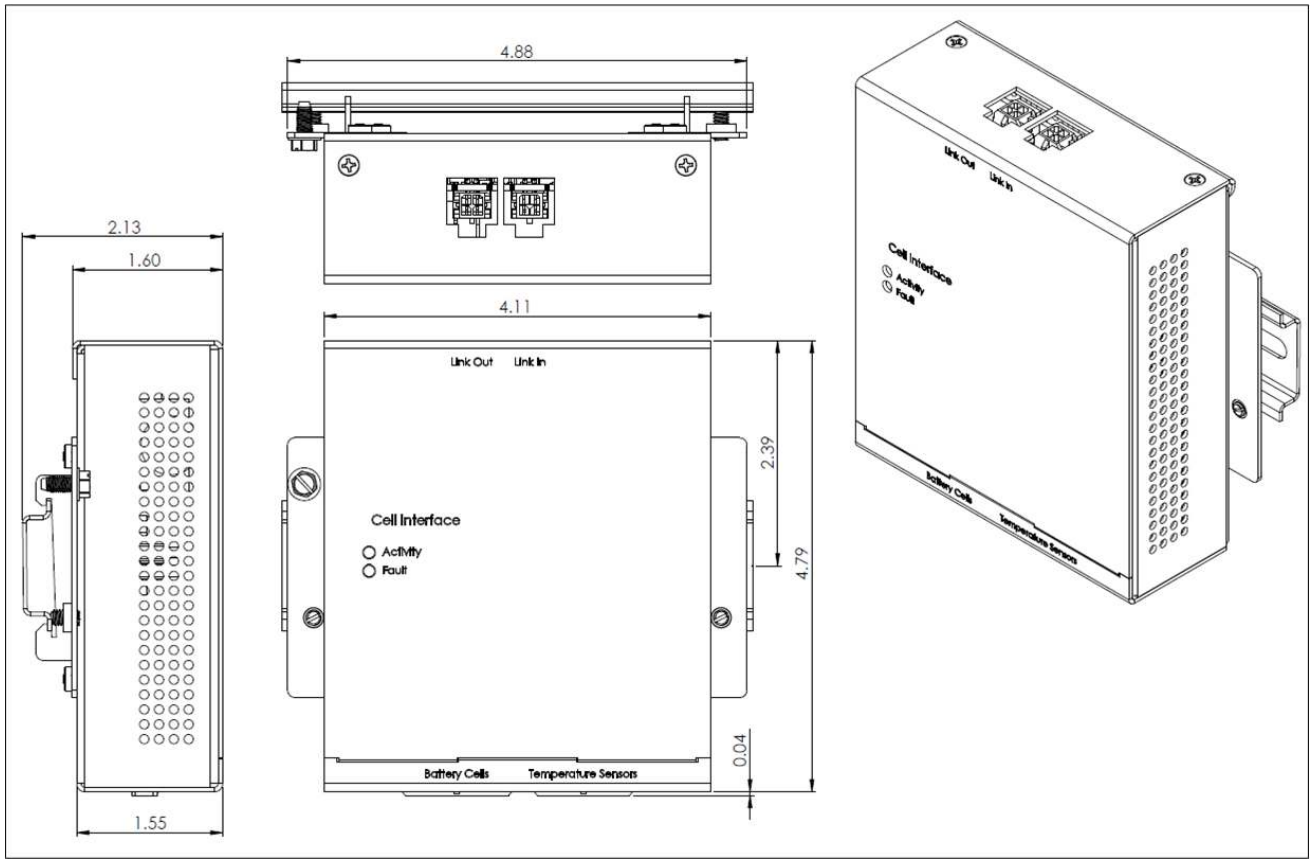


Figure 20. Mechanical Drawing of Cell Interface with DIN Enclosure (NRND)

3. Installation

3.1. Stack Switchgear Installation

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

3.1.1. Mechanical Installation

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 6 mm) are included with any mounting bracket orders. 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 [0.25 in].

After removing the Stack Switchgear from its packaging, perform the following steps.

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.
3. Attach the Stack Switchgear (with brackets installed) to the shelf.

For rack installations (i.e. using the **NUVP-SSG-RB-19**):

1. Install the third-party side-support angle brackets 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.
4. Secure the Stack Switchgear to the rail of the rack using the brackets installed.

For 2-post 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.
4. Attach the Stack Switchgear (with brackets installed) to the posts.

3.1.2. Electrical Installation

After the mechanical installation, perform the following steps:

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

- The service disconnect switch's lock-out / tag-out should be used.

2. Using a multimeter, verify that the system is de-energized.
   - The battery itself cannot be de-energized.
   - In some situations, it may not be possible to de-energize the DC bus.
3. Install the ground.
4. Install the input power and fan power.
   - Input power and fan power should be de-energized during installation; this usually involves turning off a breaker at a panel.
5. 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 3.2.
6. Install the Link Bus cable between the Stack Switchgear and the first Cell Interface in the Link Bus chain.
7. Install the connection to the battery and the DC bus.
   - This step is done with live voltage; for this reason it is left for last.
   - In order to reduce the risk of a catastrophic short, only install one connection at a time.

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.

3.2. Cell Interface Installation

3.2.1. Electrical Connections

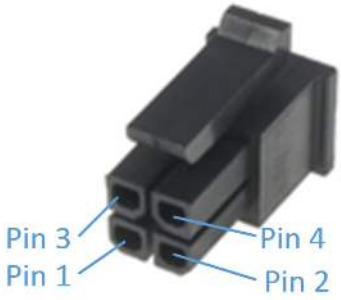
The Cell Interface module has 4 connectors. Each connector is described in the following sections in detail.

Link Out

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

Connect the Cell Interface that is measuring the next series-connected cell above the most positive cell connected to this connector.

Table 11. 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 12. Link Out Connector Pin Assignment

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

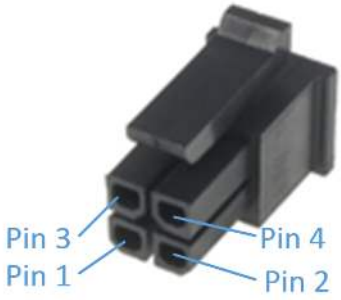
Link In

The Link In connector provides power and communication to this Cell Interface from the Cell Interface modules below this Cell Interface, or from the Stack Controller if this Cell Interface is measuring the most negative cell in the stack.

The amount of current sourced into this connector is the sum of current consumed by this Cell Interface and all those above it (which amounts to all Cell Interface modules if this Cell Interface is measuring Cell 1).

Connect to the Link Out connector on the Cell Interface that is measuring the previous series-connected cell below this Cell Interface to this connector, or connect the Stack Controller to this connector if this Cell Interface is measuring the bottom cell in the stack.

Table 13. 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 14. Link In Connector Pin Assignment

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

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 750mA to survive worse-case current.

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 - 12V 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 - 12V 4 channel model.

Connect the battery cell voltage sense leads to this connector.

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.

Table 15. 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

Battery Cell Connector for Cell Interface - 12 channel

Table 16. 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

Pin	Connection	Description	Connected to Device
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

The following is an example wiring guide for a Cell Interface - 12 channel with 12 cells and 8 cells

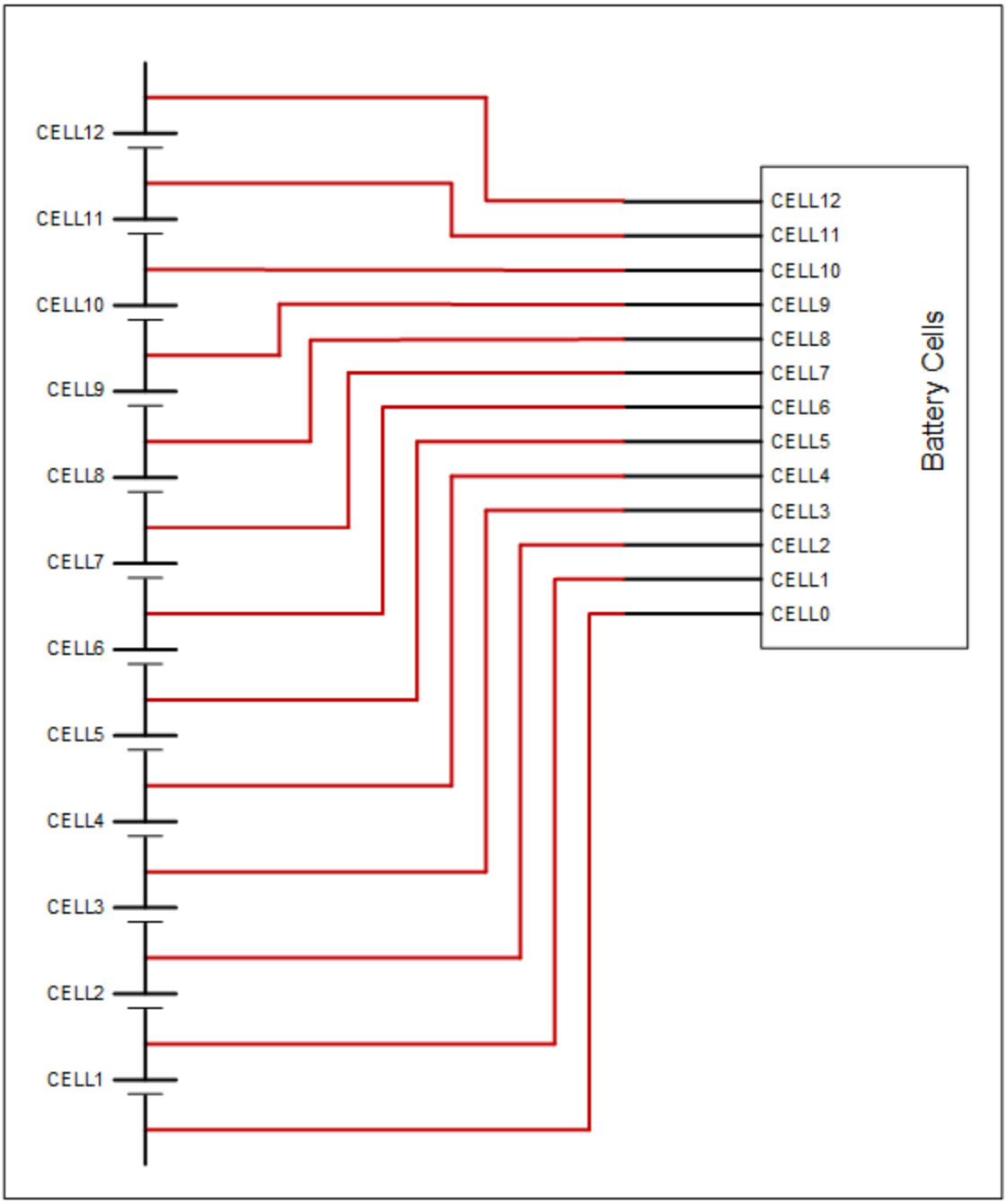


Figure 21. Example wiring 12 cells in a Cell Interface - 12 channel

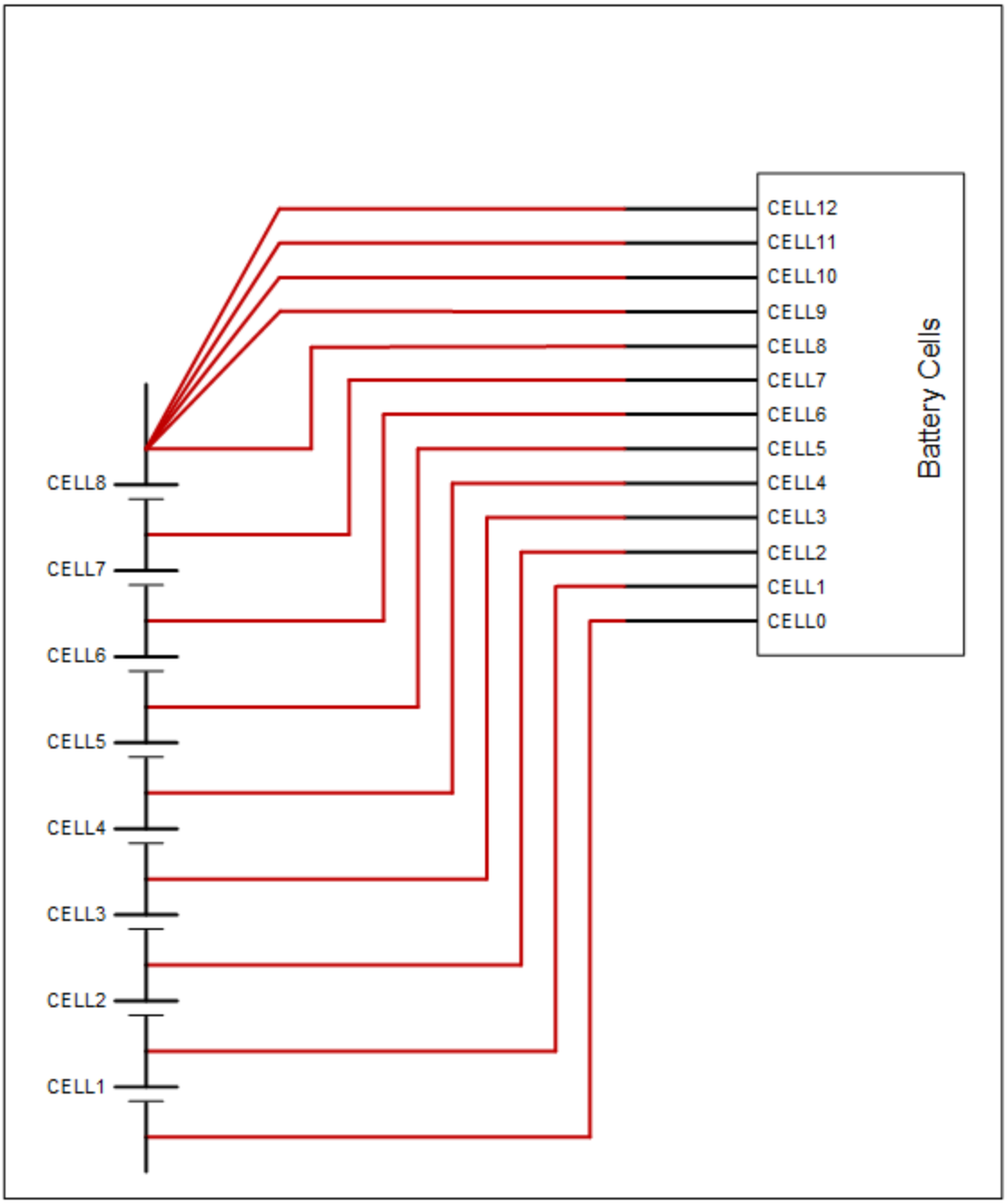


Figure 22. Example wiring 8 cells in a Cell Interface - 12 channel

Battery Cell Connector for Cell Interface - 16 channel

Table 17. 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

Pin	Connection	Description	Connected to Device
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
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

The following is an example wiring guide for a Cell Interface - 16 channel with 16 cells and 11 cells

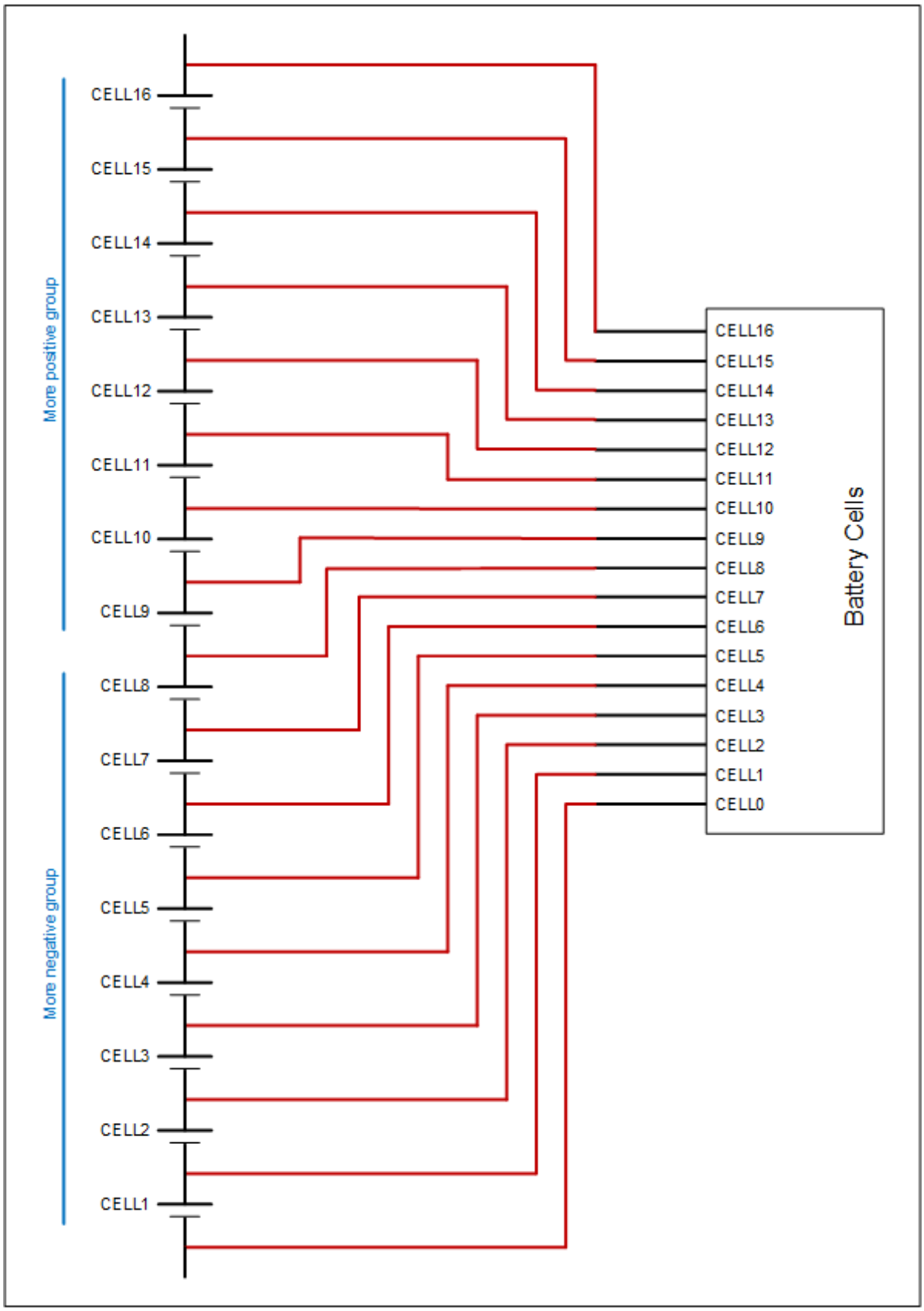


Figure 23. Example wiring 16 cells in a Cell Interface - 16 channel

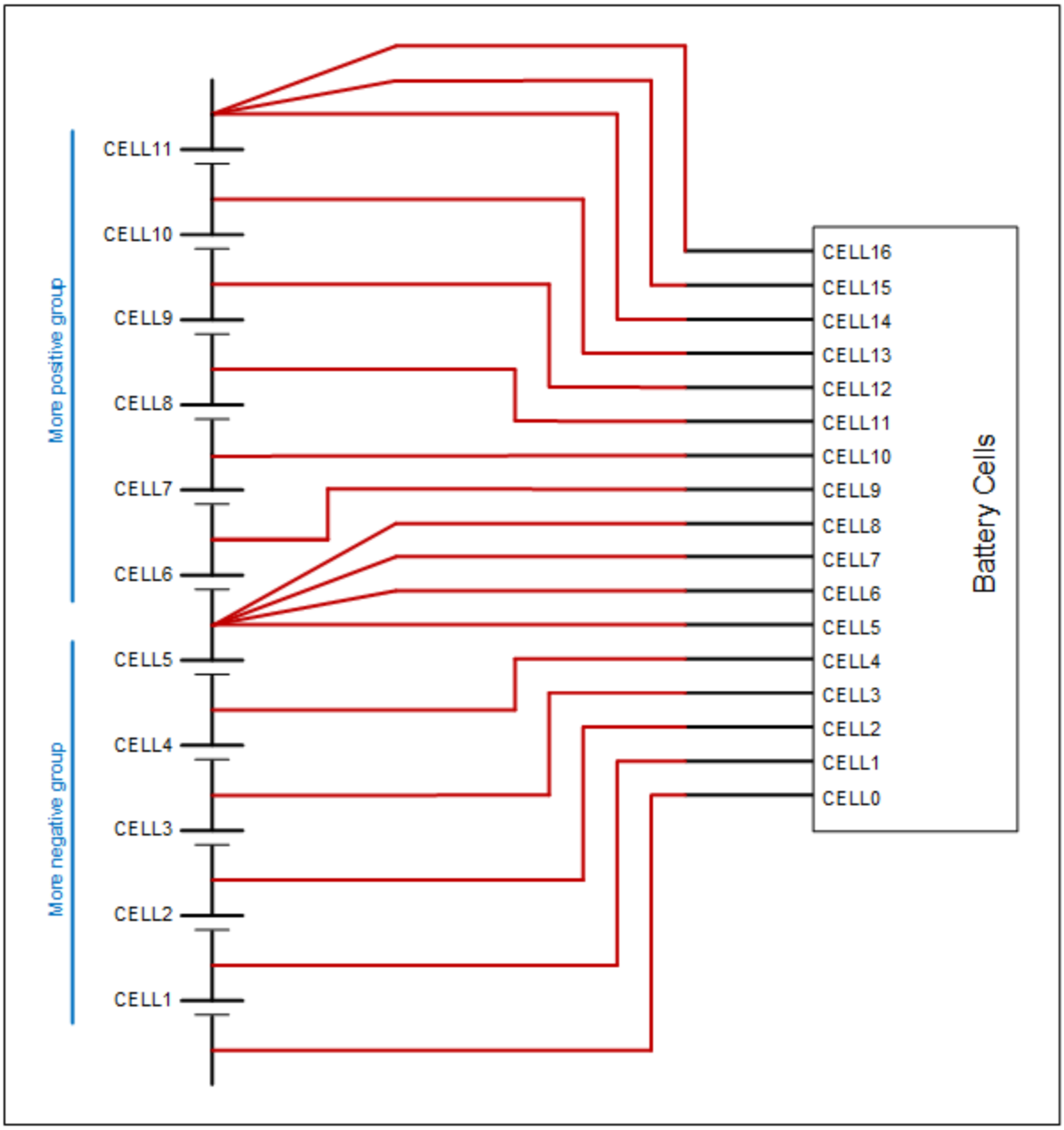


Figure 24. Example wiring 11 cells in a Cell Interface - 16 channel

Battery Cell Connector for Cell Interface - 12V 4 channel

Table 18. Cell Interface - 12V 4 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	No Connect	Not Connected	No Connect
3	CELL4	Cell 1 voltage sense	Connect to positive terminal of the lowest cell (Cell 1)

Pin	Connection	Description	Connected to Device
4	No Connect	Not Connected	No Connect
5	CELL8	Cell 2 voltage sense	Connect to positive terminal of Cell 2
6	No Connect	Not Connected	No Connect
7	CELL1	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	CELL16	Cell 4 voltage sense	Connect to positive terminal of Cell 4

The following is an example wiring guide for a Cell Interface - 12V 4 channel with 4 cells and 3 cells

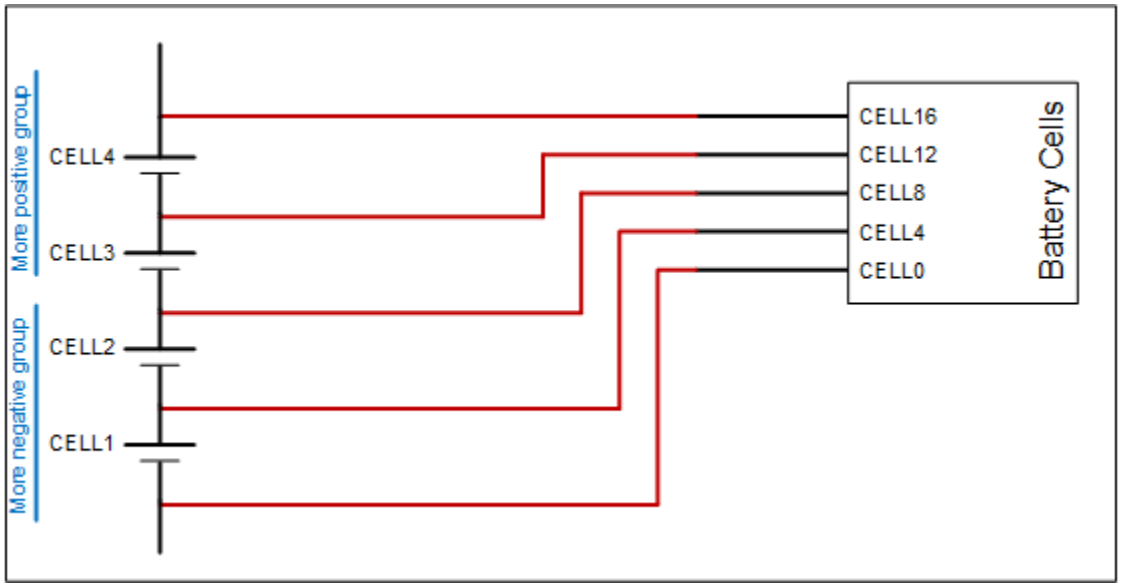


Figure 25. Example wiring 4 cells in a Cell Interface - 12V 4 channel

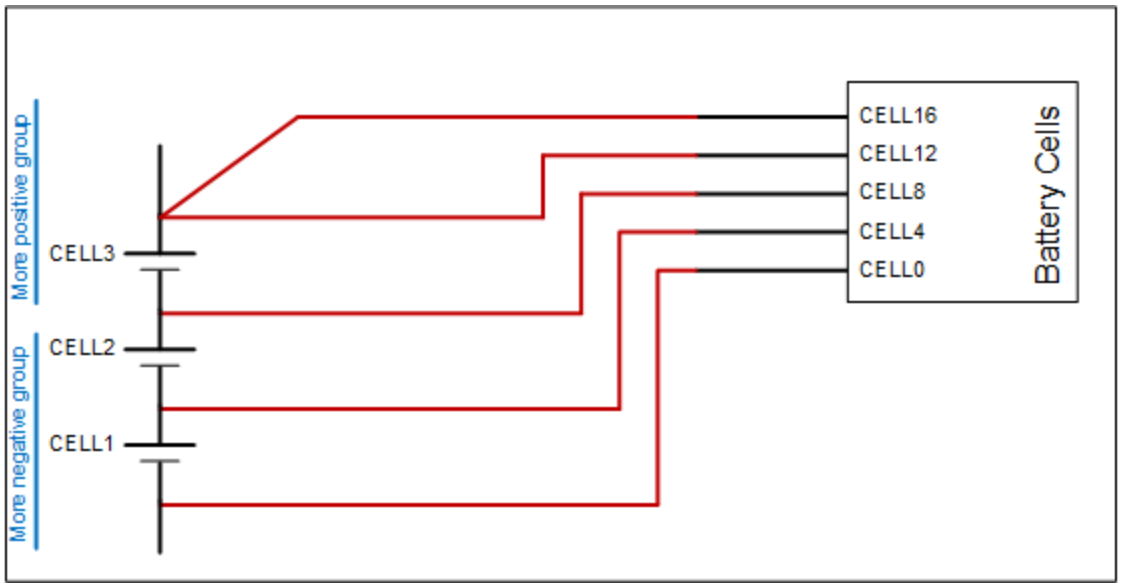


Figure 26. Example wiring 3 cells in a Cell Interface - 12V 4 channel

Temperature Sensors

The Temperature Sensors connector provides NTC thermistor inputs for temperature measurement of the cells and/or surrounding area. All signals are referenced to Pin 1 of the `Battery Cells` connector. 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 10 kΩ NTC thermistors to this connector.

Table 19. 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 20. 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
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 two but no more then seven thermistors installed per Nuvation Energy Cell Interface in a specific pattern. The following table lists the expected pattern of thermistor installation approved for safety certification.

Table 21. 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

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.

4. 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 Stack Switchgear can now be connected to a network, either through a network switch or directly to a computer/laptop's network adapter. The default IP address of the Stack Switchgear is 192.168.1.21. Refer to the Section 6 for instructions on using the Operator Interface.

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 *Software Reference Manual*. Once all faults are cleared, the Stack Switchgear is able to connect the battery to the DC bus.

5. Using the Stack Switchgear

5.1. Service Disconnect

A manual service disconnect switch is accessible on the front of the Stack Switchgear, to be used for lockout-tagout to ensure that the battery stack does not connect to the DC bus or power conversion system during servicing. The service disconnect switch features a lock-out / tag-out. The 'OFF' position is vertical. The 'ON' position is horizontal.

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.

Figure 27. Service Disconnect

5.2. Panel Status LEDs

The three LEDs on the front panel are controlled by the internal Stack Controller to indicate health and functional status to the user.

5.2.1. 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 28. Power LED

5.2.2. 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 29. Activity LED

5.2.3. 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 30. Fault LED

6. Nuvation Energy BMS Software Setup

6.1. Install the Operator Interface

6.1.1. Overview

The Operator Interface can be accessed from any computer/tablet with the latest Firefox or Chrome web browser. The Operator Interface is used to access the Stack Switchgear in a single stack installation.

6.1.2. Installing the Operator Interface

The latest Nuvation Energy BMS 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. Unzip the package to a suitable location on your computer. 7-ZIP is a free tool that can be downloaded here: http://www.7-zip.org
3. The archive's password is `nuvation`.
4. Releases follow a naming convention similar to `nuvation-hv-bms-babbage-18.08.1.zip`. The archive 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.

6.2. Connect to the Operator Interface

6.2.1. Overview

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 Nuvation Energy BMS.

6.2.2. Connecting to the Operator Interface

By default, Nuvation Energy BMS is configured with a static IP address of `192.168.1.21`. To connect to a Nuvation Energy BMS that is using the default IP address:

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`

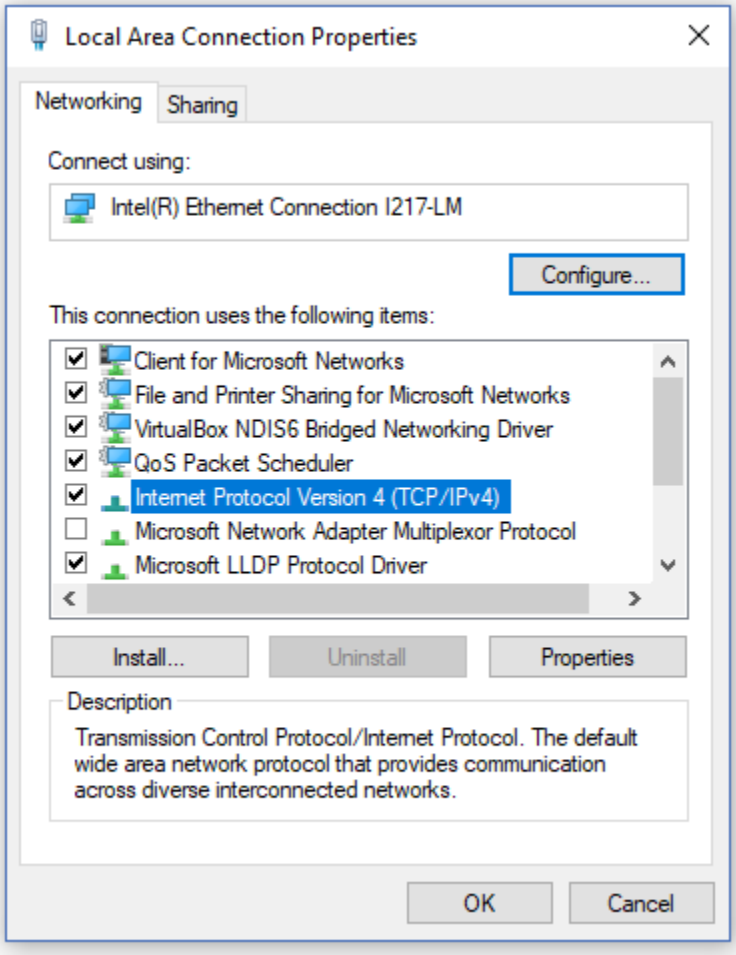


Figure 31. Network Adapter Properties on Windows

4. Update your network adapter TCP/IPv4 settings to the following:
   - Static IP Address: `192.168.1.x` (where `x` is not 21)
   - Subnet Mask: `255.255.255.0`
   - Default gateway: `192.168.1.1`

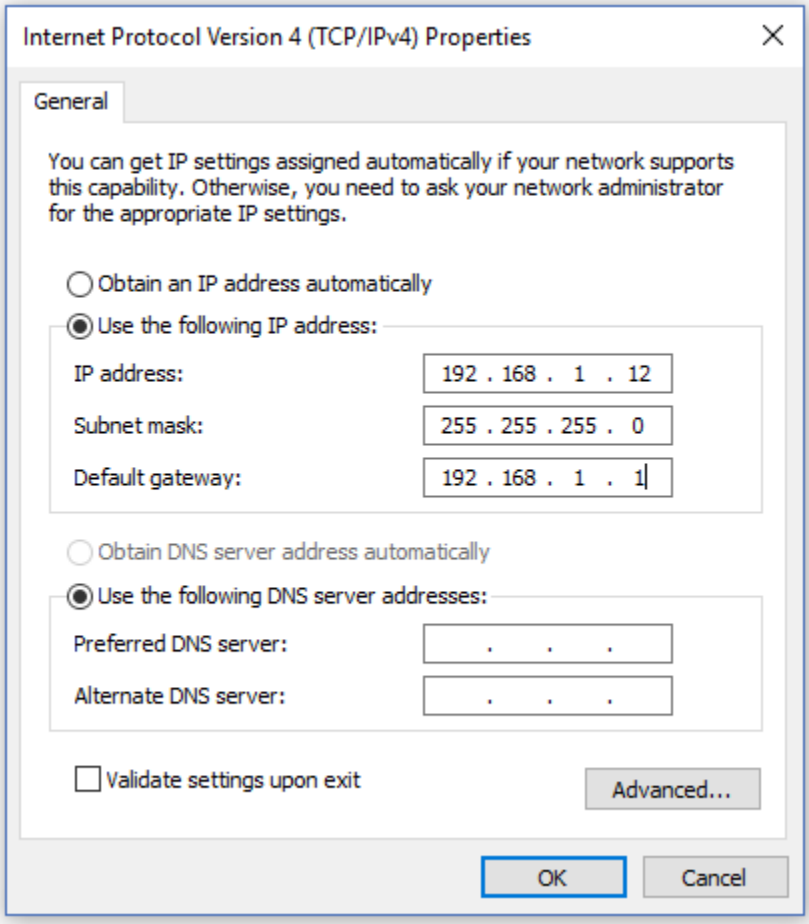


Figure 32. Network Adapter Settings on Windows

5. Ensure your computer is on the same network as your Stack Switchgear.
   - You can connect an Ethernet cable between Nuvation Energy BMS 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.

6.3. Upgrade the Nuvation Energy BMS

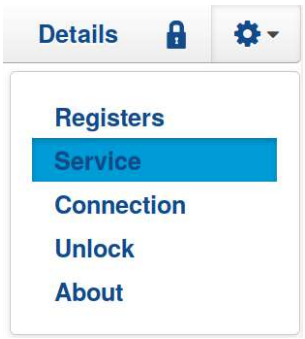
6.3.1. Overview

The Operator Interface is packaged with the appropriate version of Nuvation Energy BMS firmware. The firmware for Nuvation Energy BMS can be upgraded using the Operator Interface.

To upgrade the firmware Nuvation Energy BMS must be in Service Lockout. Please see Section 7.5 for more details.

6.3.2. Enter Service Lockout

1. Unlock the Operator Interface by clicking the menu and `Unlock`
2. From the menu, select `Service` to bring up the Service page



3. Click `Lockout` to enter Service Lockout

> Entering Service Lockout will open all contactors and GPOs

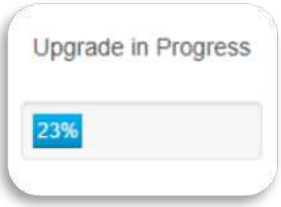
> When in Service Lockout, you will not be able to access the Operator Interface dashboard.

6.3.3. Upgrading the Firmware

The `Upgrade` option will become available when Nuvation Energy BMS successfully enters Service Lockout. If a newer firmware version is available, proceed with the firmware upgrade.

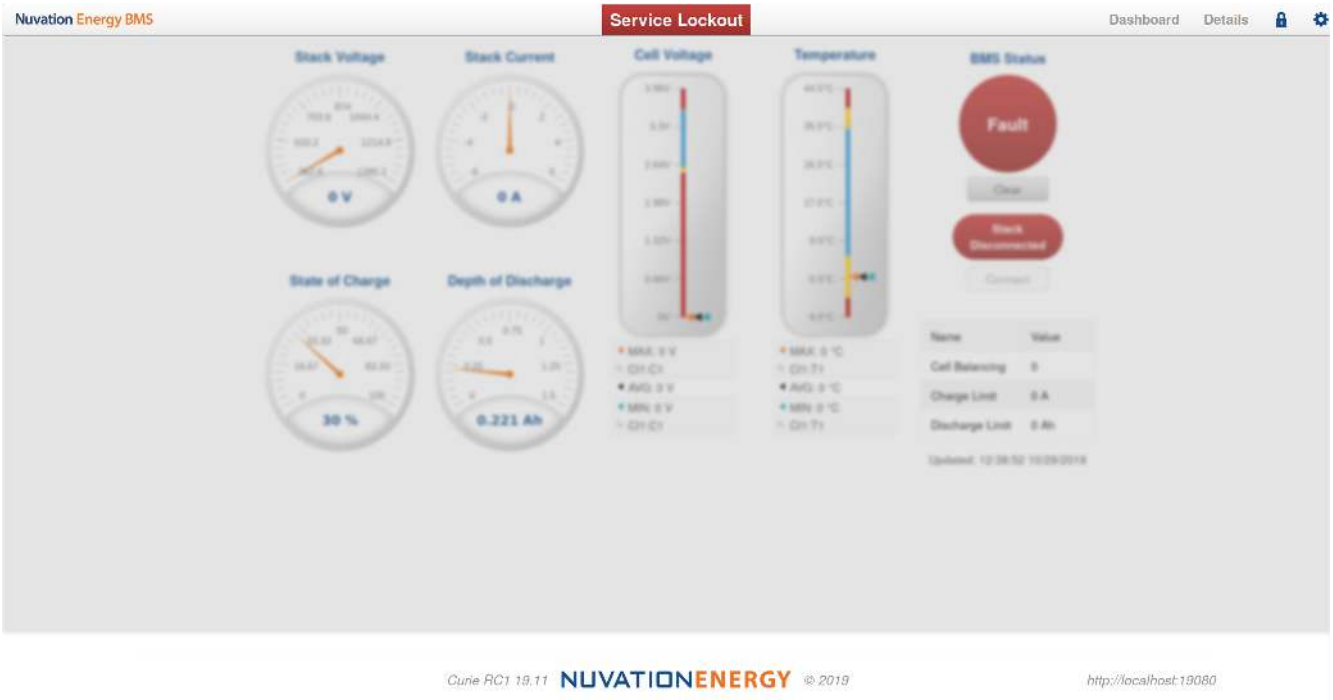
> The firmware upgrade will erase the configuration file on your Nuvation Energy BMS. If this is not a new install and you have a configuration file loaded on your Nuvation Energy BMS, please remember to export and save it. You can import this file after the upgrade is complete.

1. Click the `Upgrade` button to begin the upgrade. A progress bar allows you to monitor the upgrade process.



2. Wait until a dialog box appears with the upgrade result. It should indicate that the firmware upgrade is complete.

3. If the upgrade is successful, you will be returned to the dashboard. Nuvation Energy BMS will remain in Service Lockout.



You will need to import a valid configuration file before attempting to exit Service Lockout.

6.3.4. Troubleshooting

During the firmware upgrade, if a failure is reported, retry the upgrade.

While exiting the service lockout, if a failure is reported, please see Section 7.5 for troubleshooting

details.

If the failures persist, please submit a support ticket with as much detail as possible to support@nuvationenergy.com.

6.4. Generate a Configuration File

6.4.1. Overview

Your Nuvation Energy BMS needs a valid configuration file to operate. You can generate and download a configuration file via the nCloud and import it to your Nuvation Energy BMS. The Operator Interface provides tools for importing and exporting configuration files to and from Nuvation Energy BMS as a way to set or retrieve the state of all configuration registers.

6.4.2. Generating your Configuration file

For Nuvation Energy High-Voltage BMS installations

For High-Voltage BMS installations please refer to the *Software Reference Manual* for details on how to create a configuration file for your setup.

For Nuvation Energy Low-Voltage BMS installations

To generate a configuration file, visit the nCloud at: https://ncloud.nuvationenergy.com. nCloud is the Nuvation Energy online portal to remote battery management.

In the nCloud, configuration files can be generated and retrieved from the `Configurations` menu option by following these steps:

1. Click `Create New Configuration`
2. Follow the instructions in the `Quick Start Wizard`.
3. Download the `.config` configuration file
4. Store the configuration file on the computer running the Operator Interface.

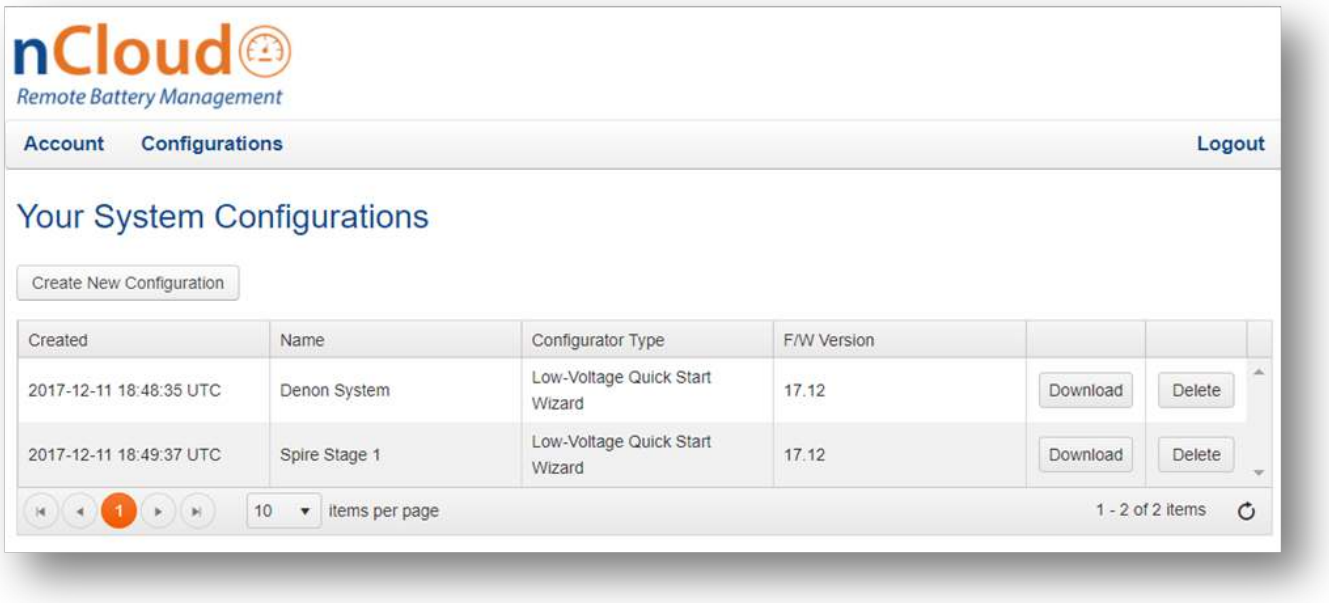


Figure 33. Configuration screen in the nCloud

If your Nuvation Energy BMS is connected to a computer that doesn't have internet access, you can use a USB stick to transfer the configuration file between computers.

6.4.3. Edit the Configuration File (optional)

This is an optional step. If you would like to further adjust your Nuvation Energy BMS settings, to meet the requirements of your particular system, you may choose to edit the configuration file.

To edit the Configuration file, open the file in any text editor. Please backup the modified configuration file for future use. Nuvation Energy BMS doesn't store the file internally; it only stores the register values. The export feature will export a configuration file with an alphabetical listing of all registers and their set values.

For instructions on how to modify the configuration file and understand the various registers please refer to the *Software Reference Manual* for your Nuvation Energy BMS.

6.5. Import the Configuration File

6.5.1. Overview

Once you have exported your configuration file to the computer connected to Nuvation Energy BMS, you can proceed to import it to Nuvation Energy BMS.

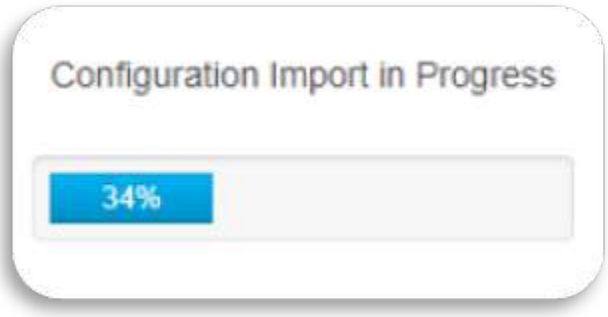
To import a configuration file Nuvation Energy BMS must be in Service Lockout. Please see Service Lockout for more details.

6.5.2. Import the configuration file

1. Ensure you are in Service Lockout
2. Ensure `Persist Configuration to BMS` is checked

> **Persist Configuration to BMS**
>
> Enabling this option tells Nuvation Energy BMS to persist the imported configuration file. If you are using known, good, configuration files you should check this box.
>
> Disabling this option tells Nuvation Energy BMS to not persist the newly imported configuration file. On reboot, Nuvation Energy BMS will revert to the previous configuration file. This is useful when tweaking and testing configuration files. It allows you to recover from incorrect configuration settings by rebooting Nuvation Energy BMS

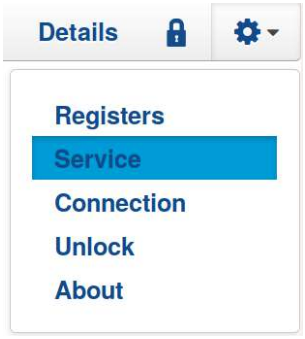
3. Click `Import Configuration`
4. Select the configuration file to use and click `Open`
5. A dialog indicating progress will pop-up



6. Wait until a dialog box appears with the configuration import result. It should indicate that the import was successful.

6.5.3. Exit Service Lockout

1. Unlock the Operator Interface by clicking the menu and `Unlock`



2. From the menu, select `Service` to bring up the Service page
3. Exit the Service Lockout by clicking `Exit Service Lockout`

> Exiting Service Lockout may close contactors

You will be able to access the dashboard controls once Nuvation Energy BMS has successfully exited service lockout.

6.5.4. Troubleshooting

During the configuration file import, if you receive a `Register Write failure error`, ensure you have valid entries in your configuration file. For details on the various registers and their intended use, please refer to the *Software Reference Manual* for your Nuvation Energy BMS.

While exiting the service lockout, if a failure is reported, please see Section 7.5 for troubleshooting details.

> If the failures persist, please submit a support ticket with as much detail as possible to support@nuvationenergy.com.

6.6. Calibrate the Nuvation Energy BMS

6.6.1. Overview

Before you start regular operation of your Nuvation Energy BMS, it is recommended that you calibrate it for accurate usable capacity measurements.

This calibration should be done if changes are made to the energy storage installation or if a new configuration file has been imported.

6.6.2. Calibration

1. Refer to the section *Measurement Calibration* in the *Software Reference Manual* for steps to calibrate the stack current, voltage, and temperature measurements
2. Fully charge up the batteries to 100% State-of-Charge (as defined in the configuration file)
3. Discharge the batteries to 0% State-of-Charge (as defined in the configuration file)
4. Optionally, charge the batteries back up to 100% State-of-Charge

7. Using the Nuvation Energy BMS Operator Interface

7.1. The Dashboard Tab

7.1.1. Overview

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.

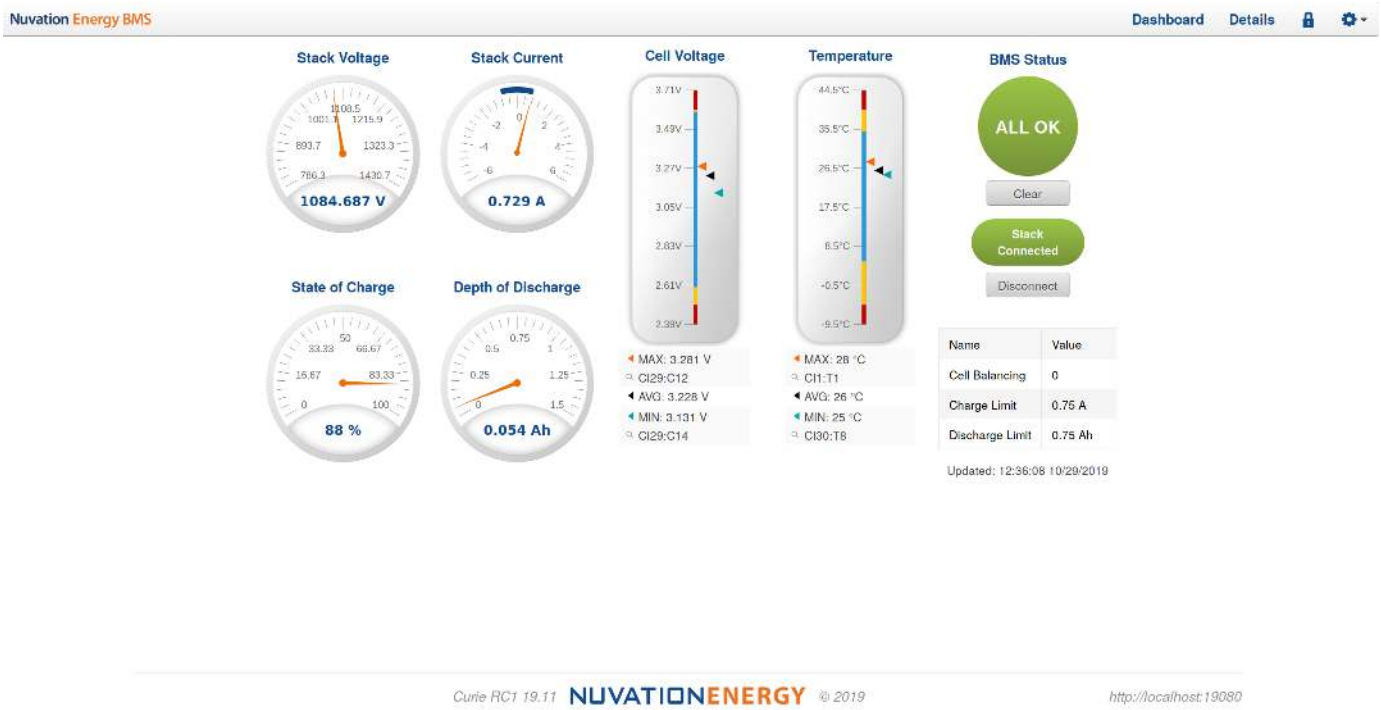


Figure 34. Nuvation Energy BMS Operator Interface Dashboard screenshot

7.1.2. 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.

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

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

7.1.3. Stack Voltage

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

Refer to the Stack Voltage Thresholds section in the *Software Reference Manual* to tune this gauge

7.1.4. Stack Current

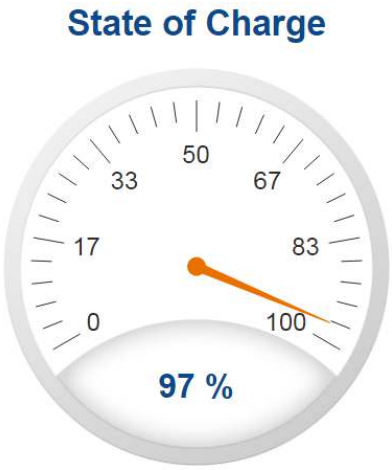
The stack current radial gauge shows the battery stack current as well as the maximum charge current limit and the maximum discharge current limit. The acceptable current range is visualized on the gauge by the blue arc. An absence of the blue arc indicates the battery stack cannot be charged or discharged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

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

Refer to the Stack Current Thresholds section in the *Software Reference Manual* to tune this gauge

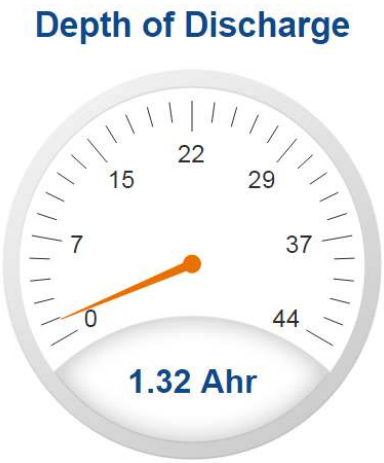
7.1.5. State of Charge

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%.



7.1.6. 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% SOC.



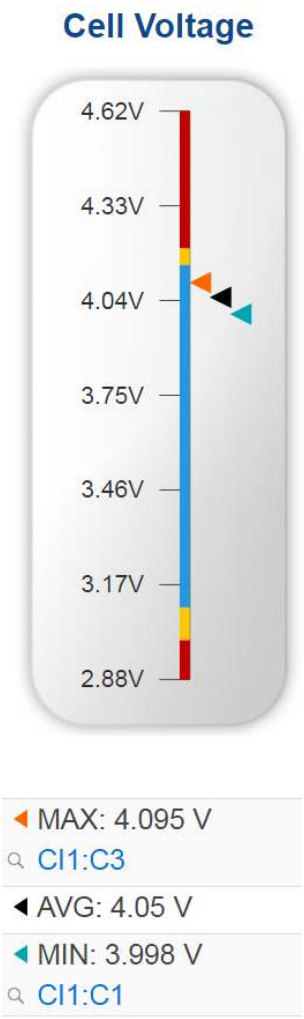
7.1.7. Cell Voltage

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 value are shown below the gauge, along with the average cell voltage value.



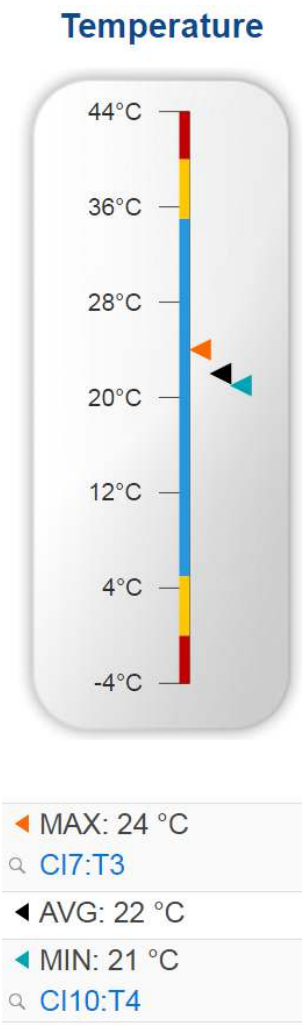
7.1.8. Temperature

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 value are shown below the gauge, along with the average cell temperature value.



7.1.9. Nuvation Energy BMS Status

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

Operation Status

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

Figure 35. 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 all warnings and faults active in the battery stack.

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

Connection State

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

Figure 36. 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.

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
Cells Balancing	70
Charge Limit	-32.266 A
Discharge Limit	132 A

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

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

Last Update

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

Updated 21:42:07 4/6/2017
Error: Register read error

If a communication timeout has occurred, a notification appears beneath the `Updated` time and date. If a timeout has occurred, the information shown on the Dashboard is no longer recent.

7.2. The Details Tab

7.2.1. Overview

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.

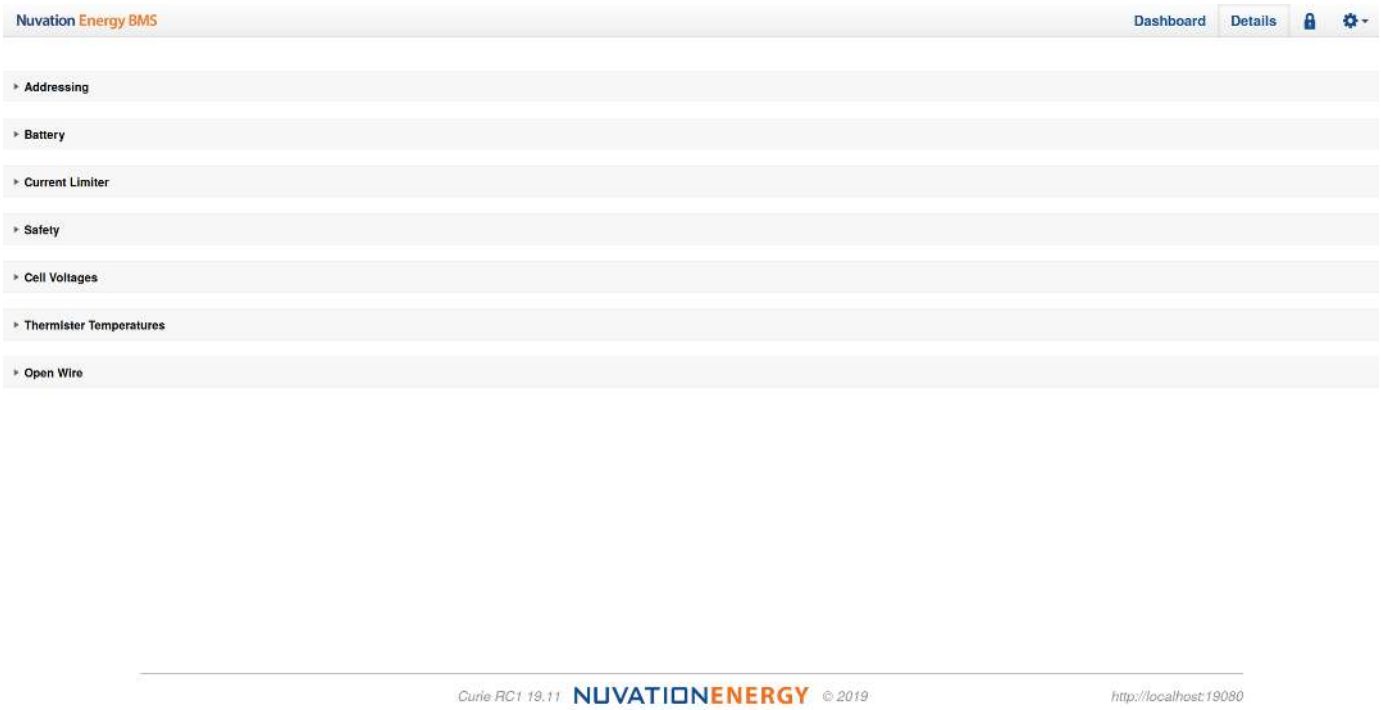


Figure 37. Nuvation Energy BMS Operator Interface Details tab screenshot

7.2.2. Addressing

The Addressing accordion presents the addressing information for your Nuvation Energy BMS. Refer to Appendix B for details on how to change your Nuvation Energy BMS IP address.

Figure 38. Addressing accordion in Details Tab

7.2.3. 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.

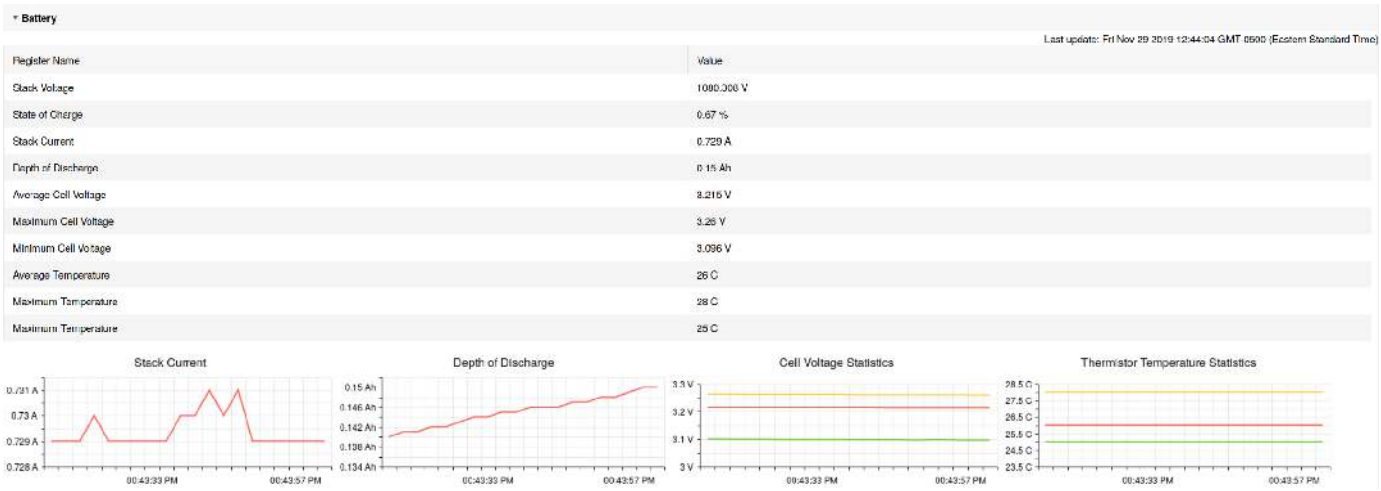


Figure 39. Battery accordion in Details Tab

7.2.4. Current Limiter

The Current Limiter accordion contains the maximum charge current limit, 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. The unit of the current limit values is mA.

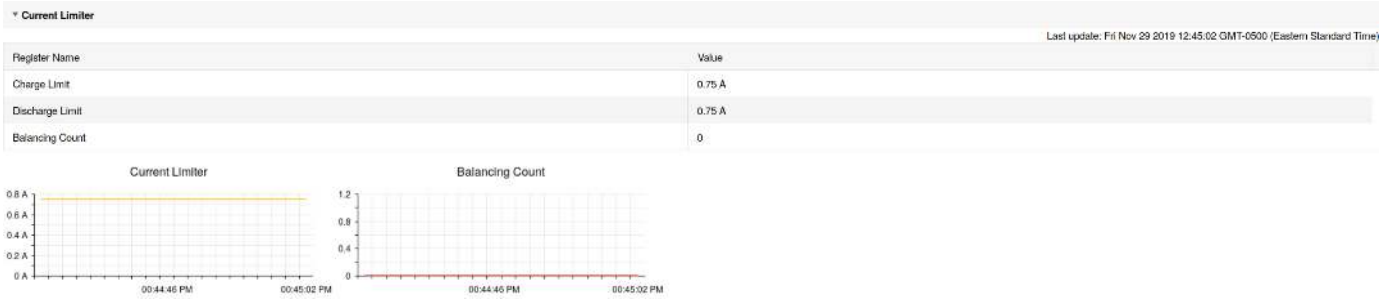
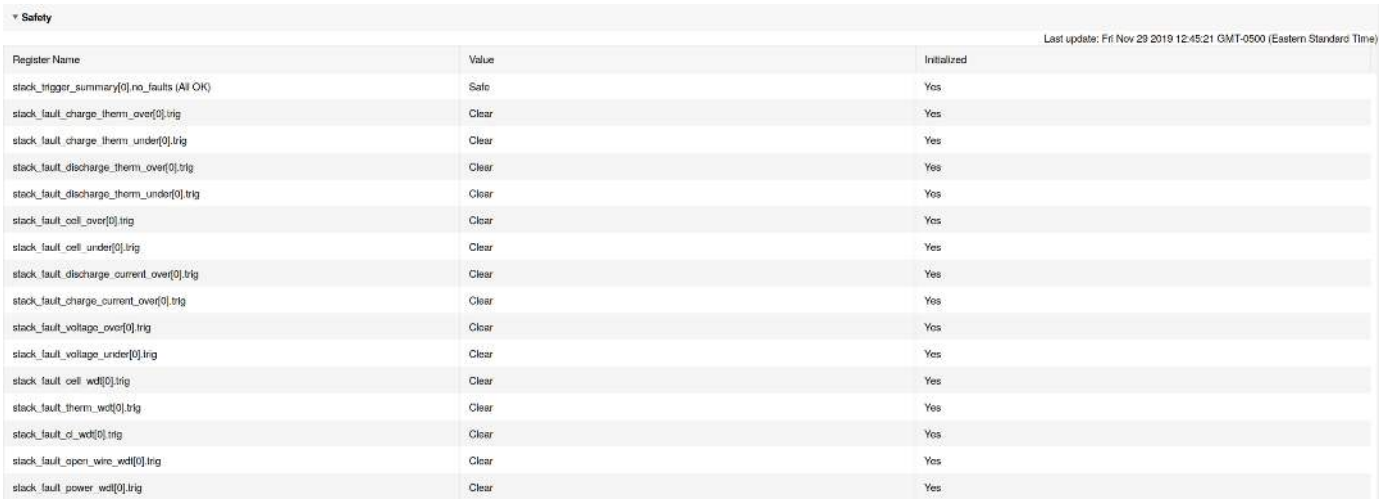


Figure 40. Current Limiter accordion in Details Tab

7.2.5. 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.



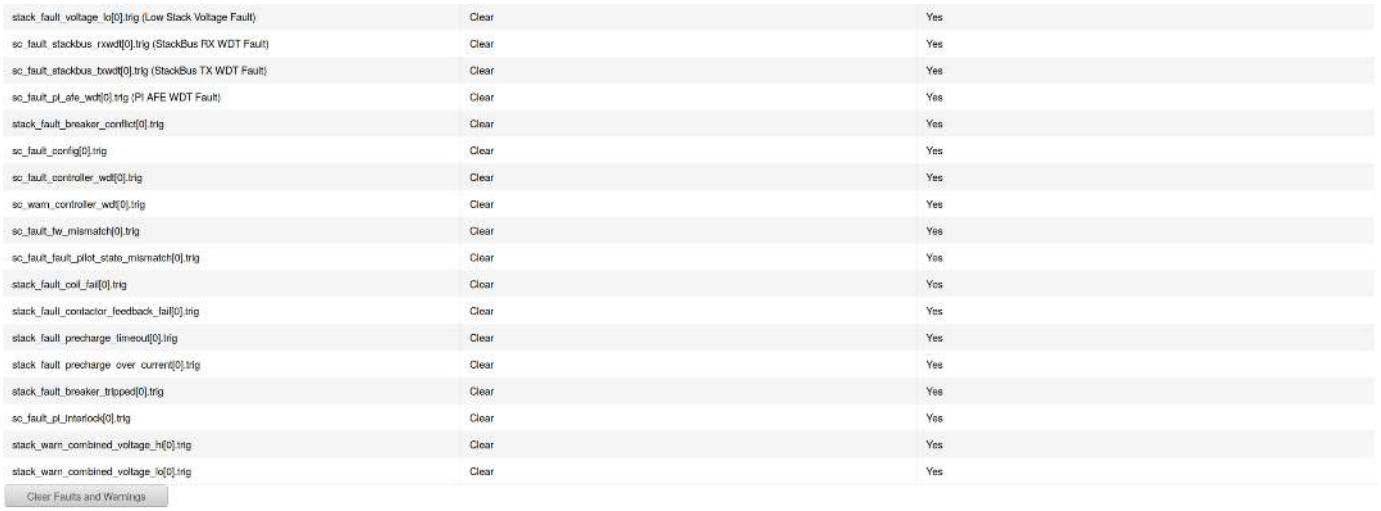
Safety

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_ci_wdt[0].trig	Clear	Yes
stack_fault_open_wire_wdt[0].trig	Clear	Yes
stack_fault_power_wdt[0].trig	Clear	Yes

Figure 41. Safety accordion in Details Tab

Clicking on the `Clear Faults and Warnings` button at the bottom of this accordion will clear any faults that are not self-clearing. It will not clear any warnings that are not self-clearing; the `Clear` button on the Dashboard must be used to clear warnings that are not self-clearing. When faults are `Tripped`, refer to the Troubleshooting sections of the *Software Reference Manual* document.



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_pi_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_pi_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 42. Bottom of Safety accordion in Details Tab

7.2.6. Cell Voltages

The Cell Voltages accordion lists all installed cell voltage measurements. Cells that are not installed 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.

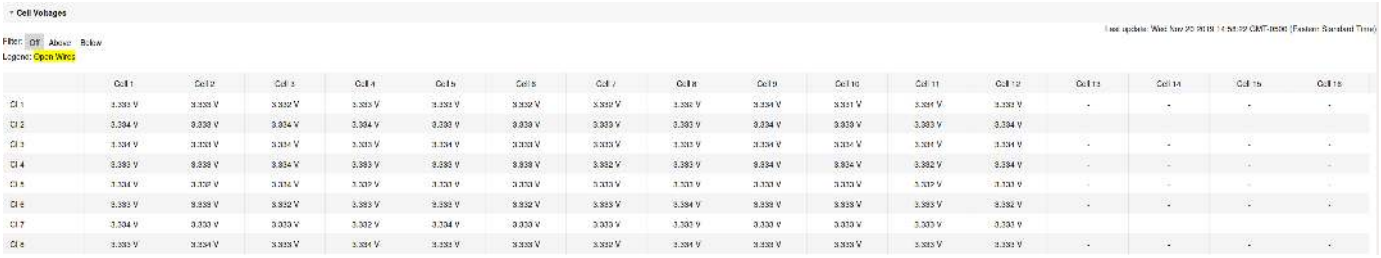


Figure 43. Cell Voltages accordion in Details Tab

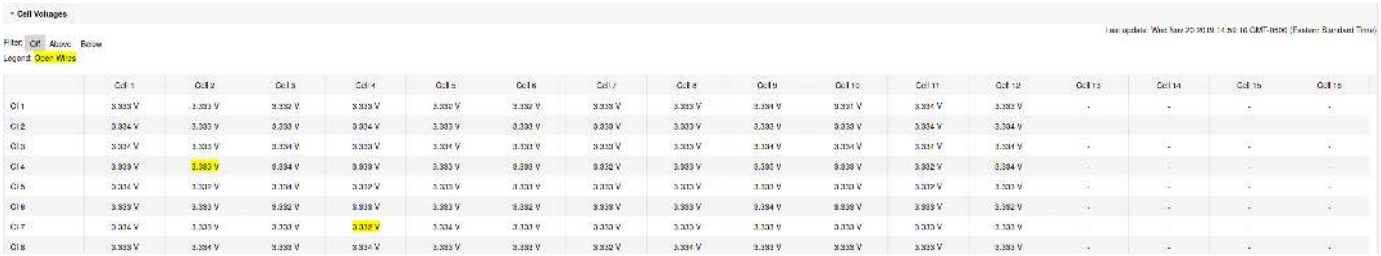
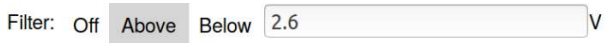


Figure 44. Cell Voltages with open wires accordion in Details Tab

Filtering

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



7.2.7. Thermistor Temperatures

The Thermistor Temperatures accordion lists all installed thermistor temperature measurements. Thermistors that are not installed 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.

▼ **Thermister 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 45. Thermistor accordion in Details Tab

Filtering

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

7.2.8. Open Wire

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

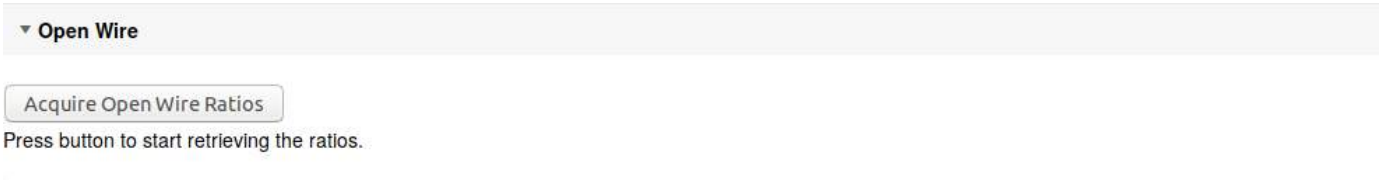


Figure 46. Open Wire accordion in Details Tab

To collect diagnostics for all cells this is triggered manually by clicking the "Acquire Open Wire Ratios". Once this is clicked the process for scanning the open wires and collecting the data begins.

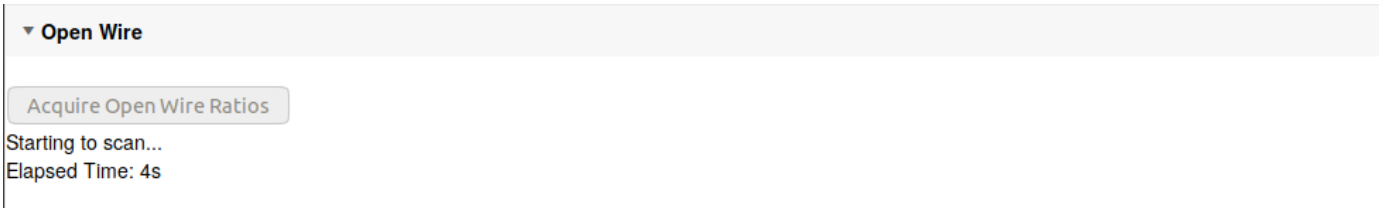


Figure 47. Open Wire aquiring accordion in Details Tab

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.

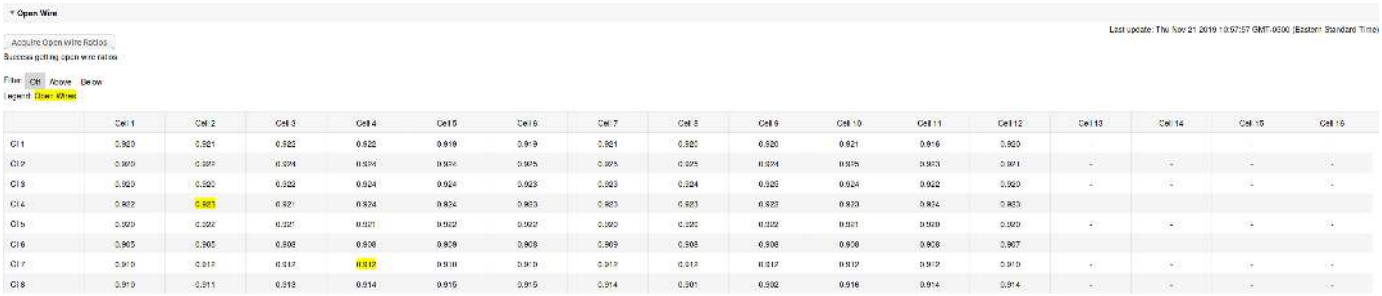


Figure 48. Open Wire diagnostics accordion in Details Tab

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. See the Software Reference Manual: Single-Stack for further details on the difference between monobloc open wire detection and the other modules.

Filtering

You can filter the display to ratios with values above or below a value you specify.

7.3. The Menu Options

7.3.1. Overview

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.

7.3.2. Registers

This screen allows you to change registers and customize your Nuvation Energy BMS to your needs. Please refer to the *Software Reference Manual* for more details on what the registers do.

7.3.3. Service

This screen allows you to enter and exit Service Lockout in-order to perform an upgrade or configuration file import. For more details refer to Understanding the Service Lockout.

Importing a Configuration File

This menu option allows you to import a configuration file.

If you have a configuration file ready to import, refer to Import the Configuration File for instructions.

If you need to generate a configuration file, refer to Generate a Configuration File for instructions. For instructions on how to modify the configuration file or understand the various registers, please refer to the *Software Reference Manual* for your Nuvation Energy BMS.

Exporting a Configuration File

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

To export your configuration file:

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

Upgrade

Refer to Upgrade your Nuvation Energy BMS above for instructions.

The firmware upgrade will erase the configuration file on your Nuvation Energy BMS. Please remember to export and save your current configuration file to import after the upgrade is complete.

7.3.4. Connection

The connection screen allows you to change the IP address of Nuvation Energy BMS you are trying to

access.

If you are connecting to a Stack Switchgear 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

7.3.5. Locking and Unlocking

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

Figure 49. Operator Interface Lock indicator

Figure 50. Operator Interface Unlock indicator

Lock the Operator Interface

To lock the Operator Interface 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, please refer to the *Software Reference Manual* for details on how to enable this functionality.

7.3.6. Unlock the Operator Interface

To Unlock the Operator Interface bring up the settings menu and select `Unlock`

7.3.7. About

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

In the screenshot below, the release name is Ampere. 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.

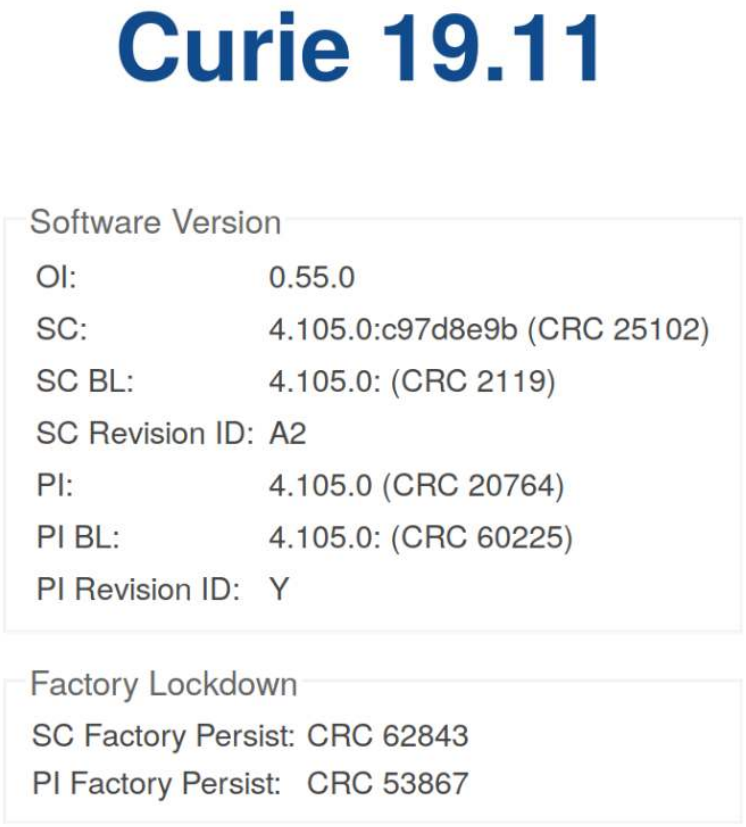


Figure 51. Sample About screen

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.

7.4. The Status Banner

7.4.1. Overview

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.

Service Lockout Indication

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

Figure 52. Operator Interface Service Lockout indicator

Figure 53. Operator Interface Exiting Service Lockout indicator

Figure 54. Operator Interface Entering Service Lockout indicator

Communication Loss

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

Figure 55. Operator Interface Communication lost indicator

7.5. Understanding the Service Lockout

7.5.1. Overview

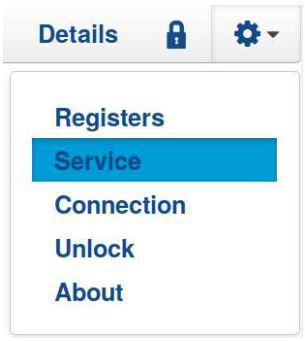
Service Lockout allows you to put your Nuvation Energy BMS into a Lockout state while you perform maintenance on your energy storage installation such as loading new configurations, or upgrading the firmware.

If you are making physical wiring changes, you should enter Service Lockout before powering down Nuvation Energy BMS.

When in Service Lockout, Nuvation Energy BMS will flag all faults and notify other Operator Interfaces.

7.5.2. Entering Service Lockout

1. Unlock the Operator Interface by clicking the menu and `Unlock`
2. From the menu, select `Service` to bring up the Service page



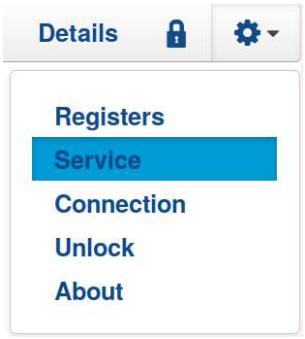
3. Click `Lockout` to enter Service Lockout

Entering Service Lockout will open all contactors and GPOs

When in Service Lockout, you will not be able to access the Operator Interface dashboard.

7.5.3. Exiting Service Lockout

1. Unlock the Operator Interface by clicking the menu and `Unlock`



2. From the menu, select `Service` to bring up the Service page
3. Exit the Service Lockout by clicking `Exit Service Lockout`

> Exiting Service Lockout may close contactors

You will be able to access the dashboard controls once Nuvation Energy BMS has successfully exited service lockout.

7.5.4. Stealing a Lock

The Operator Interface that puts Nuvation Energy BMS into Service Lockout, *owns* the lock. Only the Operator Interface that *owns* the lock, can take Nuvation Energy BMS out of Service Lockout.

If for some reason another Operator Interface needs to *take ownership* of the lock, it can use the `Steal Lock` option and *take ownership* of the lock on Nuvation Energy BMS it is connected to.

> Steal Lockout will take control away from the operator that owns this lockout

7.5.5. Shutdown Timer for Battery Controller

To protect your batteries, a Low-Voltage Battery Controller will automatically shutdown after an hour of being in Service Lockout.

The Nuvation Energy High-Voltage BMS doesn't use a shutdown timer when in service lockout.

7.5.6. Troubleshooting

If Nuvation Energy BMS fails to exit service lockout you will receive an error notification. The reason for the failure is that some form of input to the battery management system could not be initialized. This means that the battery management system was expecting some measurement (e.g. cell voltage, current) but it never was received by the software. Because of this lack of initialization, the battery management system should not be operated and the issue(s) needs to be resolved. There are two main causes for a lack of initialization:

- Misconfiguration: The current configuration does not match the battery management system deployment.
- Incomplete setup: There is an issue in the setup of the battery management system (i.e. cables are missing)

You can identify the uninitialized parts of the battery management system by referring to the `Details > Safety` accordion section. The fault registers that failed to initialize are shown on the right side of the display. Refer to the *Software Reference Manual* to the Troubleshooting section for details on how to address the uninitialized data registers.

If you just imported a configuration file, re-import a known-good configuration file. You can download a previously generated configuration file from the nCloud (https://ncloud.nuvationenergy.com).

If the failures persist, please submit a support ticket with as much detail as possible to support@nuvationenergy.com.

8. Servicing

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.
   - This initiates the disconnection sequence.
   - Wait for the connection state to show **Stack Disconnected**.
   - Refer to the Section 7.1.9 for instructions on connecting/disconnecting a stack.
3. Put the Service Disconnect switch in the **OFF** position and insert a lock-out / tag-out.

The Stack Switchgear and its components 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.
   - Wait for the connection state to show **Connected**.
3. Using the Operator Interface, connect the stack by clicking the **Connect** button.
   - This initiates the connection sequence.
   - Refer to the Section 7.1.9 for instructions on connecting/disconnecting a stack.

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.

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

9. Transportation

It is recommended that the Stack Switchgear unit be transported in its original packaging via pallet whenever possible. When shipping with the Stack Switchgear already installed, the product is rated for SAE J2380 (random vibration) and SAE J2464 (shock).

10. Extended Warranty

The Stack Switchgear tracks usage and operating conditions throughout its lifetime.

It has a concept of *remaining life* for several of its components (e.g. fuse, contactors, relays). The health of these components decreases with time and/or with events.

The **fuse** and **pre-charge resistor**'s remaining lives are calculated by taking a baseline number (TBD) and continuously substracting an amount dependent on current through them. The life of these components decreases more rapidly at higher currents.

$$\mathrm{life}_{\mathrm{fuse}}(t) = \mathrm{life}_{\mathrm{fuse}}(t=0) - k\int_{t=0}^{t} \mathrm{f}(\mathrm{i}(t_n))\,\mathrm{d}t$$

$$\mathrm{life}_{\mathrm{precharge\_resistor}}(t) = \mathrm{life}_{\mathrm{precharge\_resistor}}(t=0) - k\int_{t=0}^{t} \mathrm{f}(\mathrm{i}(t_n))\,\mathrm{d}t$$

The **contactor**'s remaining life is calculated by taking a baseline number (TBD) and substracting the an amount (dependent on switching voltage and current) at every switching event. The impact of switching under load is significantly higher than at no load.

$$\mathrm{life}_{\mathrm{contactor}}(t) = \mathrm{life}_{\mathrm{contactor}}(t=0) - k\sum_{n|(0<t_n\leq t)} \mathrm{f}(\mathrm{v}(t_n),\mathrm{i}(t_n))$$

The **safety relay**, **fan relay**, and **service disconnect switch**'s remaining lives are calculated by taking a baseline number (TBD) and substracting the an amount at every switching event.

$$\mathrm{life}_{\mathrm{safety\_relay}}(t) = \mathrm{life}_{\mathrm{safety\_relay}}(t=0) - k\sum_{n|(0<t_n\leq t)} 1$$

$$\mathrm{life}_{\mathrm{service\_disconnect}}(t) = \mathrm{life}_{\mathrm{service\_disconnect}}(t=0) - k\sum_{n|(0<t_n\leq t)} 1$$

$$\mathrm{life}_{\mathrm{fan\_relay}}(t) = \mathrm{life}_{\mathrm{fan\_relay}}(t=0) - k\sum_{n|(0<t_n\leq t)} 1$$

In the event of a warranty claim, the remaining life of each component is queried. If the damage is found to be related to a component that has been put under excessive stress (for example, a contactor that's been repeatedly switched under load), the warranty may be voided.

The Stack Switchgear is not designed to be opened and serviced in the field. Opening the Stack Switchgear voids its warranty.

Contact support@nuvationenergy.com to get a damaged Stack Switchgear unit repaired. Fees may apply for repairs that are outside of the warranty.

Appendix A: Stack Switchgear Operating Limits

This section outlines the operating limits of the Stack Switchgear.

Exceeding the ratings may damage the system.

External Specifications

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{input}	Stack Switchgear Input Supply AC Voltage	60 Hz	85	-	250	V AC
I_{input}	Stack Switchgear Input Supply AC Current	60 Hz	0.6	1.1	1.3	A AC
P_{input}	Stack Switchgear Input Supply AC Power	-	-	33.7	60	W
f_{input}	Stack Switchgear Input Supply AC Frequency	-	45	50/60	65	Hz
V_{fan_AC}	Cooling Fan AC Voltage	-	-	-	250	V AC
V_{fan_DC}	Cooling Fan DC Voltage	-	-	-	50	V DC
I_{fan}	Cooling Fan Current	-	-	-	5	A DC/AC
$V_{E\text{-}Stop}$	E-Stop Input Voltage Rating	-	19.2	24	28.8	V DC
$I_{E\text{-}Stop}$	E-Stop Input Current Rating	-	-	-	9.6	mA DC

Electrical Characteristics

Symbol	Parameter	Min	Typ	Max	Units
	Stack Switchgear Configuration: 1250 V DC, XXX A*				
V_{stack_ov}	Stack Over-Voltage Threshold (contactors open)	0	Configurable	1250	V DC
V_{stack_uv}	Stack Under-Voltage Threshold (contactors open)	0	Configurable	-	V DC
$I_{discharge\_oc}$	Stack Discharging Over-Current (contactors open)	0	Configurable	XXX	A DC
I_{charge_oc}	Stack Charging Over-Current (contactors open)	0	Configurable	XXX	A DC
	Battery Cell Specifications				
C_{ov}	Cell Over-Voltage Threshold (contactors open)	-	Configurable	-	V
C_{uv}	Cell Under-Voltage Threshold (contactors open)	-	Configurable	-	V
	Temperature Sensors Specifications				
T_{ut}	Under-Temperature Threshold (contactors open)	-	Configurable	-	°C
T_{ot}	Over-Temperature Threshold (contactors open)	-	Configurable	-	°C
T_{fan_en}	Fan Enable Temperature Threshold	-	Configurable	-	°C

* The current configurations available are as follows:

- 100 A
- 200 A
- 300 A

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	-	65	%
	Storage Relative Humidity	5	-	65	%

Appendix B: Changing the Nuvation Energy BMS Network Configuration

BMS Network Configuration

Overview

Nuvation Energy BMS is flexible and allows changing its network configuration if you need the IP address of Nuvation Energy BMS to match your existing network settings.

> Improperly modifying the network settings can result in a Nuvation Energy BMS that cannot communicate over Ethernet.
>
> Be sure to record the updated IP address, netmask, and gateway settings if you decide to make changes to these settings.

Modifying the Network Settings

1. Unlock the Operator Interface by clicking the menu and `Unlock`
2. From the menu, select `Registers` to bring up the register browser page
3. Under the `Manual Register Configuration` panel, expand the row for Component Name `sc_ethernet`. The `sc_ethernet` component contains network settings like IP address, gateway, etc.

> Use the find feature (`Ctrl + F`) in your browser to locate components in the page

sc_ethernet | Ethernet Parameters | 0x31500 | 1

Register Offset	Register Name	Description	Type	Units	Storage	
0x0	use_dhcp	Flag indicating if DHCP is used	Boolean	Flag	Configuration	Edit
0x1	ip_address	IP address to be used in static configuration	IpAddress	IP	Configuration	Edit
0x2	net_mask	Network mask to be used in static configuration	IpAddress	IP	Configuration	Edit
0x3	gateway	Gateway address to be used in static configuration	IpAddress	IP	Configuration	Edit
0x4	mac	MAC address of this board	UInt64	Value	Manufacturing	Edit

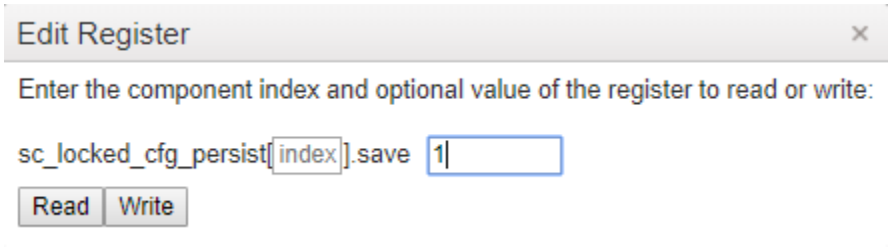
4. Click the `Edit` button on the register you need to modify to meet your desired network configuration. This will bring up the `Edit Register` dialog box
5. Enter the desired value for the register. Then click `Write`

> The index field may be left blank for all operations.

6. Confirm that the value has been updated by clicking `Read`
7. Under the `Manual Register Configuration` panel, expand the row for component name

`sc_locked_cfg_persist`.

8. Click the `Edit` button for the `save` register and write a value of `1`



9. Verify that the configuration has been saved correctly by reading the error register. The value will be `0` if no errors have occurred.

The network settings have been updated. Any changes will take effect when Nuvation Energy BMS is rebooted.

Appendix C: Nuvation Energy BMS: Best Practices

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

Grounding

It is assumed that Stack Switchgear will be attached electrically to an earth or local chassis ground point, via its grounding provision. Similarly, it is also assumed that the Cell Interface modules will be attached electrically to an earth or local chassis ground point, via the DIN rail grounding provision (#8-32 , ¼" Hex-head drive, earth grounding screw), and the mounting brackets on Nuvation Energy BMS component enclosures.

Voltages and signals on the Link Bus cables are chassis/earth ground referenced.

All connections to the battery stack are isolated from chassis ground. This includes:

- The Current Shunt and Stack Power connections on the Stack Switchgear unit's internal Power Interface
- The Battery Cells and Temperature Sensors connections on the Cell Interface
- The Ethernet and CAN interfaces on the Stack Switchgear unit's internal Stack Controller

It is acceptable, as may be required in some cases, for the battery stack to be ground-referenced at some single point. However, when the Stack Switchgear option for external 24 V DC (no internal AC to DC converter) is selected, the power supply connected to the Stack Switchgear unit's internal power must be isolated from earth/chassis ground, with a working isolation voltage of at least 60 V RMS.

Protective earthing conductors must be attached to each DIN enclosure at the designated ground screw location on the Cell Interface modules' DIN clips. Furthermore, the DIN rail itself should be connected to earth ground. 14 AWG wire with a jacket color appropriate for indicating it is a protective earthing conductor must be used.

An example of this grounding scheme is shown below:

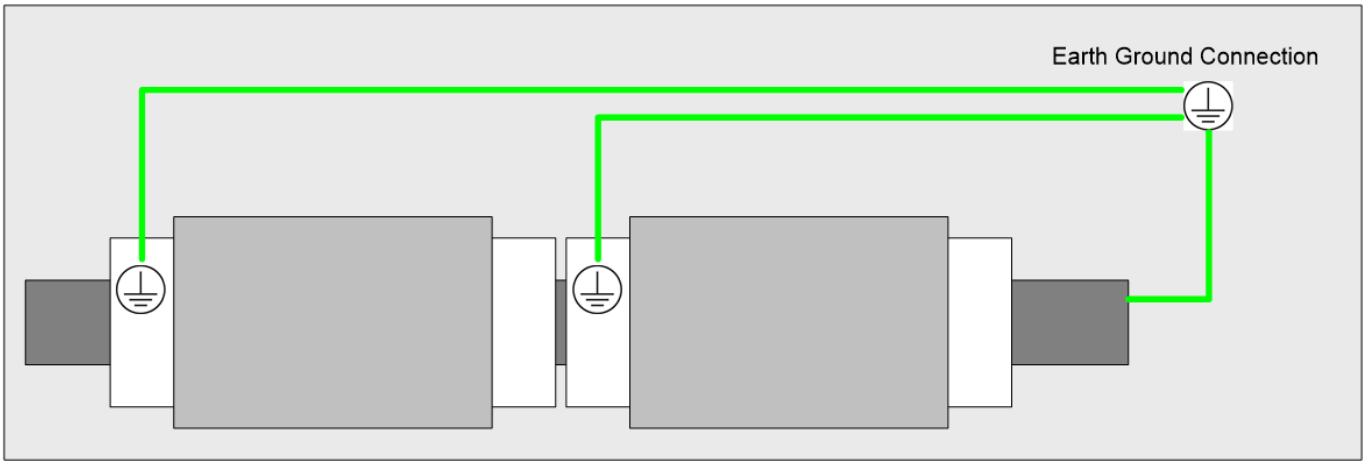


Figure 56. Example Earth Ground Wiring Diagram

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.

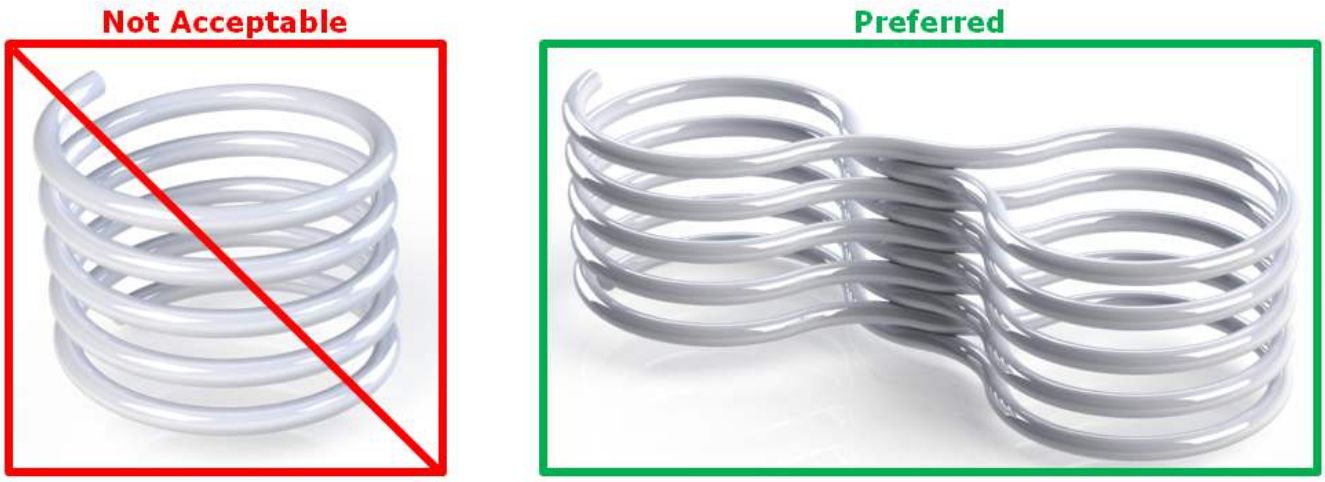


Figure 57. Excess Cable Management Examples

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 a 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 Nuvation Energy 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:

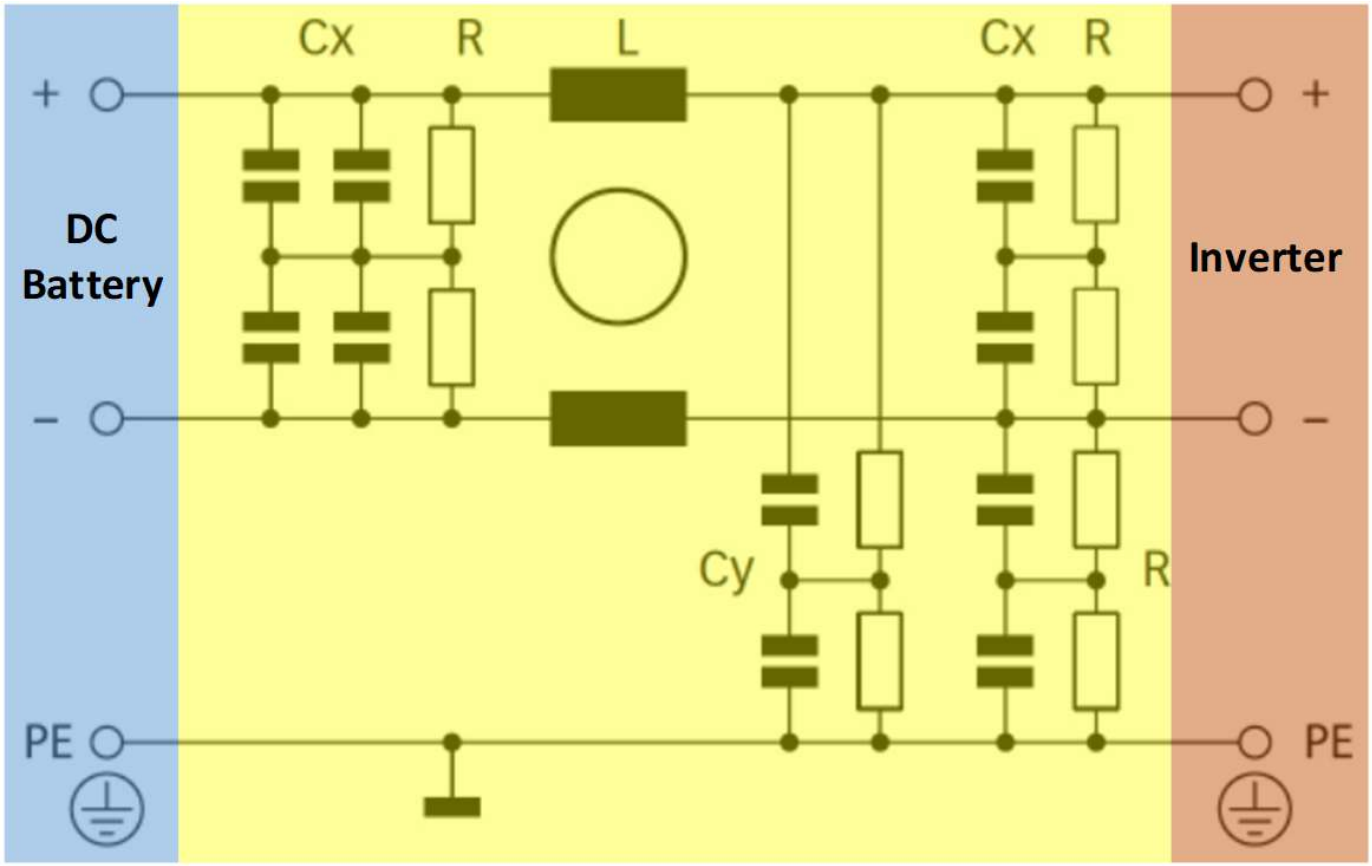


Figure 58. Example DC Filter Schematic

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.

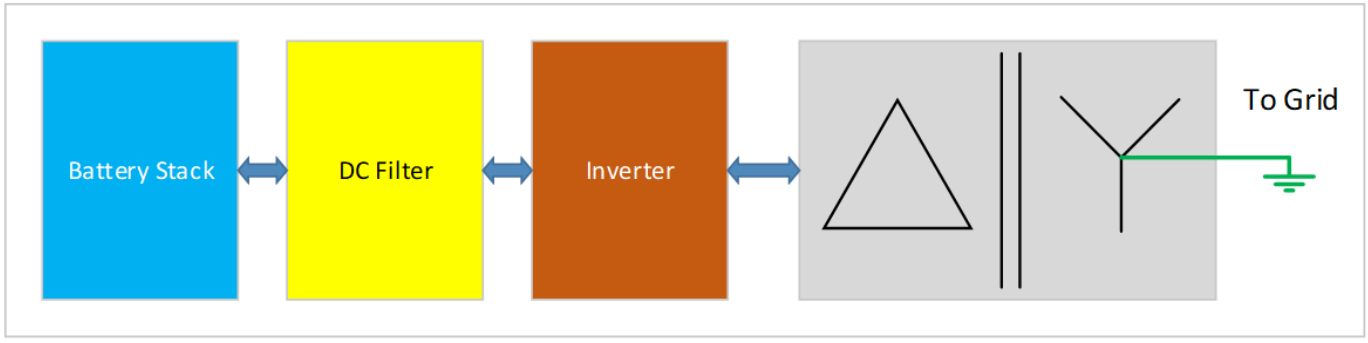


Figure 59. Example Isolation Transformer Installation Diagram

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. The Link Bus connector on the Stack Switchgear, along with Link Out and Link In connectors on the Cell Interface modules must have pins 1 and 2 unpopulated. Also, the High-Voltage BMS must be configured to disable power to the Link Bus, by setting this register to 0:

```
sc_linkbus.power_mode = 0
```

From time to time Nuvation Energy will make updates to Nuvation Energy BMS 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.