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Nuvation Energy G5 High-Voltage BMS

NUVG5 Datasheet

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1. Product Overview

The Nuvation Energy G5 High-Voltage BMS provides cell-level and stack-level control for battery stacks up to 1500 VDC and modules that use cells in the 1.6 V - 4.3 V range. The G5 Stack Switchgear and G5 Cell Interface modules operate together as a complete system called the G5 High-Voltage BMS.

Figure 1. G5 High-Voltage BMS.

Both Nuvation Energy G5 Stack Switchgear and G5 Cell Interface are designed to enable UL 1973 certification of the battery stack. The UL 1973 Recognized Nuvation Energy BMS in each stack ensures safe battery operation and significantly reduces the effort of certifying the Energy Storage System to meet UL 1973 and UL 9540.

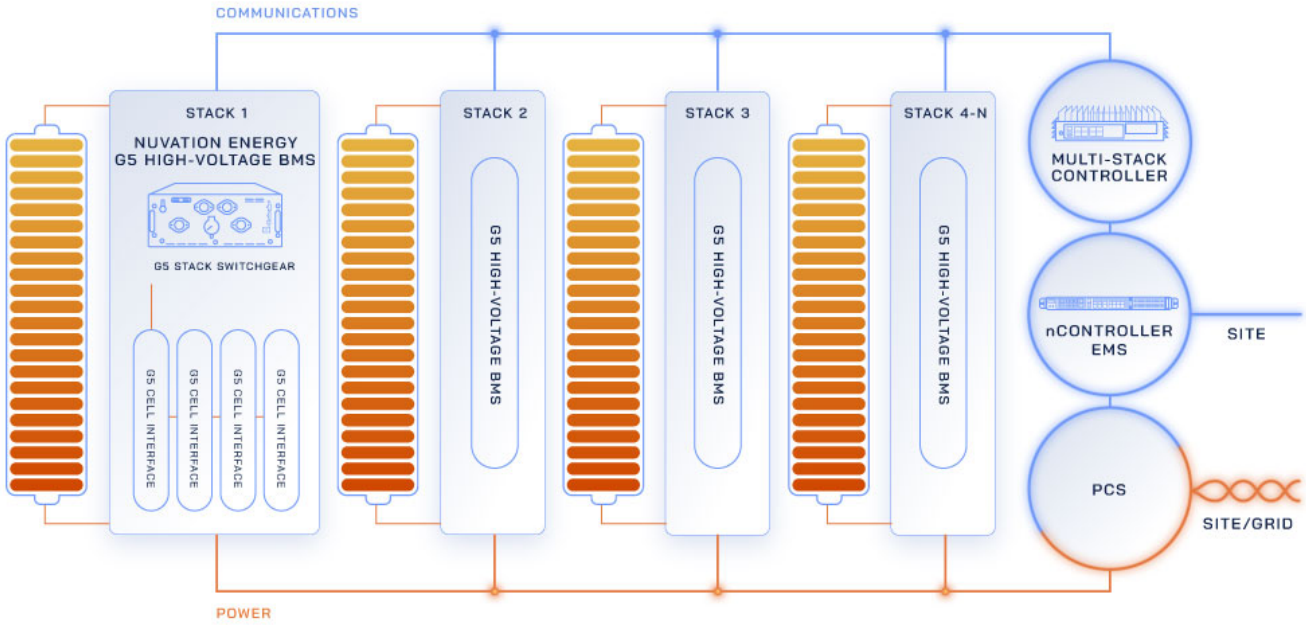

Figure 2. Sample ESS Application

Single Stack

Typically, a single battery stack requires one G5 Stack Switchgear and one or more G5 Cell Interface modules.

The Nuvation Energy G5 Stack Switchgear unit manages a single battery stack and connects it to

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

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

Multi-stack

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

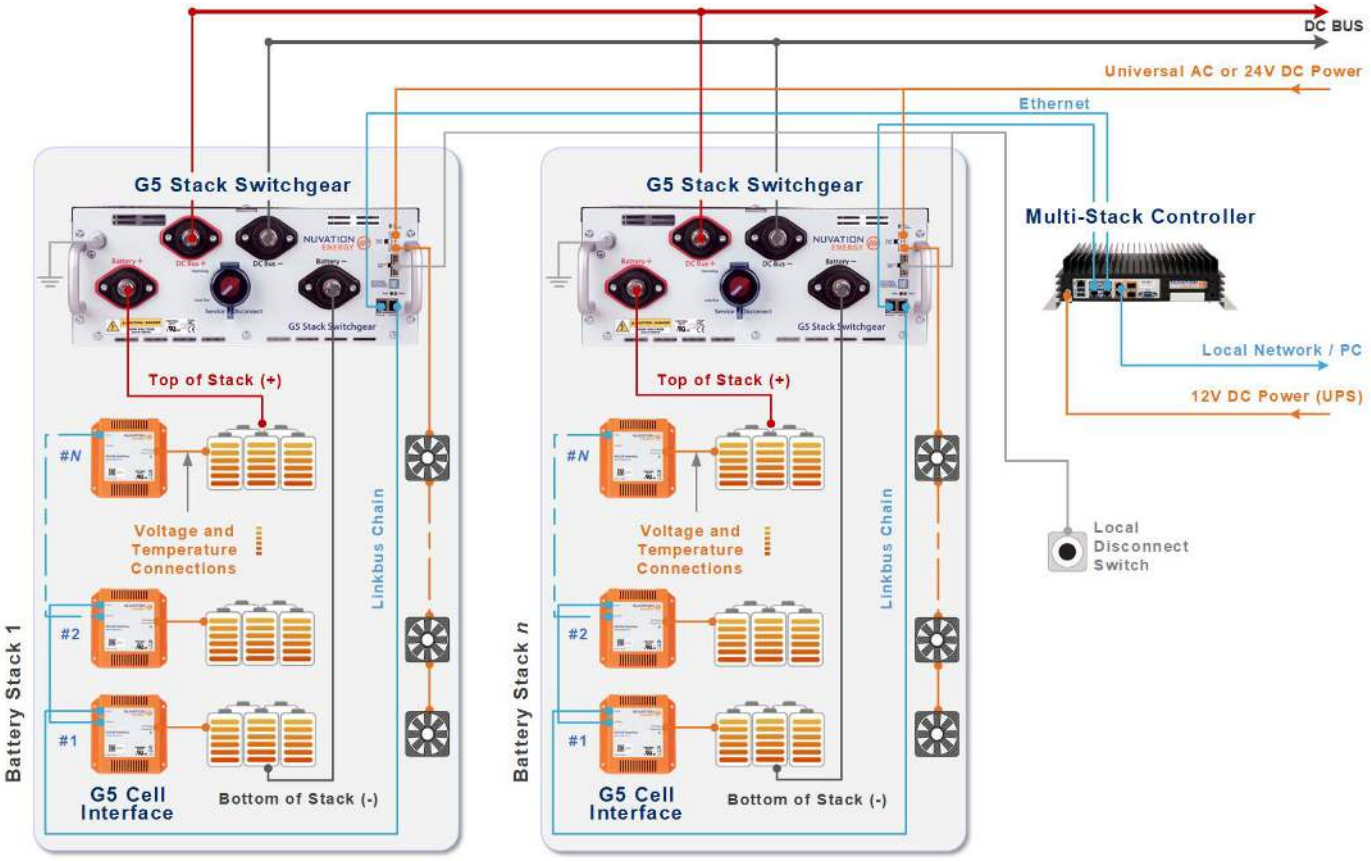

Figure 3. G5 High-Voltage BMS multi-stack diagram

1.1. Functional Overview

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

Monitor DC Bus and Stack Voltages

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

Configurable for Different Battery Chemistries

- **G5 Cell Interface (24 channel)** is capable of measuring cells which vary in voltage between 1.6 and 4.3 volts. This range of voltage can support many lithium and lead-acid cell chemistries. A maximum of 480 cells can be measured by using a maximum of 20 G5 Cell Interface modules connected to one G5 Stack Switchgear.

Configurable Safe Limits of a Stack

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

User Configurable Operational Range

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

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

GPI/GPO Interfaces

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

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

Internal Temperature Monitoring

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

reduces passive balancing at high temperatures.

Dedicated Enable, Shutdown, and Disconnect inputs

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

External Fan Control

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

Cell Open Wire Detection and Diagnostics

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

- Open circuits
- Short circuits
- High impedance connections/wiring
- Internal BMS hardware failures

SunSpec Modbus TCP with Configurable Points

The G5 Stack Switchgear provides SunSpec Energy Storage Models (Draft 3) 801/802/803 data models over its Modbus TCP port. Furthermore, the device can be configured to map internal data registers to a reserved set of Modbus points. This functionality allows internal data that is not within SunSpec data models to be accessed over Modbus TCP.

Continuous Balancing

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

Pre-Charge Circuit

The G5 Stack Switchgear has a pre-charge circuit to ensure safe connection of its battery stack to the DC bus. The pre-charge circuit temporarily connects the stack to the DC bus through a power resistor. This resistor allows a smaller current (proportional to the difference in voltage between the stack and the DC bus) to flow between the stack and the DC bus. The pre-charge process successfully ends once the measured voltage difference between the battery stack and the DC bus falls below the defined safe threshold. This ensures the battery stack will not connect to the DC bus when an unsafe voltage mismatch is present. The G5 Stack Switchgear includes a 150 Ω, 210 W power resistor, suitable for a DC bus capacitance up to 8.5 mF at 1500 V DC.

1.2. G5 Stack Switchgear

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

- G5 Stack Switchgear, 1500 V, 200 A
- G5 Stack Switchgear, 1500 V, 300 A
- G5 Stack Switchgear, 1500 V, 350 A

Within a battery stack, the G5 Stack Switchgear connects to the daisy-chained Nuvation Energy G5 Cell Interface modules. The G5 Cell Interface modules convert cell voltage and temperature measurements to digital values to be relayed to the G5 Stack Switchgear, and enable or disable cell balancing as required. Daisy-chaining the G5 Cell Interface modules facilitates the design of flexible and scalable Battery Energy Storage Systems.

Figure 4. Nuvation Energy G5 Stack Switchgear

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

The external interfaces to this unit are:

- Battery Stack and DC Bus connectors
- Service Disconnect Switch
- 10/100 Base-T Ethernet RJ45 jack (Modbus-TCP)
- Link Bus RJ45 connector
- Fan control input and output
- Power In
- Power LED and Fault LED
- Earth bonding connection (grounding stud)
- Enable, Shutdown, and Disconnect inputs
- General Purpose Inputs, and General Purpose Outputs
- Network Reset and Factory Restore

- Under Voltage Lockout (UVLO) Enable Config Switch
- AC Fan Circuit Breaker

The internal high-current path of G5 Stack Switchgear is shown in the block diagram below:

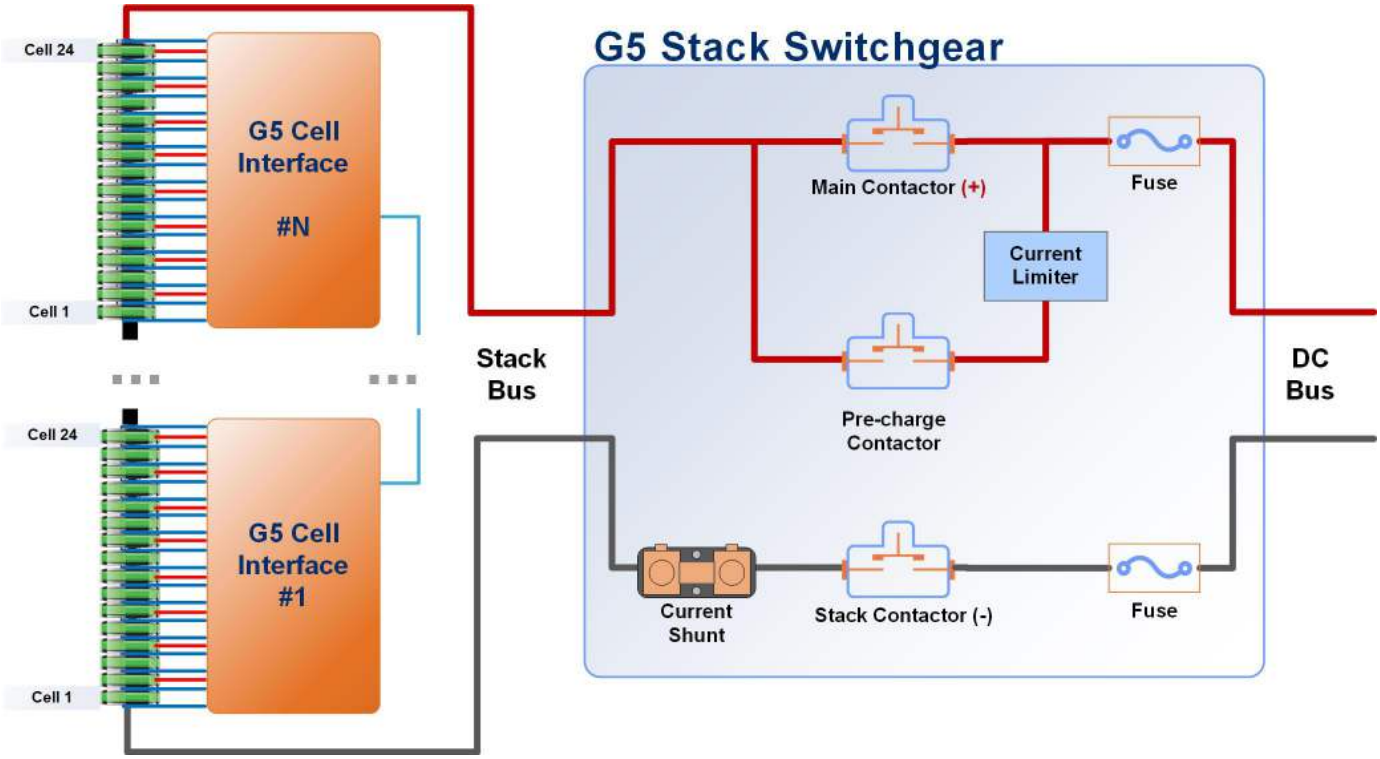

Figure 5. G5 High-Voltage BMS internal high-current path.

1.3. G5 Cell Interface

The Nuvation Energy G5 Cell Interface is the direct link between the individual battery stack cells and the rest of the Battery Management System. It facilitates battery monitoring and balancing functionalities.

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

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

Figure 6. G5 Cell Interface (24 channel)

The external interfaces to this module are:

- Cell Voltage and Temperature Sensors connector
- 2 Linkbus RJ45 connectors for 'Link In' and 'Link Out'

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

1.4. G5 BMS Software

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

1.4.1. Operator Interface

Figure 7. Operator Interface Dashboard

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

Key Features

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

1.4.2. G5 BMS Firmware

The G5 BMS Firmware is a highly configurable software that manages the stack operation and

controls. It enables the BMS to be used as a protection device against unsafe voltage, temperature, and current conditions in battery systems.

Key Features

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

2. Operating Limits

2.1. G5 Stack Switchgear

Exceeding the ratings will damage the system.

2.1.1. External Specifications

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

2.1.2. Electrical Characteristics

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

Part number format: `NUVG5-SSG-<absolute-max-voltage>-<continuous-current-rating>-<fuse-rating>` For the fuse rating, please see Table 12, “Fuse rating and code”.

2.1.2.1. Voltage and Temperature Specifications

Table 1. Voltage and Temperature Sensor Specifications for all Configurations

Symbol	Parameter	Min	Typ	Absolute Max	Units
	Battery Stack Specifications				
V_{stack_ov}	Stack Over-Voltage Threshold (triggers contactors to open)	-	*configurable*	1500	V DC
V_{stack_uv}	Stack Under-Voltage Threshold (triggers contactors to open)	-	*configurable*	-	V DC
	Battery Cells Specifications				
C_{ov}	Cell Over-Voltage Threshold (triggers contactors to open)	-	*configurable*	-	V
C_{uv}	Cell Under-Voltage Threshold (triggers contactors to open)	-	*configurable*	-	V
	Temperature Sensors Specifications				
T_{ut}	Under-Temperature Thresholds Charge/Discharge (triggers contactors to open)	-	*configurable*	-	°C
T_{ot}	Over-Temperature Thresholds Charge/Discharge (triggers contactors to open)	-	*configurable*	-	°C
T_{fan_en}	Fan Enable Temperature Thresholds Charge/Discharge	-	*configurable*	-	°C

Table 2. Overvoltage Category Specifications for all Configurations

Symbol	Parameter	Absolute Max	Units
CAT_{II}	Phase to Ground Rated System Voltage (RMS or DC)	1000	V
CAT_{III}	Phase to Ground Rated System Voltage (RMS or DC)	600	V

2.1.2.2. Continuous and Maximum Current Ratings

Table 3. Maximum Rated Current : NUVG5-SSG-1500-200-x

Symbol	Parameter	Continuous	Absolute Max	Units
$I_{discharge_oc}$	Stack Discharging Over-Current (triggers contactors to open)	200	250	A DC
I_{charge_oc}	Stack Charging Over-Current (triggers contactors to open)	200	250	A DC

Table 4. Maximum Rated Current: NUVG5-SSG-1500-300-x

Symbol	Parameter	Continuous	Absolute Max	Units
$I_{discharge_oc}$	Stack Discharging Over-Current (triggers contactors to open)	300	350	A DC
I_{charge_oc}	Stack Charging Over-Current (triggers contactors to open)	300	350	A DC

Table 5. Maximum Rated Current: NUVG5-SSG-1500-350-x

Symbol	Parameter	Continuous	Absolute Max	Units
$I_{discharge_oc}$	Stack Discharging Over-Current (triggers contactors to open)	350	400	A DC
I_{charge_oc}	Stack Charging Over-Current (triggers contactors to open)	350	400	A DC

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

2.1.2.3. Contactor Life Ratings

Table 6. Contactor Life Ratings : NUVG5-SSG-1500-200-x

Symbol	Parameter	Min	Max	Absolute Max	Units
$I_{min_breaking}$	Minimum breaking current of contactors	200	-	-	A DC
N_{min}	Number of contactor opening cycles below the minimum breaking current	6000	-	-	cycles
$I_{max_breaking}$	Maximum breaking current of contactors	-	250	-	A DC
N_{life}	Number of contactor opening cycles between the minimum and maximum breaking currents	-	50	-	cycles
N_{max}	Number of contactor opening cycles above the maximum breaking current	-	1	-	cycle
I_{max}	One time contactor maximum breaking current	-	-	1500	A DC

Table 7. Contactor Life Ratings : NUVG5-SSG-1500-300-x

Symbol	Parameter	Min	Max	Absolute Max	Units
$I_{min_breaking}$	Minimum breaking current of contactors	200	-	-	A DC
N_{min}	Number of contactor opening cycles below the minimum breaking current	6000	-	-	cycles
$I_{max_breaking}$	Maximum breaking current of contactors	-	350	-	A DC
N_{life}	Number of contactor opening cycles between the minimum and maximum breaking currents	-	50	-	cycles
N_{max}	Number of contactor opening cycles above the maximum breaking current	-	1	-	cycle
I_{max}	One time contactor maximum breaking current	-	-	1500	A DC

Table 8. Contactor Life Ratings : NUVG5-SSG-1500-350-x

Symbol	Parameter	Min	Max	Absolute Max	Units
$I_{min_breaking}$	Minimum breaking current of contactors	200	-	-	A DC
N_{min}	Number of contactor opening cycles below the minimum breaking current	6000	-	-	cycles
$I_{max_breaking}$	Maximum breaking current of contactors	-	400	-	A DC
N_{life}	Number of contactor opening cycles between the minimum and maximum breaking currents	-	10	-	cycles
N_{max}	Number of contactor opening cycles above the maximum breaking current	-	1	-	cycle
I_{max}	One time contactor maximum breaking current	-	-	1500	A DC

To extend the lifetime of the G5 Stack Switchgear a disconnect delay can be configured to allow time for the PCS controller to reduce the current flowing through the battery stack before the G5 Stack Switchgear will open contactors, which will avoid exposing the contactors to high breaking currents.

Contactors will open immediately for the following conditions which will bypass the disconnection delay:

1. Unpowering the G5 Stack Switchgear.
2. Using the Fast Disconnect feature.

2.1.2.4. Fuse Performance

The G5 Stack Switchgear includes fuses to protect the battery stack from external short-circuit failures. The response time of the fuse to the fault current depends on the type of fuse selected fpr the G5 Stack Switchgear. The variant of the G5 Stack Switchgear depends on the orderable fuse option as shown below:

Table 9. Fuse rating and code

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

The chart below shows the fuse pre-arcing time in response to a short-circuit fault (I^2T Chart):

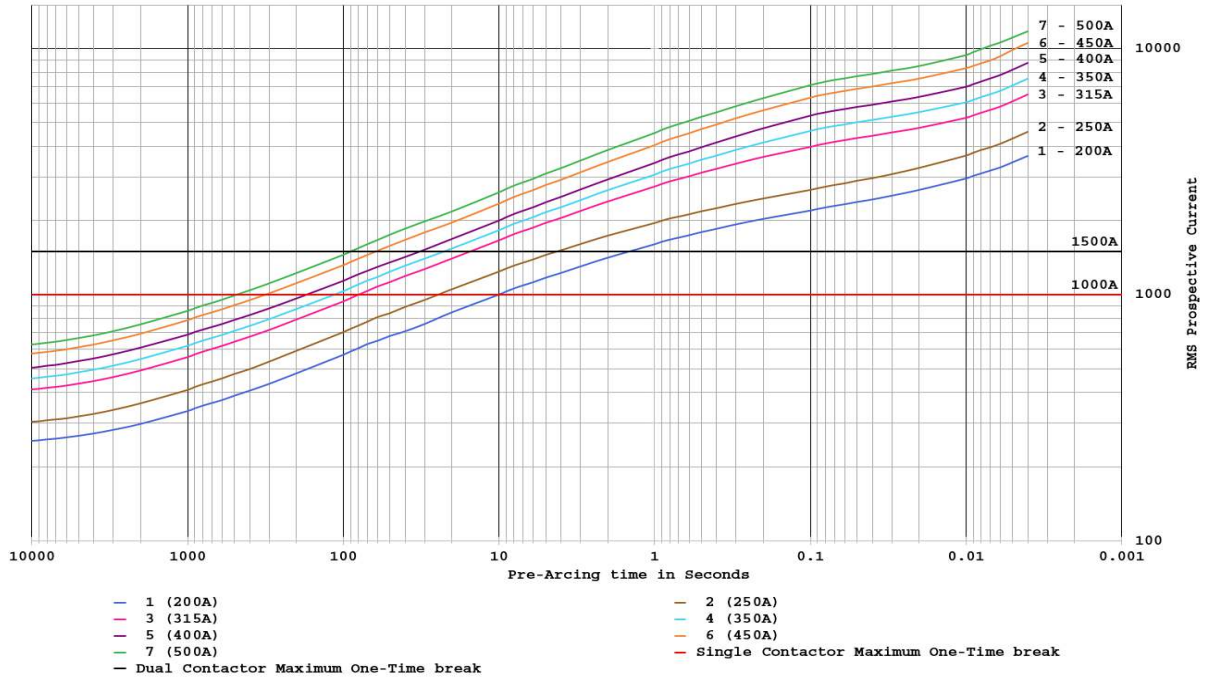

Figure 8. Fuse Response to Short Circuit Faults – Current Cut-Off Diagram

Note: The values indicated in the graph above are subject to a +/- 10% tolerance.

To obtain information on the peak let-through current performance of the fuse in question, please contact support@nuvationenergy.com. Additionally, please provide the L/R time constant of your battery stack, the estimated magnitude of potential short circuits in the system, and your chosen fuse option.

Without a single point of failure within the G5 Stack Switchgear, the contactors will collectively share the breaking current capacity, allowing them to interrupt a maximum current of 1500 A. However, in the event of a failure, each individual contactor is capable of interrupting up to 1000 A during a short circuit event.

2.1.2.5. Fuse Life Ratings

The G5 Stack Switchgear fuses have been designed to outlive the expected operational lifetime of the battery stack with no nuisance trips. Use the chart below Figure 9, "Fuse Derating Curve Chart" to confirm that the selected fuse option will not trip prematurely in the end-application.

To calculate the I_{load}/I_{tcc} for a G5 Stack Switchgear based on its application, please follow the instructions below:

- I_{load} is the maximum continuous current of the end-application.

- I_{tcc} is the pre-arching prospective current at the duration equivalent to the length of the maximum continuous current (from Figure 8, "Fuse Response to Short Circuit Faults – Current Cut-Off Diagram").

The ratio of I_{load}/I_{tcc} is used to look up the estimated number of cycles the G5 Stack Switchgear fuse will withstand before reaching its end of life. Exceeding the estimated number of cycles will increase the likelihood of the fuse opening prematurely. Number of Cycles can be estimated based on the expected number of charge/discharge cycles per year multiplied by the expected lifetime of the system.

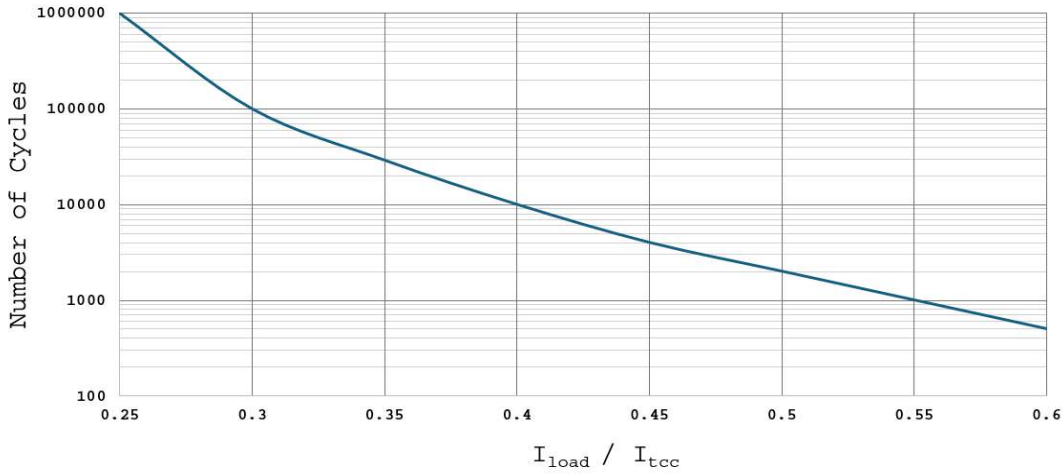

Figure 9. Fuse Derating Curve Chart

The G5 Stack Switchgear does not contain field-serviceable fuses. When its internal fuse opens, the G5 Stack Switchgear reaches its end of life. Contact support@nuvationenergy.com if you need assistance selecting the best orderable fuse option for your end-application.

2.2. G5 Cell Interface

The operating limits of each Nuvation Energy G5 Cell Interface variant is different.

The following variants are available:

- G5 Cell Interface, 24 Channel, 8 Thermistors (NUVG5-CI-24)

2.2.1. G5 Cell Interface (24 channel)

Exceeding the maximum ratings will damage the system.

2.2.1.1. Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Absolute Max	Units
		Link In Specifications				
I_{P_LINK}	Output Current	-	-	-	22	mA DC
I_{N_LINK}	Output Current	-	-	-	22	mA DC
		Link Out Specifications				
I_{P_LINK}	Output Current	-	-	-	22	mA DC
I_{N_LINK}	Output Current	-	-	-	22	mA DC
		Battery Cells Specifications				
$C_{(n)}$ - $C_{(n-1)}$	Input Cell Voltage Range	-	1.6	-	4.3	V DC
V_{sum}	Voltage between C0 and C12		11.2	-	51.6	V DC
	Voltage between C12 and C24		11.2	-	51.6	V DC
I_{Active}	Between C0 and C12	Linkbus communication, Vsum = 43.2 V DC	-	13	20	mA DC
	Between C12 and C24	Linkbus communication, Vsum = 43.2 V DC	-	9	11	mA DC
$I_{Standby}$	Between C0 and C12	No Linkbus communication, Vsum = 43.2 V DC	-	70	225	µA DC
	Between C12 and C24	No Linkbus communication, Vsum = 43.2 V DC	-	70	225	µA DC
	Between $C_{(n)}$ - $C_{(n-1)}$	No Linkbus communication, Vsum = 43.2 V DC	-	1.2	15	µA DC
TME	Total Measurement Error		±0.1	±1.6	±2.8	mV DC
$I_{(n)}$	Cell Balancing Current	$C_{(n)}$ - $C_{(n-1)}$ = 4 V DC	145	150	159	mA DC
V_{ins}	Internal reinforced insulation rating from Chassis/COM	-	-	-	1500	V DC
CAT_{II}	Overvoltage category	Phase to Ground Rated System Voltage (RMS or DC)	-	-	1000	V

Symbol	Parameter	Conditions	Min	Typ	Absolute Max	Units
CAT_{III}	Overvoltage category	Phase to Ground Rated System Voltage (RMS or DC)	-	-	600	V
		Temperature Sensors Specifications				
$I_{(n)}$	Output Current to Temperature Sensor	-	-	-	305	µA DC
$R_{t(n)}$	Temperature Sensor Resistance	External sensor at 25 °C	-	10	-	kΩ
$T_{(n)}$	Input Temperature Sensor Voltage Range	Cell 0 = 0 V DC	0	-	3.012	V DC
V_{ins}	Internal Reinforced Insulation Rating from Chassis/COM	-	-	-	1500	V DC
CAT_{II}	Overvoltage category	Phase to Ground Rated System Voltage (RMS or DC)	-	-	1000	V
CAT_{III}	Overvoltage category	Phase to Ground Rated System Voltage (RMS or DC)	-	-	600	V

2.2.1.2. Maximum Stack Deployment

G5 Cell Interface modules are deployed as a daisy chain to monitor the cells of a stack. G5 Stack Switchgear can support a maximum of 32 G5 Cell Interface (24 channel) modules.

2.2.1.2.1. Limits Due to Cell Voltage Scan Rate

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

The following are approximate cell voltage scan rates for different lengths of G5 Cell Interface (24 channel) daisy chains where all cells are installed.

Table 10. Cell Voltage Scan Rates for CI-24

CI-24 Chain Length	Scan Rate [Hz]
1	4.43
5	3.20
10	2.38
15	1.88
20	1.51
32 (max)	0.90

The temperature sensor scan rate is 12.5% of the cell voltage scan rate. For example, the temperature sensor scan rate in a chain length of 5 G5 Cell Interface (24 channel) modules is 0.40 Hz

2.3. Environmental Conditions

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

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

Symbol	Parameter	Min	Typ	Absolute Max	Units
	Thermal Specifications				
T_a	Operating Temperature	-20	25	60	°C
	Storage Temperature	-30	25	60	°C
	Humidity Specifications				
RH	Operational Relative Humidity	5	-	85	%
	Storage Relative Humidity	5	-	85	%
	Shock and Vibration Specifications				
Vertical	Vertical Random Vibration (SAE J2380)	-	-	10	m/s^2
Longitudinal	Longitudinal Random Vibration (SAE J2380)	-	-	10	m/s^2
Transverse	Transverse Random Vibration (SAE J2380)	-	-	10	m/s^2
Pulse Vibration (Shock)	On each axis (SAE J2464)	-	-	245	m/s^2
	Altitude Specifications				
A_a	Operating Altitude	-	-	2000	m

3. Certifications and Standards

3.1. UL Recognition

Recognition of the BMS for stationary battery applications and for functional safety ensures safe battery operation and significantly reduces the effort of certifying the end-product energy storage solution to meet the requirements of UL 1973 and UL 9540.

Nuvation Energy G5 High-Voltage BMS is UL Recognized for Stationary and Motive Auxiliary Battery Applications (File No. MH64071) and is evaluated to the following standards:

- UL 1973 – Batteries for Use in Stationary and Motive Aux. Power Applications
- UL/CSA/IEC 60730-1 Annex H – Functional Safety

3.1.1. Functional Safety

The Nuvation Energy G5 High-Voltage BMS has key safety features that comply with the following standard: - UL/CSA/IEC 60730-1 Annex H – Functional Safety

3.1.1.1. Functions Evaluated for Functional Safety

The following safety functions have been investigated to UL/CSA/IEC 60730-1 Annex H for functional safety:

- Cell Overvoltage
- Cell Undervoltage
- Stack Overvoltage
- Stack Undervoltage
- Charge Over-Temperature
- Discharge Over-Temperature
- Charge Under-Temperature
- Discharge Under-Temperature
- Charge Over-Current
- Discharge Over-Current
- Power Connector Over-Temperature
- Contactor Life Estimation
- Auxiliary Over-Temperature
- Auxiliary Under-Temperature

3.1.2. EMC for Functional Safety

The Nuvation Energy G5 High-Voltage BMS has been tested to the following standard:

- IEC 61000-6-7 (required for IEC 62933-5-2)

3.2. CE Compliance

Nuvation Energy declares that the Nuvation Energy G5 High-Voltage BMS conforms with CE requirements. A CE Declaration of Conformity is available upon request.

Relevant standards include:

- IEC 61000-6-2 – Immunity for Industrial Equipment
- IEC 61000-6-4 – Emissions for Industrial Equipment
- IEC 62368-1 – Safety Standards for Audio/Video, Information and Communication Technology Equipment
- RoHS and REACH compliance

4. Mechanical Overview

4.1. G5 Stack Switchgear

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

The G5 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 installations may require additional space.

The unit weighs 23.5 kg [51.8 lbs].

Please visit https://nuvationenergy.com/technical-resources to download CAD files for the G5 Stack Switchgear.

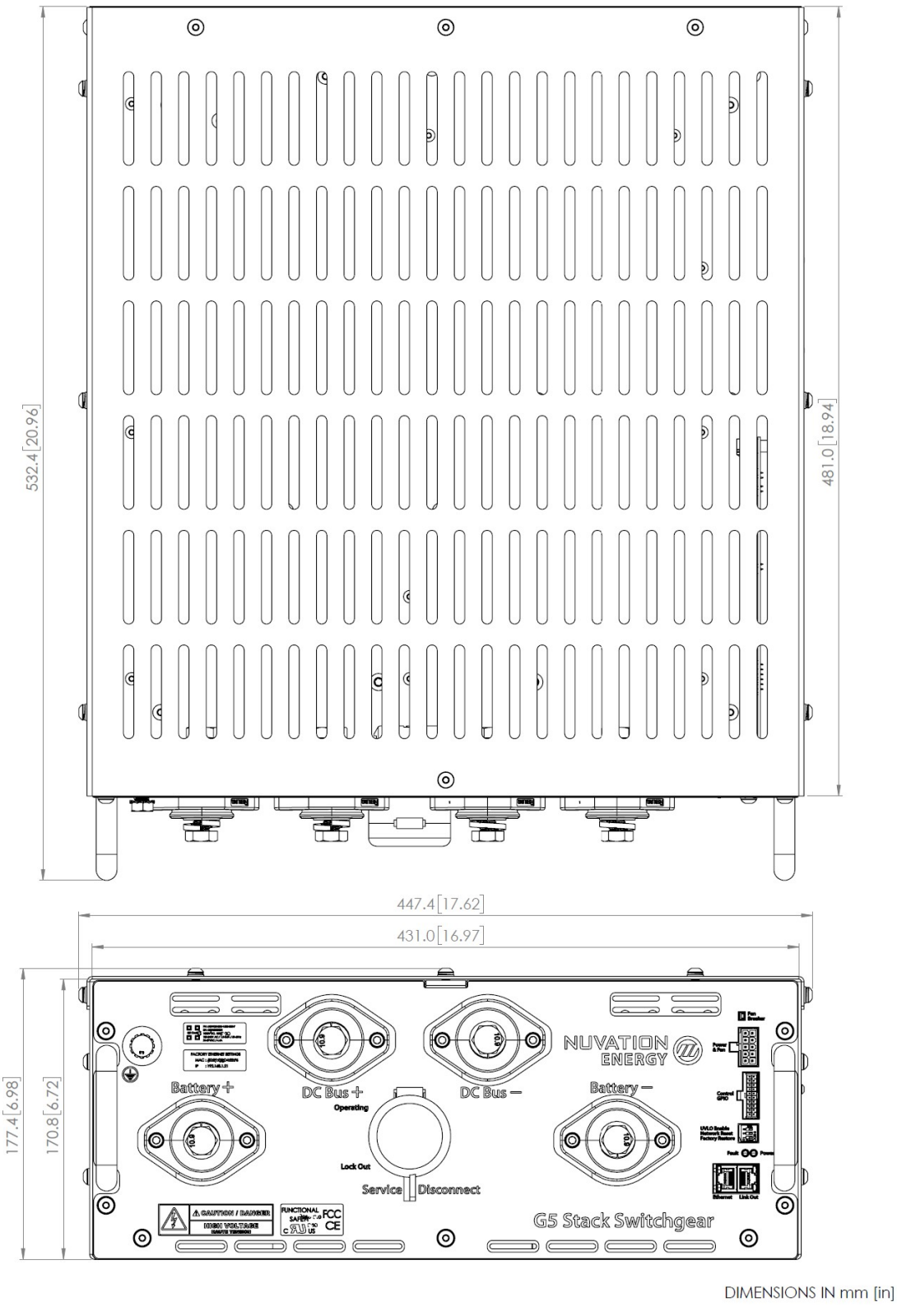

Figure 10. Mechanical Drawing of G5 Stack Switchgear

4.1.1. Mounting Brackets

4.1.1.1. Shelf-Mount Bracket

Render of G5 Stack Switchgear with brackets for shelf-mounting

Figure 11. Shelf-mount

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, note that the corresponding bracket slots have widths designed for M5 screws.

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

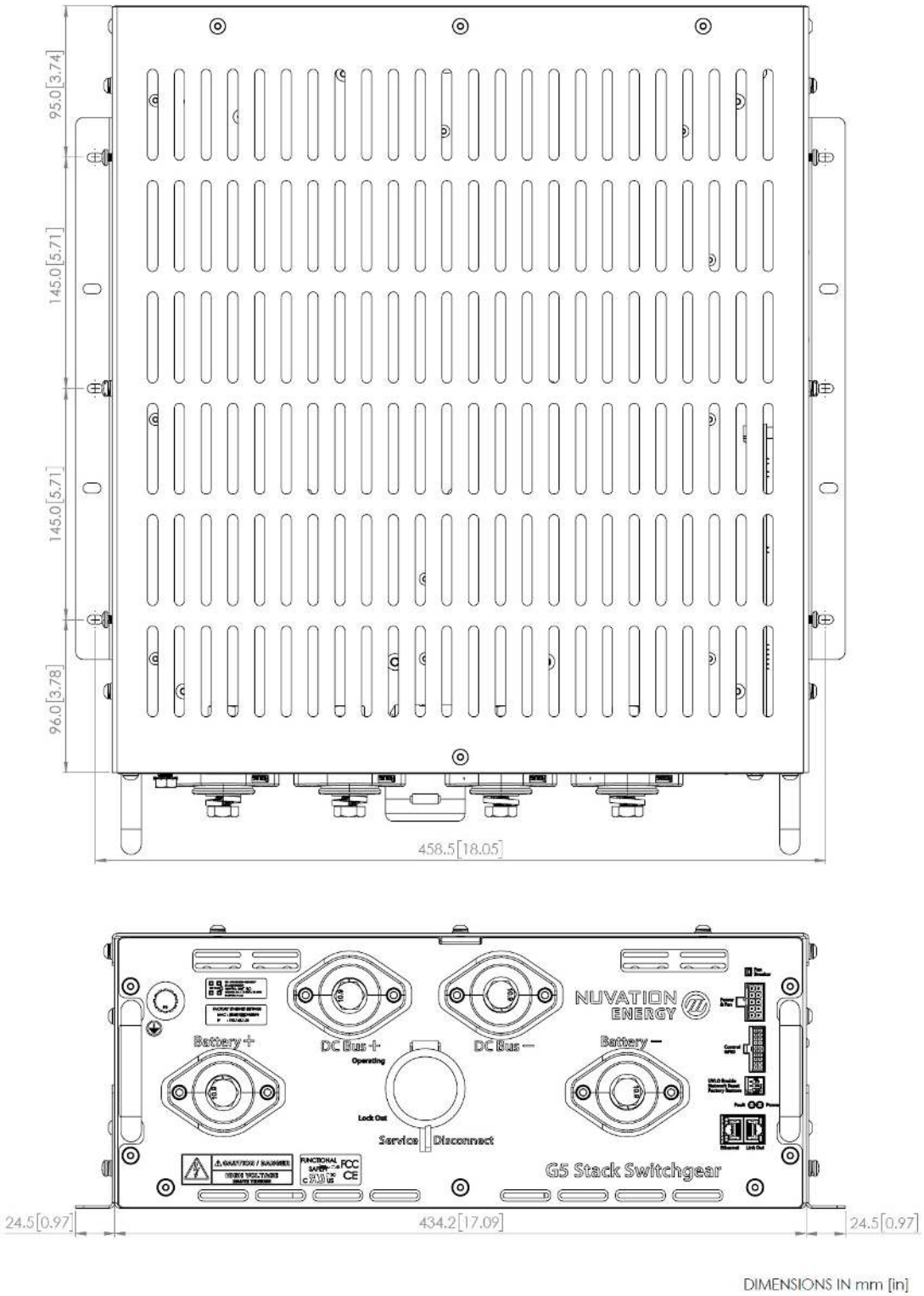

Figure 12. Dimensions, shelf-mount

4.1.1.2. Rack-Mount Bracket

Figure 13. Rack-mount, 19", front-securing

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

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

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

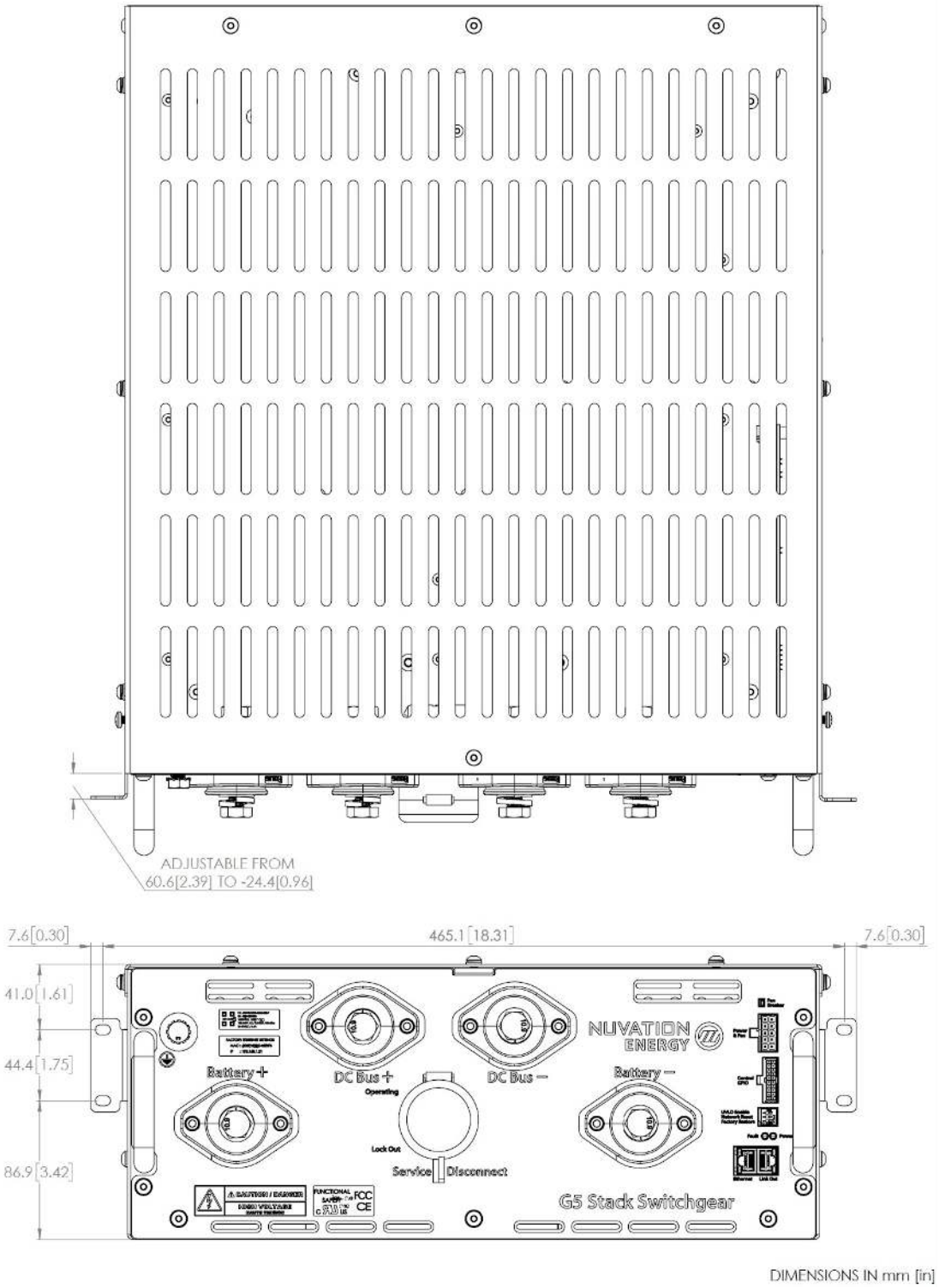

Figure 14. Dimensions, rack-mount, 19", front-securing

4.2. G5 Cell Interface

The G5 Cell Interface (24 channel) is available in a bulkhead-mountable enclosure.

The overall dimensions of the G5 Cell Interface (24 channel) are 118.5 mm x 116.2 mm x 25.4 mm [4.67 in x 4.58 in x 1 in]. The module weighs approximately 116 g [0.25 lbs].

The G5 Cell Interface (24 channel) module dissipates up to 16 W during cell balancing. Extra space should be provided around the module to allow for sufficient heat dissipation, and cable installation.

Please visit https://nuvationenergy.com/technical-resources to download CAD files for the G5 Cell Interface (24 channel).

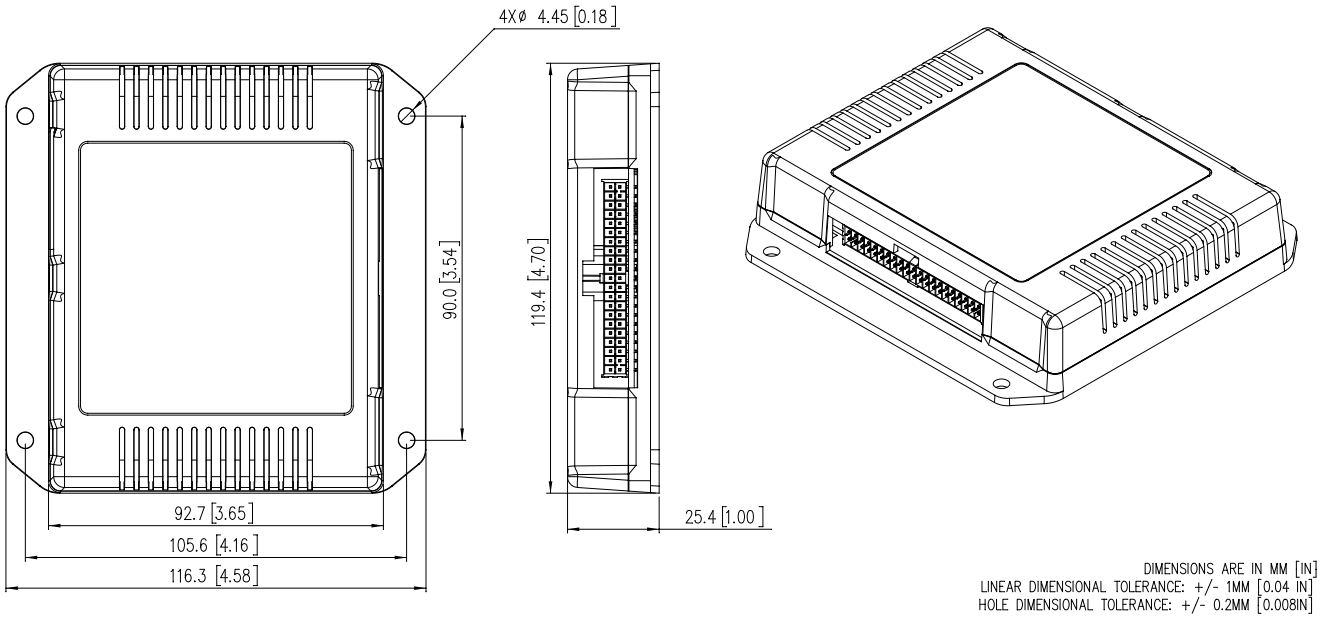

Figure 15. Mechanical Drawing of G5 Cell Interface (24 channel)

5. Ordering Information

5.1. G5 Stack Switchgear

Product part numbers for ordering a G5 Stack Switchgear are listed below.

Table 11. G5 Stack Switchgear Unit Ordering Information

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

* x = fuse rating code.

Kits are available for purchase online at https://nstore.nuvationenergy.com. These kits include the product, cables, and any accessories needed to get you started.

5.1.1. Fuse Rating Code

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

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

Table 12. Fuse rating and code

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

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

By default, the G5 Stack Switchgear ships with bracket `NUVP-SSG-SB-B` for shelf-mounting. The following mounting bracket options are available upon request.

Table 13. Mounting Bracket Ordering Information

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

Fasteners for attaching the brackets to the unit are included.

Bracket CAD files are available online at https://nuvationenergy.com/technical-resources.

5.2. G5 Cell Interface

Product part numbers for ordering a G5 Cell Interface are listed below.

Table 14. G5 Cell Interface Ordering Information

Part Number	Product Name
NUVG5-CI-24	G5 Cell Interface (24 channel)

Kits are available for purchase online at https://nstore.nuvationenergy.com. These kits include the product, cables, and any accessories needed to get you started.

6. Document Revision History

Revision	Date	Details
1.0	2023-05-27	Initial Release
1.1	2023-06-30	Minor Updates
1.2	2023-08-18	Updated G5 Stack Switchgear mounting bracket details
1.3	2023-08-29	Updated G5 Stack Switchgear ordering options and UL Recognized status
1.4	2024-04-05	- Added contactor life tracking. - Introduced the G5 Stack Switchgear 350 A variant.
1.5	2024-07-26	- Added software functional overview - Added Altitude specifications
1.6	2024-11-15	Added guidance on fuse performance and ratings
1.7	2025-03-10	Added clarity on the UL1973 and related standards used for establishing product recognition.
1.8	2025-10-27	Updates from the Faraday Update 2 firmware release.

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

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