Technical Support
support@nuvationenergy.com

Sales Inquiries
sales@nuvationenergy.com
855-261-0507

Nuvation Energy nController®

Product Manual

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nController Software Version 6.5.0

Table of Contents

Definitions

Acronym	Definition
AC	Alternating Current
API	Application Programming Interface
BESS	Battery Energy Storage System
BMS	Battery Management System
CI	Cell Interface
DHCP	Dynamic Host Configuration Protocol
EMS	Energy Management System
FFR	Fast Frequency Response
GPIO	General-Purpose Input/Output
IPMI	Intelligent Platform Management Interface
kW	Kilowatt
kWh	Kilowatt-Hour
mDNS	Multicast Domain Name System
NE	Nuvation Energy
OI	Operator Interface
PC	Personal Computer
PCS	Power Conversion System, specifically bi-directional DC to AC power translation
RS485	Differential Serial Communication Bus Standard
RS232	Single-ended Serial Communication Bus Standard
RTU	Remote Terminal Unit
SOC	State-of-Charge
SOE	State-of-Energy available capacity in Wh
SOH	State-of-Health
SSG	Stack Switchgear
TCP	Transmission Control Protocol
U	Unit to denote height inside server racks (1u = 44.45mm/1.75")
UPS	Uninterruptible Power Supply
URL	Uniform Resource Locator
UTC	Coordinated Universal Time
DoD	Depth of Discharge

1. Introduction

Thank you for choosing Nuvation Energy.

The nController® controls and monitors a Battery Energy Storage System (BESS).

The nController® provides a unified control interface. It integrates a single- or multi-stack battery with a power conversion system (PCS). The nController® enables the BESS to be used as an AC-coupled asset for grid attached and microgrid applications.

The nController® has the following product features:

- Provides dispatch interface for higher-level controls
- Enables load shifting
- Enables backup power applications
- Enables battery maintenance policy management and execution
- Provides parallel battery stack management
  - Provides parallel stack aggregation and intelligent control
  - Manages 1-16 parallel battery stacks on a DC-bus
  - Each battery stack is managed by Nuvation Energy G4 or G5 Stack Switch Gear
  - Collects pack-level data and compiles statistics for stack voltage and current as well as statistics for cell voltages and temperatures
  - Calculates State-of-Charge (SOC)and State-of-Health (SOH) of the unified energy storage system
  - Aggregates system-wide faults and warnings and provides battery pack diagnostics
  - Ensures that measurements and control signals are propagating though all BMS modules
  - Functions as a data analytics gateway by providing access to battery measurements for data capture
- Provides unified control for one PCS, selectable from multiple supported energy policies
- Provides monitoring and control of BESS auxiliary systems via networked digital IO module
- Local data logging
- Remote support monitoring to facilitate pilot system integration support
- Optional Touch Screen HMI (Hardware not included)
- Two form factor options:
  - 1U Rack Mount Server
  - Compact Form Factor, ruggedized (SAE J2464, SAE J2380), suitable for use in mobile applications

The nController® provides a dispatch interface for an AC-couple BESS and can also enable load shifting and some resiliency applications as a stand alone controller.

1.1. About this Manual

This manual is comprehensive and provides the following details:

- Details about the features offered by the standard offering of the nController®
- Setup instructions to properly install this product
- Guidance for configuration settings for the nController®
- Connections from the nController® to energy assets
- Guidance on operating the nController® to control your multi-stack Battery Energy Storage System

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

2. Specifications

This product is a standard offering of nController®, design to control an AC-block with the associated auxiliary equipment.

The core functions of the BESS are to provide charging and discharging on demand while attached to the utility grid.

This system controls and monitors up to 1x power conversion systems (PCS) with the ability to operate in grid-following and some microgrid configurations dependent on PCS and supporting equipment capabilities. The system also manages up to 16x stacks of Nuvation Energy Battery Management System and battery strings.

The system provides:

Charge and discharge API for higher-level controller

- Follow set points for real and reactive power

Timed dispatch with recovery

- Triggerable dispatch at a set power for a set duration of time
- Rest period after dispatch with zero power
- Recovery after going back to a configured SOE setpoint

Target SOE schedules

- Autonomous operation to maintain energy capacities
- Set target energy capacities for available energy for charge and available energy for discharge
- Set schedules based on time of day and time of year for load-shifting applications

Test patterns

- Test patterns based on SOC and time durations

Manages battery maintenance charge

- Perform maintenance charge when authorized
- Remove request for maintenance charge when complete

Enables forming of islanded power grid (not supported by all PCSs)

- Enable/disable islanding
- Provide set points for frequency and voltage while grid-forming
- Enable transition from grid-forming to grid-connected

Human Machine Interface (HMI)

- Connection to external human machine interface (HMI)

BESS status reporting

- BESS status over Modbus TCP
- BESS status over browser based user interface

IO Controller

- Used to monitor BESS subsystems via GPI
  - Input examples: smoke detectors, hydrogen detectors, door sensors, E-stop, ground fault detector, arc fault circuit interrupter, etc.
- Use to control BESS subsystems via GPO
  - Output examples: ventilation fans, HVAC, etc.

2.1. nController® Extension Program

For projects with more complex requirements, Nuvation also offers an nController® Extension Program that can add advanced features such as demand charge management, integration of local generation, and custom control logic. Nuvation Energy works directly with clients to create system-specific extensions to the standard nController® product. Contact Nuvation Energy to learn more.

3. nController® Installation Instructions

There are two form factors for the Nuvation Energy nController®, as indicated in the following sections below. The following sections outline the installations instructions for each form factor.

3.1. Compact Form Factor Installation

3.1.1. Mechanical Installation for Compact

3.1.1.1. Dimensions and Weight

The overall dimensions of the nController® Compact are 340 mm × 218.5 mm × 89.8 mm.

The nController® Compact module weighs approximately 4.5 kg (9.9 lb).

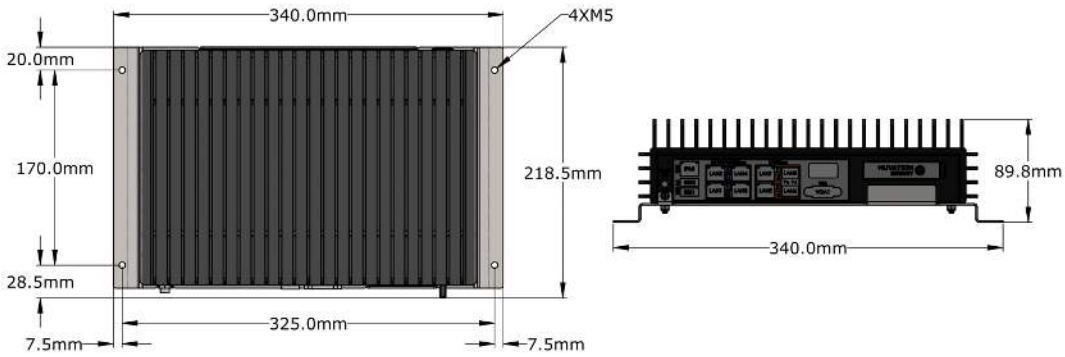


Figure 1. Mechanical Drawing of nController® Compact

3.1.1.2. Installation Location and Position

The nController® Compact is rated to operate in the temperature range of 5 °C to 40 °C. It is designed for indoor use.

For best thermal performance, the nController® Compact should be mounted to a flat vertical surface such that the face with the Ethernet / Power connectors is pointing up.

The nController® Compact can be mounted using four M5 screws.

3.1.1.2.1. Mounting Clearances

Extra space should be provided around the module to allow for cable connections, easy installation and maintenance, and to provide adequate fan-less cooling. The spatial clearance is illustrated below.

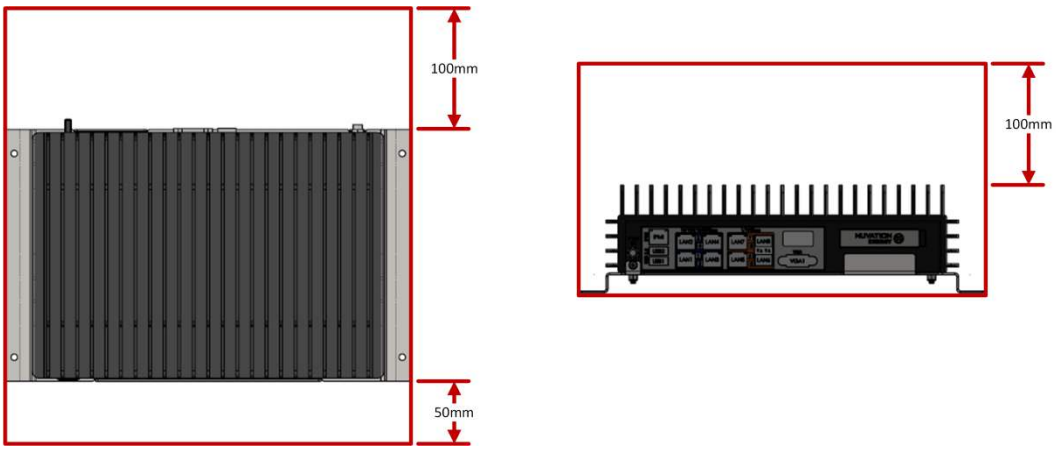


Figure 2. nController® Compact Restricted Areas

Before making any connections, ensure that power is not applied to the nController®.

3.1.2. Electrical Connections for Compact

3.1.2.1. Getting Started

Before connecting power to the nController® you need to:

1. Connect Stack Switchgear communications
2. Connect external network or system
3. Verify grounding

3.1.2.2. nController® External Interfaces

Below are images of the external interfaces available on the front and back of the nController®.

Figure 3. nController® External Interfaces (front) for Compact

Figure 4. nController® External Interfaces (back) for Compact

The following table outlines the port connections of the nController®.

Table 1. Network Port Connection Map

Port Name	Function	Port Label	Port Speed
External	Manage network traffic external to the nController®. Operator Interface is accessed from this port.	7 & 8	1/10 Gbps
Internal	Manage traffic from Nuvation Energy BMS stacks.	1-4	10/100/1000 Mbps
		5 & 6	1/10 Gbps

These port numbers refer to the numbering found on the front panel, as shown in the image below.

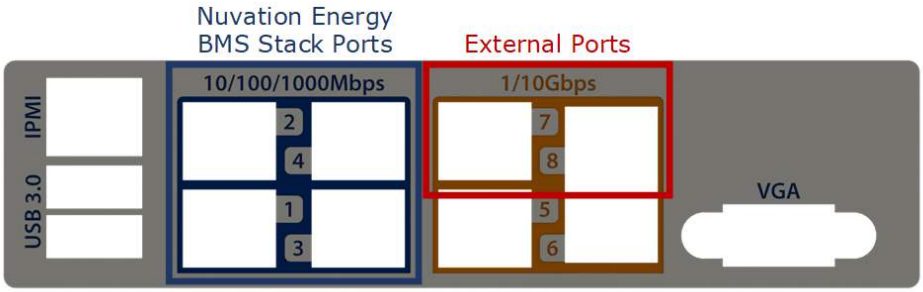


Figure 5. nController® Port Types for Compact

The nController® supports the following types of ports:

- 4x internal Ethernet ports at 10/100/1000 Mbps (ports 1-4)
- 1x internal Ethernet port at 1/10 Gbps (port 5)
- 1x internal SFP+ port at 1/10 Gbps (port 6)
- 1x external Ethernet port at 1/10 Gbps (port 7)
- 1x external SFP+ port at 1/10 Gbps (port 8)

3.1.2.3. Step 1: Connect Stack Switchgear Communications

To connect the Stack Switchgear units to the nController®, connect the Stack Switchgear units to Ethernet RJ45 ports labelled 1 to 4 using Cat5e-rated or higher Ethernet cables of suitable lengths.

The Stack Switchgear only supports ports at 10/100 Mbps Ethernet. To connect a Stack Switchgear to port 5 or 6, an Ethernet switch supporting 1 Gpbs and 10/100 Mbps is required.

Depending on the nController® variant purchased, you may also use an external unmanaged network switch to connect more than 4 Stack Switchgear products to the nController®.

The *external* and *internal* networks of the nController® should remain separated and independent for the best operation of the battery pack. Excessive network traffic on the *internal* network can interfere with the nController® management of the stacks.

3.1.2.4. Step 2: Connect External Network or System

The Ethernet RJ45 port labelled 7 or the SFP+ port labelled 8 may be used to connect the nController® to an external system, such as:

- Energy management systems which manage oversight to the Battery Energy Storage System
- A laptop, to configure operating parameters and observe status
- A local area network (LAN) connection, for wired internet access
- An Ethernet switch, to access any number of the above devices

The External Ethernet interface is a standard Cat5e-rated RJ45 jack, supporting only 1 and 10 Gigabit speeds. If connecting the external network at 10Gbps, Cat6 cabling must be used, otherwise Cat5e is acceptable. Any Cat5e-rated or higher Ethernet cable of suitable length may be used to connect to this RJ45 jack.

Connecting both ports 7 & 8 at the same time will create a loop and will cause interference with the operation of the external network.

No connection should be made to the IPMI or COM1 port unless directed by Nuvation Energy.

Refer to the network port connection map Table 1, “Network Port Connection Map”.

Depending on the number of stacks, the local area network and the existence of an external controller, the nController® networking setup might change.

A typical networking configuration for a nController® with 4 stacks is demonstrated below.

In the following diagrams, green components are customer-supplied, and blue components are available from Nuvation Energy.

See Best Practices - Network Security for a description of the recommended secure networking configuration.

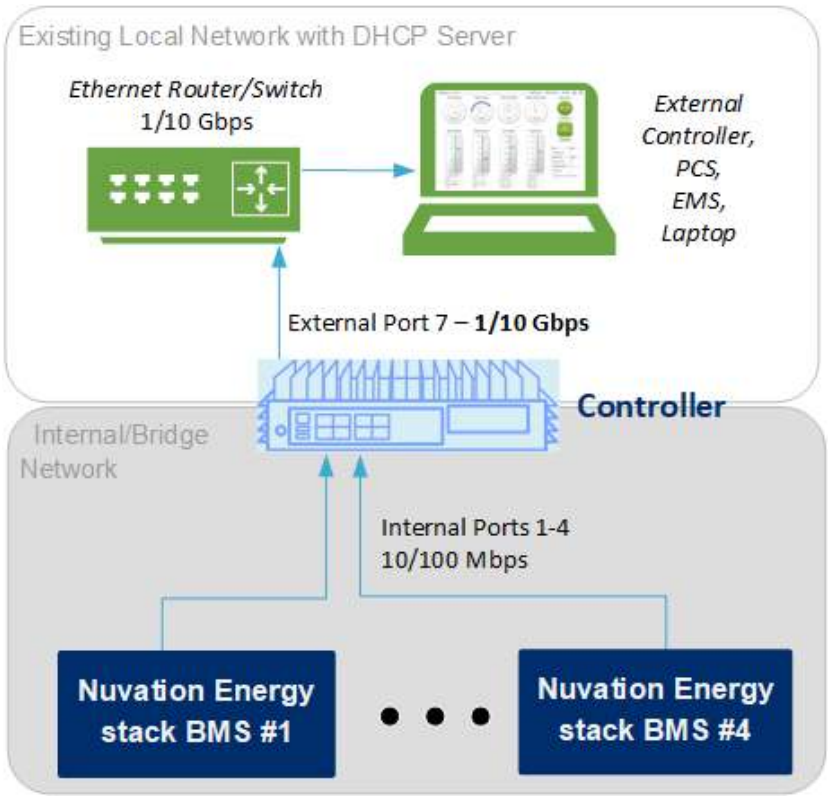


Figure 6. Typical Networking Configuration for a nController® 4 stack variant

For a nController® 8+ stack variant, an ethernet switch is needed for connecting the stacks with the nController®. Refer to the below diagram for configuration details.

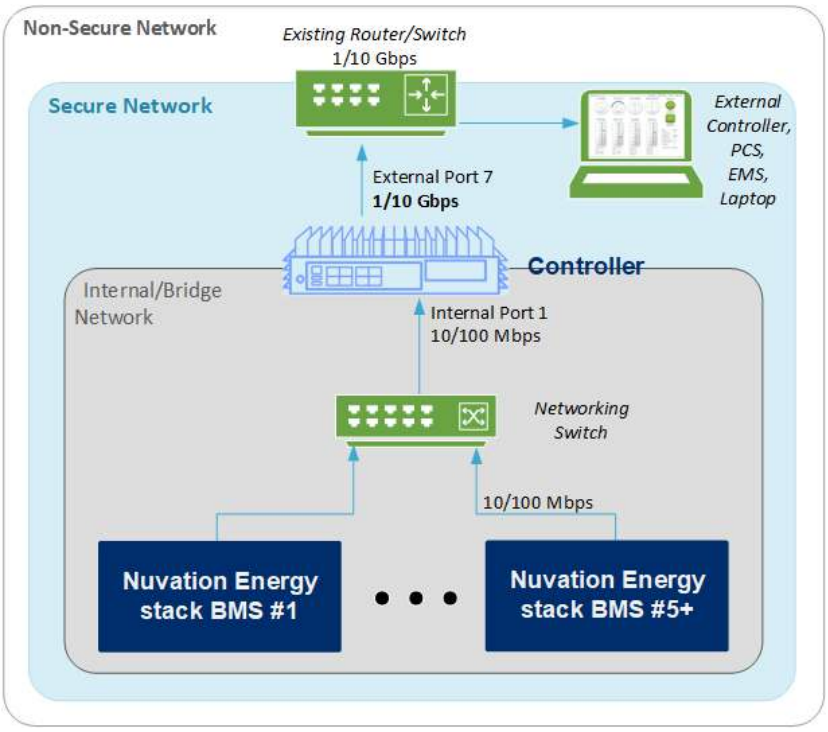


Figure 7. Typical Networking Configuration for a nController® 8 stack variant

In the case where the external controller does not support 1 Gbps and only supports 10/100 Mbps, a compatible ethernet switch must be added. Refer to the below diagram for configuration details.

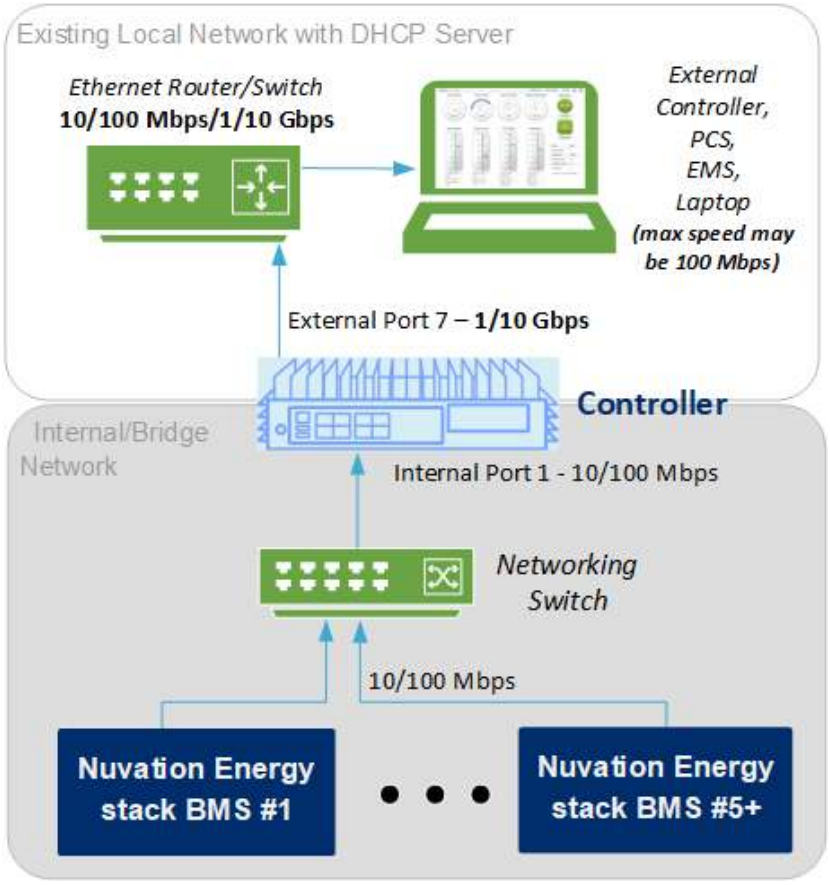


Figure 8. Typical Networking Configuration for a nController® 8 stack variant with an ethernet switch

In the case where a WiFi extender is needed, refer to the below diagram for configuration details.

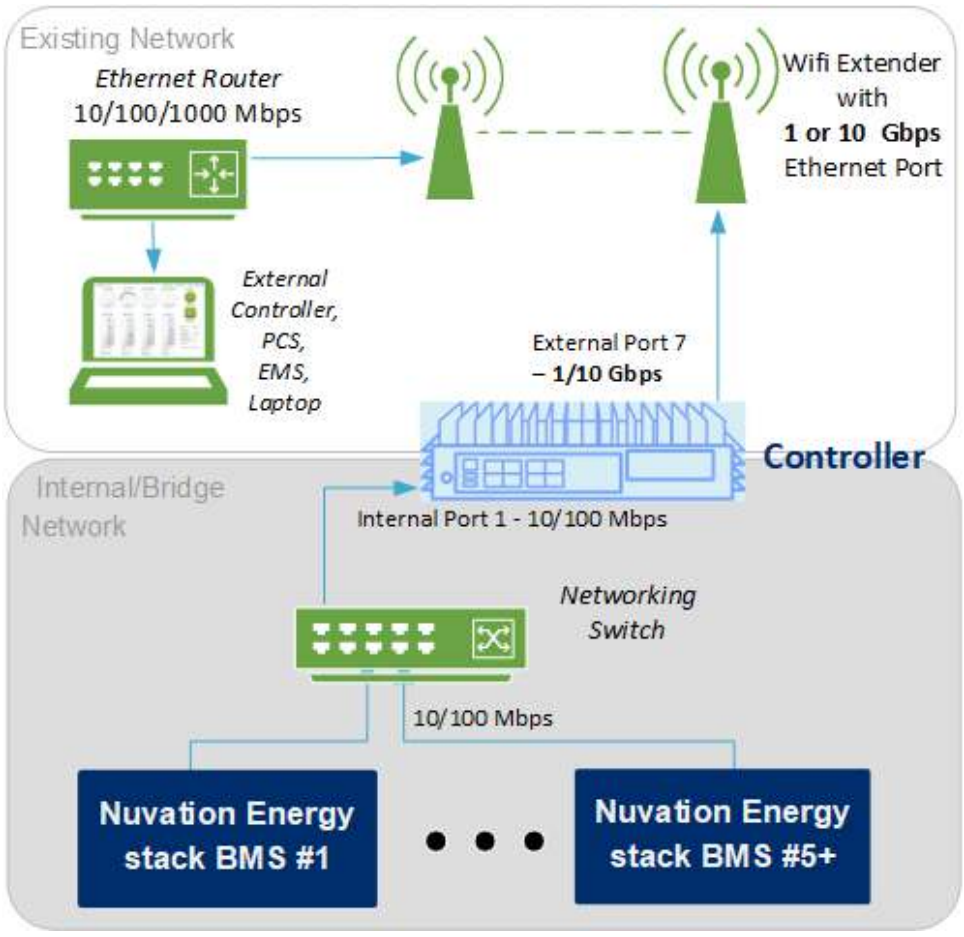


Figure 9. Typical Networking Configuration for a nController® 8 stack variant where a WiFi extender is placed from stack location to local network

3.1.2.5. Step 3: Verify Grounding

The nController® must be mounted to an Earth-bonded metal structure to maintain a reliable ground. This references all components internal to the nController® to earth ground, as the negative input of the DC power connector is also connected to the chassis. Earth ground is also passed along to shielded connectors (e.g. Ethernet and USB).

The external supply has its negative input connected to earth ground through the nController® module's chassis.

These instructions assume that attention is paid to proper grounding instructions and best practices for all Stack Switchgear units and Cell Interface modules. Please refer to the *Nuvation Energy G5 High-Voltage BMS: NUVG5 Product Manual* for this information.

It is also assumed that similar measures are taken for other components of the Battery Energy Storage System such as the batteries and the PCS.

3.1.3. First Power-Up for Compact

3.1.3.1. Connect Power for nController® Compact

Identify an appropriate AC power source

The AC power source must not be derived from the energy system itself without an ability to maintain (or turn on) the supply when the energy system is powered off (i.e. black start).

An external UPS can be used between the energy system-derived AC source and the supply providing power to the nController® when an external AC power source is not available. When using a UPS, please ensure the nController®'s power side is connected to UPS power instead of the external AC power outlet.

Table 2, "12 V Power Supply Specifications" shows the specifications of the 12V power supply that can be ordered with the nController®. If using a different 12V power source, the supply must meet the power requirements listed in Appendix A, *Operating Limits*.

Table 2. 12 V Power Supply Specifications

Symbol	Parameter	Min	Typical	Max	Units
V_{input_AC}	Input Voltage AC	90		264	V AC
f_{input_AC}	Input Frequency	47	50/60	63	Hz
I_{input_AC}	Input Current AC			2	A AC
V_{output_DC}	Output Voltage DC		12		V DC
I_{output_DC}	Output Current DC			12.5	A DC
P_{output}	Output Power			150	W

Powering up the system

Verify that all the mechanical and electrical installation steps are completed and the nController® is connected to the Stack Switchgear units, network, and power.

When ready to power on the nController®, connect an IEC 320-C13 cable to the unit and then enable AC power. The nController® turns on automatically when power is applied; however, following a shutdown, the power button can be used to manually turn on the nController® as an alternative method to simply power-cycling the device. The power button will light up blue when powered on.

The nController® will emit a 4-tone startup chime when low-level software has started. This will be followed by a 3-tone chime once all software has been initialized. The Nuvation Energy BMS Operator Interface will become visible shortly after this chime.

To shutdown the system, momentarily press the power button to initiate a graceful shutdown of the nController®. A graceful shutdown is always recommended before unplugging the power supply.

The nController® initiates a factory restore after 10 sequential unsuccessful boot sequences. To avoid this situation, ensure that the unit is fully powered up before power cycling.

In the event the unit has initialized a factory restore, please contact

> support@nuvationenergy.com to bring the unit back to a functional state.

3.2. Rack Mount Form Factor Installation

3.2.1. Mechanical Installation for Rack Mount

3.2.1.1. Dimensions and Weight

The overall dimensions of the nController® Rack Mount are 484 mm × 419 mm × 44 mm (19.1 in x 16.5 in x 1.7 in). It has a 1 U height and fits in a standard 48 cm (19 in) size server rack. The sliding rails on the nController® Rack Mount are adjustable to fit any 19" server rack depth between 26" to 30".

The nController® Rack Mount module weighs 6.5 kg (14.3 lb).

> The nController® Rack Mount must be shipped in it’s own package and cannot be shipped while installed in a rack.

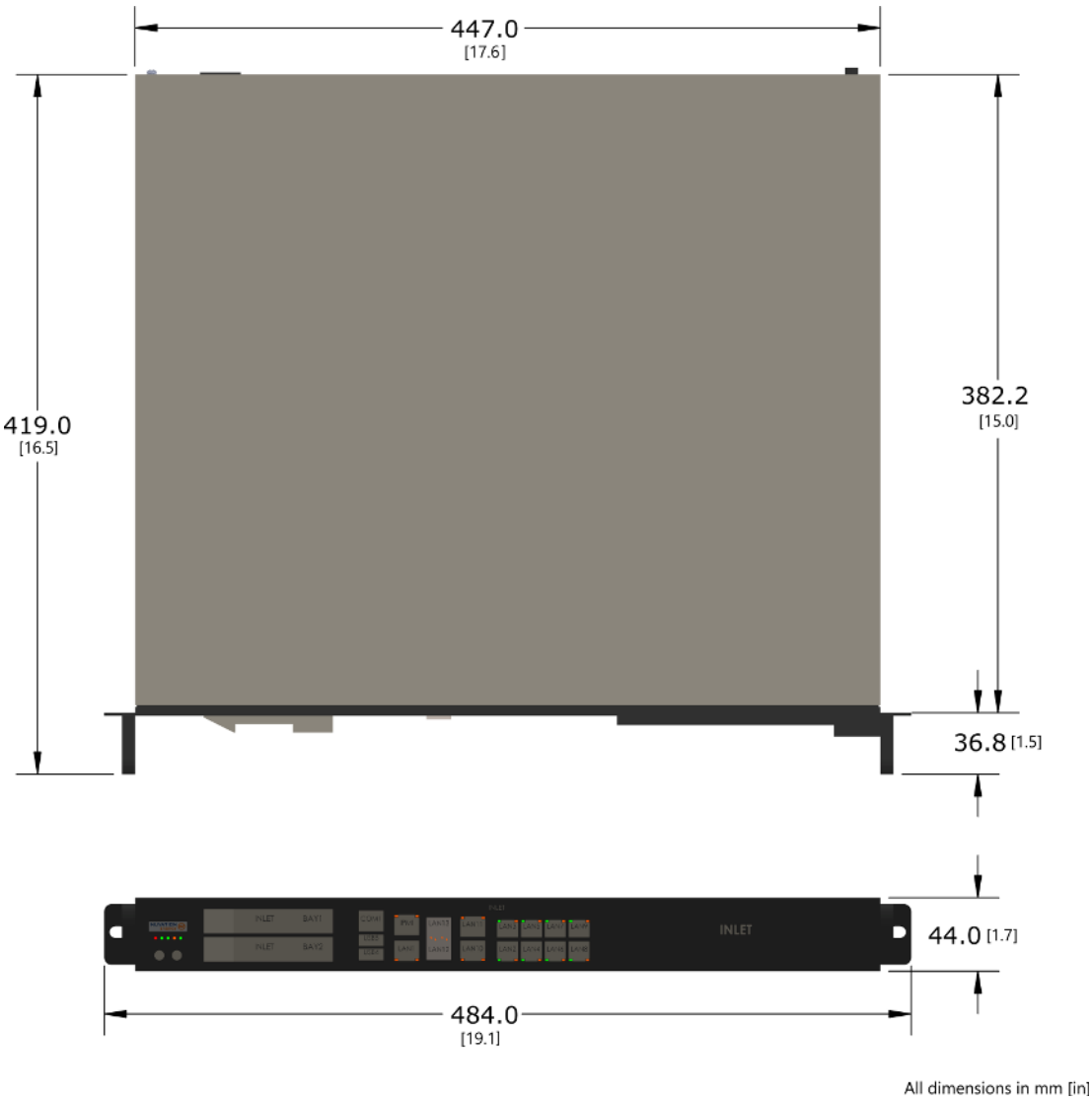


Figure 10. Mechanical Drawing of nController® Rack Mount

3.2.1.2. Installation Location and Position

The nController® Rack Mount is rated to operate in the temperature range of 5 °C (41 °F) to 45 °C (113 °F). It is designed for indoor use.

The nController® Rack Mount should be installed correctly into its supported size rack with no additional space required above or below the unit when mounting.

3.2.1.2.1. Mounting Clearances

A clearance of approximately 762 mm (30 in) in the back of the rack is recommended to allow sufficient space for airflow, cable connections, and access when servicing.

Before making any connections, ensure that power is not applied to the nController®.

3.2.2. Electrical Connections for Rack Mount

3.2.2.1. Getting Started

Before connecting power to the nController® you need to:

1. Connect Stack Switchgear communications
2. Connect external network or system
3. Verify grounding

Below is an image of the external interfaces available on the nController®.

Figure 11. nController® External Interfaces (front)for Rack Mount

3.2.2.2. Step 1: Connect Stack Switchgear Communications

Connect the Stack Switchgear units to the Ethernet RJ45 ports labelled 2 to 9 using Cat5e-rated or higher Ethernet cables of suitable lengths. Refer to the network port connection map Table 3, "Network Port Connection Map".

The Stack Switchgear only supports ports at 10/100 Mbps Ethernet. To connect a Stack Switchgear to ports 10, 11 or 13, an Ethernet switch supporting 1 Gpbs and 10/100 Mbps is required.

Table 3. Network Port Connection Map

Port Name	Function	Port Label	Port Speed
External	Manage network traffic external to the nController®. Operator Interface is accessed from this port.	LAN 1	10/100/1000 Mbps
		LAN 12	1/10 Gbps
Internal	Manage traffic from energy assets	LAN 2-9	10/100/1000 Mbps
		LAN 10, 11 & 13	1/10 Gbps

Figure 12, "nController® Port Types for Rack Mount" is an image of the nController® front panel, pointing out the different types of ports the nController® supports:

- 8x internal Ethernet ports at 10/100/1000 Mbps (LAN 2-9)
- 2x internal Ethernet port at 1/10 Gbps (LAN 10-11)

- 1x internal SFP+ port at 1/10 Gbps (LAN 13)
- 1x external Ethernet port at 10/100/1000 Mbps (LAN 1)
- 1x external SFP+ port at 1/10 Gbps (LAN 12)

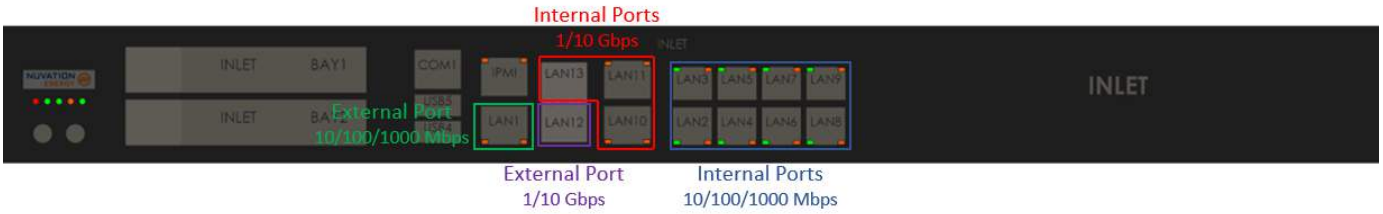


Figure 12. nController® Port Types for Rack Mount

The *external* and *internal* networks of the nController® should remain separated and independent for the best operation of the connected energy assets. In addition, excessive network traffic on the *internal* network can also interfere with the nController® management of such resources.

3.2.2.3. Step 2: Connect External Network or System

The Ethernet RJ45 port labelled 1 or the SFP+ port labelled 12 may be used to connect the nController® to an external system, such as:

- Energy management systems which manage oversight to the Battery Energy Storage System
- A laptop, to configure operating parameters and observe status
- A local area network (LAN) connection, for wired internet access
- An Ethernet switch, to access any number of the above devices

The External Ethernet interface is a standard Cat5e-rated RJ45 jack, supporting only 10, 100, and 1000 Megabit speeds. Any Cat5e-rated or higher Ethernet cable of suitable length may be used to connect to this RJ45 jack.

Connecting both ports 1 & 12 at the same time will create a loop and will cause interference with the operation of the external network.

No connection should be made to the IPMI or COM1 port unless directed by Nuvation Energy.

Refer to the network port connection map Table 3, “Network Port Connection Map”.

3.2.2.4. Step 3: Verify Grounding

For the nController®, ensure that a grounded AC power outlet is used and that the rack itself is also grounded. On the rear of the nController®, there is a dedicated earth bonding screw which should be used to ensure the nController® device has a reliable connection to Earth. This instruction also assumes that proper attention is paid to grounding for any Stack Switchgear units and all other energy assets.

3.2.3. First Power-Up for Rack Mount

3.2.3.1. Connect Power for nController® Rack Mount

Identify an appropriate AC power source

An IEC 320-C13 cable is required to connect the AC power source to the back of a unit. In addition, the AC power source must not be derived from the energy system itself without the ability to maintain (or turn on) the supply when the energy system is powered off (i.e. black start).

An external UPS can be used between the energy system-derived AC source and the supply providing power to the nController® when an external AC power source is not available.

Powering up the system

Verify that all the mechanical and electrical installation steps are completed. In addition, check if the nController® is properly connected to the Stack Switchgear units, network, any necessary energy equipment, and power.

When ready to power on the nController®, connect an IEC 320-C13 cable to the unit and then enable AC power. The nController® turns on automatically when power is applied; however, following a shutdown, the power button can be used to manually turn on the nController® as an alternative method to simply power-cycling the device. The "Power LED" will light up green when powered on.

The nController® will emit a 4-tone startup chime when low-level software has started. This will be followed by a 3-tone chime once all software has been initialized. The Nuvation Energy BMS Operator Interface will become visible shortly after this chime.

To shutdown the system, momentarily press the power button to initiate a graceful shutdown of the nController®. A graceful shutdown is always recommended before unplugging the power supply.

The nController® initiates a factory restore after 10 sequential unsuccessful boot sequences. To avoid this situation, ensure that the unit is fully powered up before power cycling.

In the event the unit has initialized a factory restore, please contact support@nuvationenergy.com to bring the unit back to a functional state.

4. On-Site Setup

4.1. Device Connectivity and Networking

This section provides an overview and general guidelines for site setup and networking. The actual wiring and setup instructions are specific to the nController® . The following is generally required for setup of the site networking:

1. 1x CAT5e Ethernet cables routed to 'External' network connecting to a DHCP network
2. 2x or more CAT5e (or higher) Ethernet cables for internal ports
3. PC or Laptop with an operating system that supports mDNS

BESS Internal Network Connections:

1. 1x or more SSGs
2. 1x PCS
3. 1x IO Controller (optional)
4. 1x UPS (optional)

Some examples of mDNS supporting operating systems are:

1. Windows 10 or later
2. Mac OS X or later
3. Linux Ubuntu 14.04 or later

The networks must not have a subnet on 172.16.0.0/24 as it conflicts with nController® internal networking.

Using the items listed above, the items provided with the nController®, and the required electrical components, connect the battery subsystem according to the connections diagram in Figure 14, “ESS Connectivity”.

The connectivity shown in Figure 14, “ESS Connectivity” will enable communications from the nController® to the Battery Management System equipment on the site. It will also allow connectivity and control of the nController® via a remote ethernet connection. Once all the above connections have been made, all lights on the connected ethernet ports should be active on all powered equipment. The nController® is accessed via the nController® URL, in the format:

http://ncontroller-<serial_number>.local

where <serial_number> is the serial number of the nController®. The serial number is located on the nController® label. An example serial number is “32011000007” resulting in a URL: http://ncontroller-32011000007.local/ncontroller

To test the connectivity from the PC/Laptop, open a web browser on the PC and navigate to the URL for your nController®.

On successful connection you should see a page like the one displayed in the figure below.

Figure 13. Technician Interface Example

Manual IP Discovery

In the event that the computer does not support mDNS, the MAC address for the external network port is labeled on the exterior of the nController®.

Look for this MAC address in the DHCP server to determine which IP address was assigned to the nController® and navigate to 'http://<ip-address>' from a compatible web browser rather than the mDNS URL http://ncontroller-<serial_number>.local.

If connection is still not possible, contact Nuvation Energy support at support@nuvationenergy.com for further assistance.

Based on the above information, you can connect to the web-based technician interface by following the URL below:

http://<ip_address>/ncontroller

5. System Operation

This system is designed as a controllable, semi-autonomous ESS AC-block.

5.1. System Block Diagrams

A more detailed drawing as shown in Figure 14, "ESS Connectivity" below outlines the specifics of how the subsystem communications and power are to be connected to the parent power system. The subsystem blocks within the control of the product are outlined in the 'BESS AC Block'.

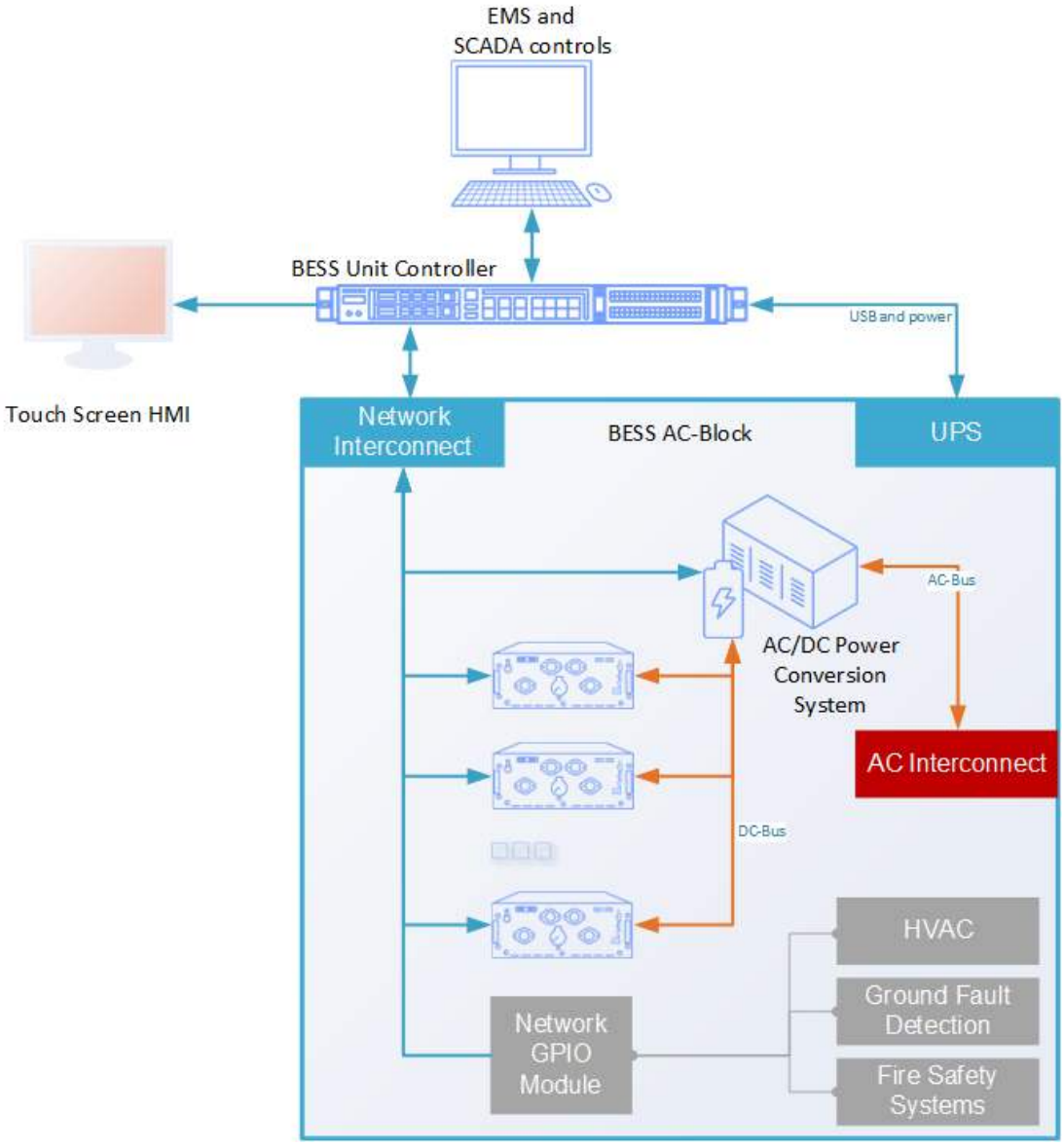


Figure 14. ESS Connectivity

5.2. Interfacing with an Energy Management System

An external Energy Management System can be used to monitor, control, and optimize the performance of distributed energy resources. The nController® is designed to work together with an Energy Management System to interface with the energy storage system along with other equipment on site.

During operation, an Energy Management System can interface with the nController® via Modbus to:

1. Command the system to shut down and stop importing or exporting energy. This can be done by writing a value 0 to point `OpCtl` in SunSpec model 715.
2. Monitor the overall system status including faults by continuously reading `SysStatus` point in the Nuvation vendor model.
3. In case of an Energy Management System fault, writing value one to point `ClrFault` in the Nuvation vendor model or value one to point `AlarmReset` in SunSpec model 715 will trigger the Energy Management System to send a clear fault command to the subsystems and associated connected equipment, see Section 6, “Faults and Warnings”.

5.3. Operating States

The controller operation is separated into the following high-level states.

5.3.1. Power On/Fault State

- All subsystems will begin initialization.
- BESS controller waits for all subsystems to be initialized and faults to clear before states other than "Offline" can be used.
- A fault in the PCS or the battery causes the nController® to enter this fault state.
- More details on faults, warnings and clearing latching faults can be found at Section 6, “Faults and Warnings”.

5.3.2. Offline

- PCS has no power flow - in standby/low power mode if supported (see Power Conversion System).
- Set `OpCtl` = 1 to change to the default energy policy.
  - The default policy is configured in `func:sunspec:api:1:configuration:staged:bess_map_configuration:default_policy`
- Set `OpCtl` = 0 in any state to return to Offline mode.

5.3.3. Grid Attached

- If `SetDERMode` = 0 else change state to Islanded.
- Regular Operation:

  - Most of the operation of this BESS system will be in Grid Attached
  - BESS will also perform regular system tasks while operating.
  - Energy policies are in operation (see Section 8.2.1, “Energy Policies”)
- In this mode only P/Q commands will be sent to the PCS.
- Providing system data and feedback
  - Available via Modbus SunSpec Energy Storage Models server
- BESS follows power setpoints from the configured energy policy
  - Setting the policy to "Manual" will allow setpoints from an external controller through Modbus.
- BESS monitors battery usage and time elapsed since last maintenance to determine when to request next maintenance cycle; status bit in `SysStatus` is updated accordingly.
- External controller will request a battery maintenance cycle by setting the `MaintMode` word from "0" to "1" in the SunSpec 61000 model.
- Maintenance mode can be stopped at any time by setting `MaintMode` to "0".
- Upon receipt of `MaintMode` value of 1 then transition to "Battery Maintenance".

5.3.4. Islanded

Islanded operation is not supported by all Power Conversion System models and drivers and this section only applies to sites with compatible equipment and site electrical design that support these feature (see Power Conversion System).

- If `SetDERMode` = 1 else change state to "Grid Attached".
- Depending on the PCS and supported islanding features, the following cases are valid:
  - PCS is operating in islanded droop mode: In this mode only V/F commands will be sent to the PCS.
  - PCS is operating in islanded non-droop mode: No commands will be sent to the PCS.
- BESS is expected to be forming the local grid on its own.
- BESS will shutdown when commanded or if available battery capacity is exhausted.
- In islanded droop mode, the following configurations apply:
  - To support the transition to grid attached there are offset and ramp configuration values for droop voltage and frequency adjustments:
    - max_frequency_offset_hz
    - max_frequency_ramp_offset_hz_p_s
    - max_voltage_offset_v
    - max_voltage_ramp_offset_v_p_s
  - The droop percentages are used to calculate compensation during grid forming:
    - island_frequency_droop_percent: slope of frequency response based on real power.

- island_voltage_droop_percent: slope of voltage response based on reactive power.

5.3.5. Battery Maintenance

Battery maintenance is not required for all systems and this depends on the usage of the system and the battery chemistry, please consult with the battery documentation and Nuvation Energy for more information.

- If `MaintMode` = 1 and current state is "Grid Attached" otherwise the maintenance cycle cannot run.
- BESS will perform the required maintenance of the batteries when requested through the `MaintMode` SunSpec point in model 61000.
- When maintenance is completed, the BESS will clear the maintenance mode bit (11) in the System Status word (SunSpec 61000 model).
- The system will return to the previously active state before maintenance mode is started.

In order to configure the maintenance feature, use the configuration file and the following parameters:

- discharge_limit_ah
  - This is the discharge limit (in Ah) before maintenance is required
- time_limit_s
  - This is the amount of time (in seconds) until maintenance is required

5.4. Modbus Communications

The system also has multiple SunSpec Energy Storage Models used to interact with the system and control its operation:

Control and feedback registers are available in the SunSpec Energy Storage Models along with the proprietary Nuvation Energy vendor model. The SunSpec models available on the system are summarized in Section 12.2, "Implemented SunSpec Energy Storage Models". See Section 12, "Modbus Protocol Support" for more details.

5.4.1. Communication Points

There are various types of feedback/control values that come from the system SunSpec interface. The control and command points along with their corresponding models are summarized in Table 4, "System SunSpec Feedback Values" and Table 5, "System SunSpec Operational Commands".

Table 4. System SunSpec Feedback Values

Feedback	Value
System Enable/Disable	model_701.st
System Status	model_61000.SysStatus
Voltage	model_701.LLV

Feedback	Value
Frequency	model_701.Hz
System Power	MV: model_701.W, model_701.Var
Watchdog	model_61000.WatchdogFB
Alarms/Faults	model_61000.SysStatus
AC Feedback	Model 701
DC Feedback	Model 714
SOC/SOH	model713.SOC/SOH
Energy Accumulation	model_701.TotWhInj/TotVarhInj

Table 5. System SunSpec Operational Commands

Function	Command
System Enable/Disable	model_715.OpCtl
Voltage	model_702.VNom
Frequency	model_61000.FSet
Power	model_704.WSet, model_704.VarSet
Watchdog	model_61000.WatchdogSet
Battery Equalization	Request: model_61000.SysStatus:bit 12, Authorization: model_61000.MaintMode
Fault Clearing	model_61000.ClrFaults

Table 6. AC Components (SunSpec Model 701)

Field	Description
W	Total active power. Active power is positive for DER generation and negative for absorption.
VA	Total apparent power.
Var	Total reactive power.
PF	Power factor. The sign of power factor should be the sign of active power.
A	Total AC current.
LLV	Line to line AC voltage as an average of active phases.
LNV	Line to neutral AC voltage as an average of active phases.
Hz	AC frequency.

- DC Components (SunSpec Model 714) (Note: Additional Modbus registers available for system diagnostics)

Table 7. DC Components (SunSpec Model 714)

Field	Description
DCA	Total DC current for all ports.
DCW	Total DC power for all ports.
Prt.DCA	DC current for the port.
Prt.DCV	DC voltage for the port.
Prt.DCW	DC power for the port.

- capacity SOC/SOH data (SunSpec Model 713) (Note: Additional Modbus registers available for system diagnostics)

Table 8. Capacity SOC/SOH (SunSpec Model 713)

Field	Description
SoC	State of charge of the DER storage.
SoH	State of health of the DER storage.

- errors, faults, warning and status information (available from various SunSpec models)

Table 9. Errors, Faults, Warnings and Status (Various SunSpec Models)

Model	Model Desc	Field	Description
701	DER AC Measurement	Alrm	Active alarms for the DER.
714	DER DC Measurement	PrtAlrms	Bitfield of ports with active alarms. Bit is 1 if port has an active alarm. Bit 0 is first port.
61000	Nuvation Energy DER	SysStatus	System status word

6. Faults and Warnings

The nController® monitors the fault and warning statuses of the following critical and non-critical subsystems:

- The battery stacks (critical)
- The PCS (critical)
- I/O Expander module (non-critical)
- UPS (non-critical)

For more information on the nController® faults, please visit the *Troubleshooting* section of this Product Manual.

A critical subsystem is crucial for the normal operation of the system, and its status is aggregated into the overall system status. When a critical subsystem is faulted the Power Conversion System will be turned off to stop power flow. A non-critical subsystem status will still be reported but has no immediate effect on the overall operation of the system.

Each subsystem has the following statuses:

1. Warning status: Indicating that the state of the system is outside of its expected range. A warning will not cause the system to stop operation but may indicate the system is operating with degraded performance. The cause of the warning should be identified and a corrective action should be performed.
2. Fault status: Indicating that the state of the system has been detected outside of its operational range. A fault will cause the system to stop operation. The cause of the fault must be identified and a corrective action must be performed.
3. Communication status: Indicating communication between the nController® and the subsystem.

The fault status in the nController® is hierarchal. The overall fault status of the system is summarized in the nController® fault. An nController® fault gets triggered under the following three conditions:

1. One or more of the critical subsystems faults
2. A watchdog timer is tripped.
3. The nController® loses communication with at least one of its critical subsystems as summarized by the subsystem communication statuses

The Power Conversion System has a latching fault and warning. The battery stacks may have self-clearing or latching faults/warning depending on the system configuration. Please see Section 14.1, “Faults” for more information regarding the faults and warnings related to the battery stacks.

In the case of a latching fault/warning, a `Clear Fault` is required to be requested through the technician interface or over Modbus.

Please see Section 12, “Modbus Protocol Support” for sending the clear request over Modbus, and Section 8, “Using the Interface for Energy Policies” for sending the clear request over the user interface.

7. Configuration

7.1. Battery Management System Configuration

The nController® allows for the management of multiple stacks, where each stack has a corresponding Stack Switchgear. For the Battery Management System to operate, the configurations below are required so that the nController® would be able to communicate with the Stack Switchgear units.

Stack Switchgear Configuration

Ensure the separate documentation for proper wiring and setup is followed for the Stack Switchgear units.

The IP addresses for all the Stack Switchgear units connected to the network should be on the 192.168.1.x subnet. All the IP addresses should be unique and not conflict with any site equipment. The default IP is 192.168.1.21, while the default IP for the nController (internal network) is 192.168.1.10.

To configure the Stack Switchgear units' IP addresses and other related settings, follow the directions outlined in section 5 of the companion document "Nuvation Energy High-Voltage BMS Solution Product Manual".

nController® Configuration

The nController® has been pre-configured for the site.

The racks can be connected to any of the internal 10/100/1000 Mbps Ethernet RJ45 ports on the nController® as shown in either Figure 5, "nController® Port Types for Compact" or Figure 12, "nController® Port Types for Rack Mount" depending on the platform type, using a standard Cat5e-rated RJ45 jack.

7.2. nController® Device Configuration

On startup, the nController® device goes through the booting sequence described in either Section 3.1.3.1, "Connect Power for nController® Compact" or Section 3.2.3.1, "Connect Power for nController® Rack Mount".

When bootup is completed, the nController® will attempt to load the configuration saved on the device. Upon successfully loading the configuration, the nController® device is initialized and ready for operation.

All devices are configured through an nController® configuration file, which contains all the information for the nController® to connect to the devices on the site. The companion `YAML` configuration file is highly configurable to allow for desired onsite connections. Refer to Section 10.5.6, "Configuration Import and Export" For details on how to upload a configuration file.

Only settings uploaded in a `YAML` configuration file are persisted over reboots.

The configuration file is a `YAML` file (https://en.wikipedia.org/wiki/YAML). `YAML` entries form a

hierarchical and structured representation of data. The basic building blocks are key-value pairs, and they can be combined to create more complex structures. Nested mapping keys define either keys for primitive keys or key-spaces with further nesting.

Primitive key

A YAML entry with an associated value.

Key-space

A YAML entry that does not have a corresponding value. Instead, the entry has more nested entries.

Example of a key-space:

"func:msc_application:api:1"

Can contain more nested key-spaces like:

"configuration"

The above key-space in turn has its own nested key-spaces and primitive keys:

- *"loaded"*
- *"reset"*
- *"staged"*

"loaded" and *"reset"* are examples of primitive keys that have values assigned to them.

The nController® contains multiple sub-systems. The top level function key-spaces are split according to each sub-system. Each sub-system has its own key-space related to it with the following naming convention, *"func:<sub-system_name>:api:<api_version>"*. The keys above are related to the 'msc_application' sub-system. The keys above are related to the plant_extension sub-system.

Each sub-system will contain a *"configuration"* key-space which contains all the entries that correspond to the settings for that sub-system.

Some sub-systems configuration key-spaces require the use of dynamic lists, others use static lists. Static lists have a fixed length. Dynamic lists on the other hand do not have a fixed length and can be extended by adding more key-spaces that contain a unique *"_lkey"*, see the following example:

```
configuration:
    loaded: true
    reset: false
    staged:
    - _lkey: '0'
        bms_type: 'nuvation'
        enabled: true
        http_port: 8000
        installed: true
        ip_address: 10.202.11.106
        maintenance:
```

```
            discharge_limit_ah: 0
            time_limit_s: 0
        modbus_port: 503
    - _lkey: '1'
        bms_type: 'nuvation'
        enabled: true
        http_port: 8001
        installed: true
        ip_address: 10.202.11.106
        maintenance:
            discharge_limit_ah: 0
            time_limit_s: 0
        modbus_port: 504
```

Configuration primitive keys can have values of type string, integer, float or boolean. Floats are defined as decimal numeric values, for example `0.0`. Integers are non-decimal numeric values. Booleans can only have the following values, `true` and `false`. Strings are values that do not fall in the scope of the above definitions.

Types are sensitive and should not be changed. The value `null` should never be used in the configuration file.

The recommended way to apply a configuration change is to first export the configuration file from the unit. Then make the required changes to the file while maintaining the structure and value types of all key-spaces and primitive keys. Then import the edited version.

For assistance with modifying this file, contact support@nuvationenergy.com.

Setting the *"reset"* key to 'true' will reset all configuration values related to the corresponding sub-system to their default values.

7.3. E-Stop Configuration

The following are suggestions that should be taken when implementing E-Stops within the system.

It is suggested that the E-Stop be implemented such that the PCS should be triggered first and the Battery Management System second with a delay. The delay is necessary to ensure that the PCS has sufficient time to safely shut down the power conversion process before disconnecting the Battery Management System. If the Battery Management System is disconnected first without this delay, the contactors (electrical switches) controlling the connection between the power source and the battery may still be under load. Disconnecting under load could lead to excessive wear on the contactors, potentially causing arcing, overheating, or damage to the system. This delay allows the PCS to stabilize the power output, ensuring the Battery Management System disconnects safely without stressing the contactors or other components in the system.

The E-Stop is not meant to be used to stop an active system for maintenance or common-use. It should be used for emergency purposes only when a device in the

> system fails under load.

> If needed a system can be stopped under load, but this may impact the service life of the equipment.

For further details on this please contact Nuvation Energy by emailing support@nuvationenergy.com.

8. Using the Interface for Energy Policies

8.1. Energy Dashboards

The energy dashboards for the nController® exposes dashboards for viewing data in the nController® and site.

The dashboards are accessed at the following URLs:

- Energy Dashboard:
  - **http://ncontroller-<serial_number>.local/dashboard/dashboards/energy-dashboard**
- PCS Faults:
  - **http://ncontroller-<serial_number>.local/dashboard/dashboards/pcs-faults**
- Stack Statistic Graphs:
  - **http://ncontroller-<serial_number>.local/dashboard/dashboards/stack-statistic-graphs**

The “Energy Dashboard” displays high-level information about the current site state, displayed in Figure 15, “Energy Dashboard”.

The above Dashboard is an example and is likely to change with the final release of the product.

The “PCS Faults" graph displays all tripped fault reasons. The dashboard is displayed in Figure 16, “PCS Faults”.

The “Stack Statistic Graphs" display a variety of stack statistics and status values. The detailed dashboard is displayed in Figure 17, “Stack Statistic Graphs”.

Figure 15. Energy Dashboard

In the case of a system fault on any device on-site, the `Clear Faults` button on the energy dashboard can be pressed to attempt to clear the latching fault.

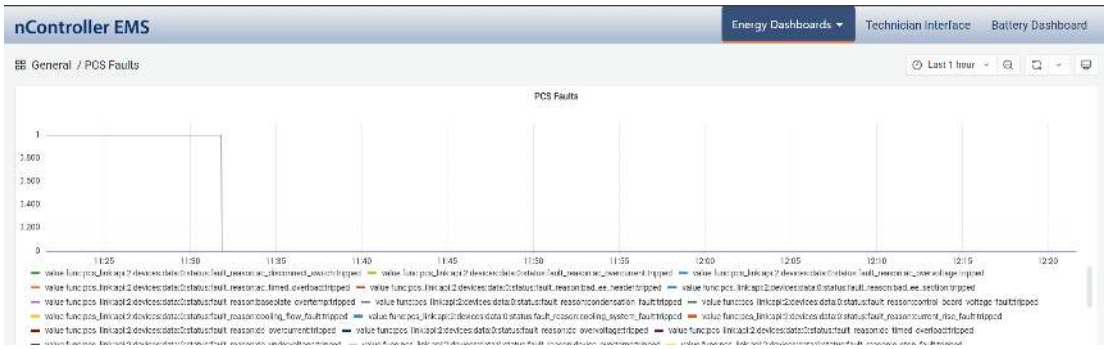


Figure 16. PCS Faults

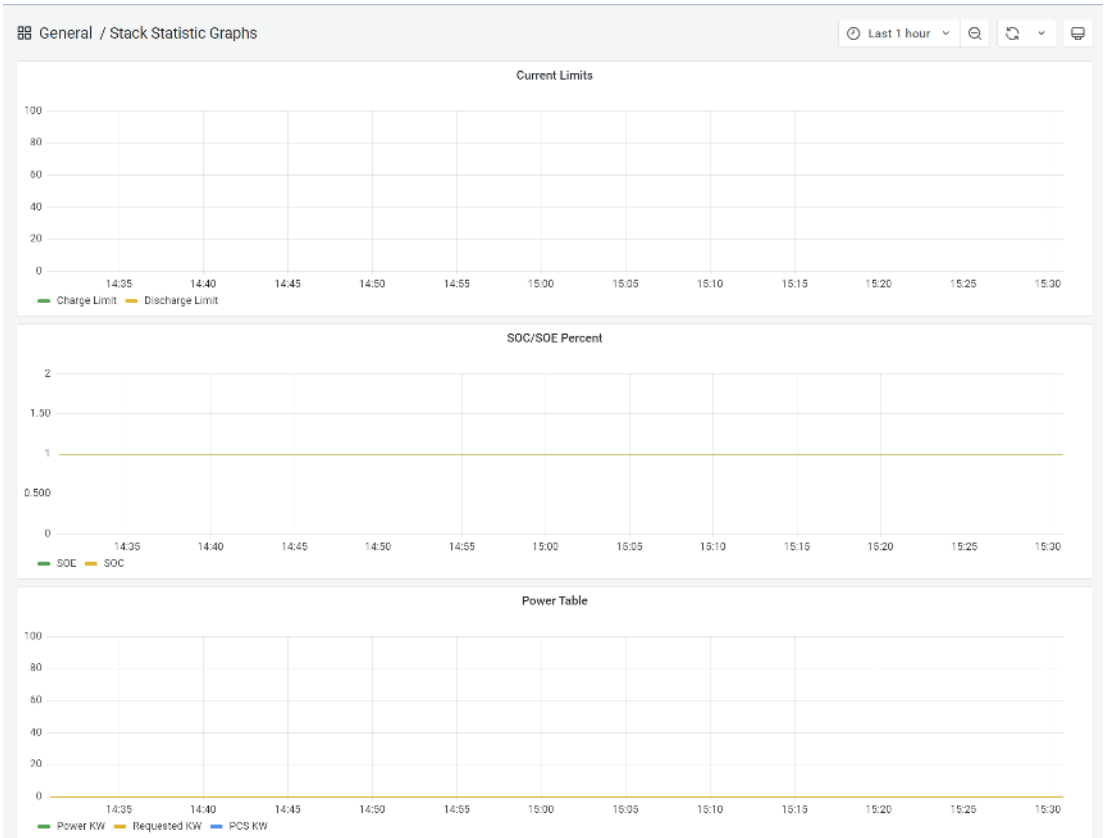


Figure 17. Stack Statistic Graphs

For customized dashboards or modifications to existing dashboards, contact your Nuvation Energy account manager at support@nuvationenergy.com.

8.2. Technician Interface

The technician interface is provided for operators and technicians who need to change the state of the nController®.

The technician interface can be reached by navigating to the following URL:

http://ncontroller-<serial_number>.local/ncontroller

Figure 18. Technician Interface

Parameters set over the technician interface are only active during run-time and does not persist across system reboots. A configuration file must be uploaded with the appropriate policy parameters to ensure the parameters are loaded after a

system restart.

8.2.1. Energy Policies

Energy policies are mutually exclusive nController® features that define how the energy flows through the system. Depending on the selected policy, system configuration, and system status, the policy will determine the requested power for the PCS. The actual PCS power output may be limited due to other system constraints such as Battery Management System current limits, PCS configuration limits, etc.

A policy will stop executing if a policy fault is detected.

For the following section, every setting entry should be prepended by `func:bess_controller:api:1:configuration:staged` key-space when creating the settings file. For example: `policies:target_capacity:export_kw` should be inputted in the setting file as `func:bess_controller:api:1:configuration:staged:policies:target_capacity:export_kw`

Maintenance algorithms are priority energy policies. Maintenance can be activated automatically or manually via an external controller. If maintenance is triggered and the system is not in Offline mode, it transitions to the maintenance algorithm. After maintenance, the system returns to the previously selected non-maintenance energy policy.

To select an energy policy during system run time, use the technician interface. To set a policy as the default policy on startup, upload a configuration file with `configuration:active_policy` set to the desired policy name.

The following energy policies are available.

8.2.1.1. Offline Policy

This energy policy will force the nController® to stop importing or exporting power.

The offline policy can be set during run time over the Modbus interface by writing 0 to point OpCtl in SunSpec model 715. Refer to Section 12, “Modbus Protocol Support” for more details.

8.2.1.2. Manual Policy

This energy policy will enable manual control of the nController® through the technician interface. When selected controls are made available to change the nController® power.

To manually set the power flow through the system:

1. Select the `MANUAL` policy in the technician interface
2. Click on `EDIT`, and select the appropriate power value

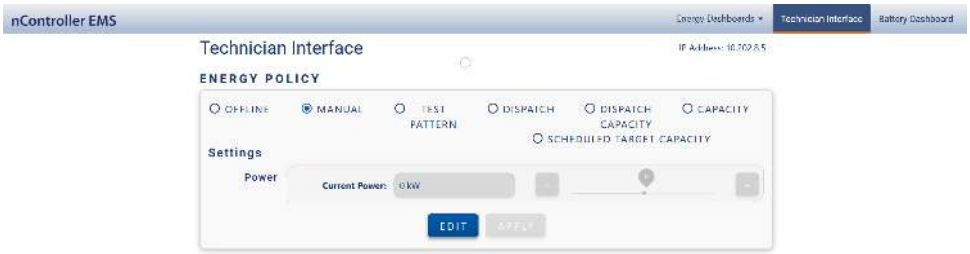


Figure 19. Technician Interface Manual Policy

8.2.1.2.1. Current Bias

Current Bias is a feature that must be configured through a configuration file before operation. When the system is idling, a bias current is automatically applied to maintain the current SOC.

The following conditions must be met for the feature to run:

- Current Bias is properly configured and enabled in the configuration file prior to operation
- The ESS is set to `MANUAL` policy
- The requested power is 0 kW
- SOC is greater than 0%

Table 10, "Current Bias Configuration Keys" below shows the configuration keys for this feature. All keys are under the `bess_controller` configuration keyspace.

Table 10. Current Bias Configuration Keys

Configuration Key	Description	Units
`policies:manual:idle:enabled`	Enable/Disable current bias feature	true/false
`policies:manual:idle:lower_tolerance`	How many percentage points SOC may drop by before starting compensation	0-100
`policies:manual:idle:higher_tolerance`	How many percentage points SOC may rise above before stopping compensation	0-100
`policies:manual:idle:power_compensation_kw`	Compensation power	kW

8.2.1.3. Dispatch Policy

This energy policy enables importing or exporting a set amount of power for a set duration. A power dispatch request can be scheduled either immediately, or in the future. To set a dispatch request through the user interface, select `EDIT` and enter the appropriate date, duration and power.

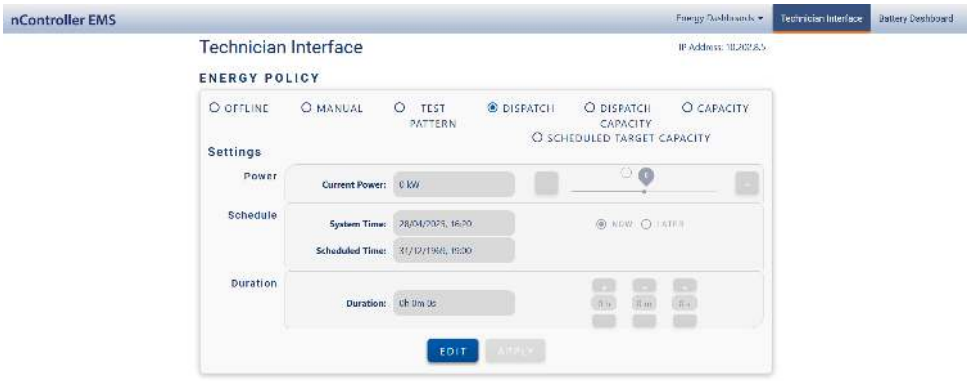


Figure 20. Technician Interface Dispatch Policy

Alternatively, a configuration file with the power dispatch request details including the magnitude of the power, the starting timestamp in UTC and the duration, can be uploaded to the system.

Table 11. Dispatch Policy Configuration

Configuration key	Description	Units
`active_policy`	`Energy Dispatch`	N/A
`policies:energy_dispatch:duration_s`	Dispatch duration	seconds
`policies:energy_dispatch:power_kw`	Dispatch power	kW
`policies:energy_dispatch:start_utc_timestamp_s`	Start UTC timestamp	seconds

8.2.1.4. Capacity Policy

This energy policy is intended to maintain the capacity of the ESS within energy setpoints. If the available ESS energy for exporting is too low, the target capacity algorithm will charge the ESS. If the available ESS energy for importing is too high, the ESS will discharge.

To set the capacity policy:

1. Select `CAPACITY` in the technician interface.
2. Click on `EDIT`.
3. Set the charge and discharge power and energy targets.
4. Toggle the `Prioritize Discharge` button if needed.
5. Set a hysteresis band for the policy.

Figure 21. Technician Interface Capacity Policy

Alternatively, a configuration file can be uploaded with the following keys.

Table 12. Target Capacity Policy Configuration

Configuration key	Description	Units
`active_policy`	`Target Capacity`	N/A
`policies:target_capacity:export_kw`	Discharge power	kw
`policies:target_capacity:export_target_kwh`	Target discharge capacity	kWh
`policies:target_capacity:export_target_prioritized`	Prioritize discharge capacity	kWh
`policies:target_capacity:hysteresis_kwh`	Hysteresis	kWh
`policies:target_capacity:import_kw`	Charge power	kW
`policies:target_capacity:import_target_kwh`	Target charge capacity	kWh

8.2.1.5. Dispatch Capacity Policy

This energy policy combines the capacity and dispatch policies.

To set the dispatch capacity policy:

1. Select `DISPATCH CAPACITY` in the technician interface.
2. Click on `EDIT`.
3. Set the charge and discharge power and energy targets.
4. Toggle the `Prioritize Discharge` button if needed.
5. Set a hysteresis band for the policy.
6. Setup the power dispatch by setting the power request, schedule and duration.
7. Set a rest duration.

Figure 22. Technician Interface Dispatch Capacity Policy

Alternatively, a configuration file can be uploaded with the following keys.

Table 13. Energy Dispatch with Target Capacity Policy Configuration

Configuration key	Description	Units
`active_policy`	`Energy Dispatch Target Capacity`	N/A
`policies:energy_dispatch_target_capacity:energy_dispatch:power_kw`	Dispatch power	kW
`policies:energy_dispatch_target_capacity:energy_dispatch:duration_s`	Duration of dispatch	seconds
`policies:energy_dispatch_target_capacity:energy_dispatch:start_utc_timestamp_s`	Start timestamp in UTC	seconds
`policies:energy_dispatch_target_capacity:target_capacity:export_kw`	Discharge power	kW
`policies:energy_dispatch_target_capacity:target_capacity:export_target_kwh`	Target discharge capacity	kWh
`policies:energy_dispatch_target_capacity:target_capacity:export_target_prioritized`	Prioritize discharge capacity	boolean (0/1)

Configuration key	Description	Units
policies:energy_dispatch_target_capacity:target_capacity:hysteresis_kwh	Hysteresis	kWh
policies:energy_dispatch_target_capacity:target_capacity:import_kw	Charge power	kW
policies:energy_dispatch_target_capacity:target_capacity:import_target_kwh	Target charge capacity	kWh
policies:energy_dispatch_target_capacity:rest_duration_s	Rest period	seconds

8.2.1.6. Test Pattern Policy

This energy policy is for running test for dispatching energy given a target state of charge and a possible test timeout. The policy allows the technician to charge or discharge the system according to pattern of multiple State of Charge levels.

To configure the entries for the Test Pattern policy, a configuration file with the following parameters must be uploaded.

Table 14. Test Pattern Policy Configuration

Configuration key	Description	Units
active_policy	Test Pattern	N/A
policies:test_pattern:repeat_count	Pattern repeat count	N/A
policies:test_pattern:repeat_forever	Always repeat when patterns are complete	boolean (0/1)
policies:test_pattern:entries	List of pattern entries	N/A
policies:test_pattern:entries:0:target_soc_percent	Target state of charge for the first entry	percentage
policies:test_pattern:entries:0:power_kw	Power to discharge/charge to reach target SOC for the first entry	N/A
policies:test_pattern:entries:0:timeout_s	Time out before moving to the next pattern for the first entry	seconds

The technician interface can be used to restart a pattern or select a specific pattern from the configured entries.

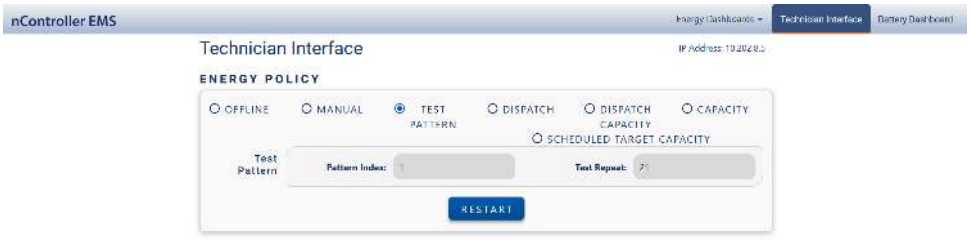


Figure 23. Technician Interface Test Pattern Policy

8.2.1.7. Scheduled Target Capacity Policy

This energy policy automatically runs a target capacity policy on a set schedule. It must be configured

through a configuration file before operation. The following table describes the configuration parameters of the policy.

Figure 24. Technician Interface Scheduled Target Capacity Policy

Table 15. Scheduled Target Capacity Policy Configuration

Configuration key	Description	Units
`active_policy`	`Scheduled Target Capacity`	N/A
`policies:scheduled_target_capacity:default_settings:*`	Target capacity setting if none of the seasonal entries match the current time	N/A
`policies:scheduled_target_capacity:seasonal:`	List of seasonal entries	N/A
`policies:scheduled_target_capacity:seasonal:0:start_month`	Seasonal zeroth entry starting month	1-Jan…12-Dec
`policies:scheduled_target_capacity:seasonal:0:start_day`	Seasonal zeroth entry starting day	1-1st Day…31-31st Day
`policies:scheduled_target_capacity:seasonal:0:default_settings:*`	Seasonal zeroth entry default settings to run if none of the weekly entries match the current time	N/A
`policies:scheduled_target_capacity:seasonal:0:weekly`	Seasonal zeroth entry list of weekly entries	N/A
`policies:scheduled_target_capacity:seasonal:0:weekly:0:start_day`	Seasonal zeroth entry, weekly zeroth entry starting day	0-Monday, 7-Sunday
`policies:scheduled_target_capacity:seasonal:0:weekly:0:default_settings:*`	Seasonal zeroth entry, weekly zeroth entry default settings to run if none of the daily entries match the current time	N/A
`policies:scheduled_target_capacity:seasonal:0:weekly:0:daily`	Seasonal zeroth entry, weekly zeroth entry list of daily entries	N/A
`policies:scheduled_target_capacity:seasonal:0:weekly:0:daily:0:start`	Daily start time	HH:MM:SS
`policies:scheduled_target_capacity:seasonal:0:weekly:0:daily:0:default_settings:*`	Seasonal zeroth entry, weekly zeroth entry, daily zeroth entry settings to run	day

Configuration parameters marked with * refer to the target capacity settings.

8.2.1.8. Maintenance Policies

To configure maintenance automatic transition, set `func:bess_controller:api:1:configuration:staged:automatic_maintenance_transition` to `true`.

8.2.1.8.1. Constant Voltage Maintenance

The policy charges the system until the DC-bus voltage is above a specified voltage. Once the voltage is above the threshold, the system will continue to charge until a specified timeout expires. This can be used for lead acid equalization charges. For configuring this policy, a configuration file must be uploaded with the following settings.

Table 16. Constant Voltage Maintenance

Configuration key	Description	Units
`maintenance_policy`	`Constant Voltage Charge`	N/A
`policies:constant_voltage_charge:voltage_limit_v`	Pack voltage at which overcharging occurs	V
`policies:constant_voltage_charge:duration_s`	Duration of the overcharging	seconds
`policies:constant_voltage_charge:timeout_s`	Timeout before the policy is forced to end. Must be higher than duration_s	seconds
`policies:constant_voltage_charge:charging_power_kw`	Charging power	kW

8.2.1.8.2. Maintenance Pattern Policy

This policy charges/discharges the battery system based on pre-configured SOC setpoints. For configuring this policy, a configuration file must be uploaded with the following settings.

Table 17. Maintenance Pattern Policy Configuration

Configuration key	Description	Units
`maintenance_policy`	`Test Pattern`	N/A
`policies:maintenance_pattern:repeat_count`	Pattern repeat count	N/A
`policies:maintenance_pattern:repeat_forever`	Always repeat when patterns are complete	boolean (0/1)
`policies:maintenance_pattern:entries`	List of pattern entries	N/A
`policies:maintenance_pattern:entries:0:target_soc_percent`	Target state of charge for the first entry	percentage
`policies:maintenance_pattern:entries:0:power_kw`	Power to discharge/charge to reach target SOC for the first entry	N/A
`policies:maintenance_pattern:entries:0:timeout_s`	Time out before moving to the next pattern for the first entry	seconds

8.2.1.8.3. Constant Power Constant Voltage Maintenance Policy

This policy charges the pack up to a pre-configured pack voltage and then performs a constant voltage charge using a PID controller. For configuring this policy, a configuration file must be uploaded with the following settings.

Table 18. Constant Power Constant Voltage Maintenance Policy configuration

Configuration key	Description	Units
maintenance_policy	CPCV Maintenance	N/A
policies:cpcv_maintenance:initial_power_request_kw	Initial power charge scalar value	kW
policies:cpcv_maintenance:voltage_setpoint_v	Voltage setpoint at which constant voltage charge starts	V
policies:cpcv_maintenance:p_constant	P constant of the PID Control	N/A
policies:cpcv_maintenance:i_constant	I constant of the PID Control	N/A
policies:cpcv_maintenance:d_constant	D constant of the PID Control	N/A
policies:cpcv_maintenance:current_cut_off_a	Magnitude of current cut off	A
policies:cpcv_maintenance:current_offset_a	Maximum current change with every execution	A
policies:cpcv_maintenance:voltage_tolerance_v	Voltage tolerance around the voltage_setpoint	V

9. Using the Multi-Stack Operator Interface

9.1. Access the Multi-Stack Operator Interface

The Multi-Stack Operator Interface can be accessed from any computer/tablet with the latest Firefox or Chrome web browser.

9.1.1. External Computer Requirements

An external computer, like a laptop or a PC, is required to perform the setup steps. Ensure the following requirements have been met when selecting a computer.

9.1.1.1. Network Connection

It is recommended to connect the computer to the same network as the *External Ethernet* on the nController®. The default settings for the *External Ethernet* are DHCP, and requires the network to have an active DHCP server. Most corporate networks and routers will have a DHCP server.

If a DHCP capable network is not available, (i.e. if the computer must be connected directly to the nController® via an ethernet cable) it is recommended to initially connect to one of the *Internal Ethernet* ports. The nController® has a static IP default on the *Internal Ethernet* network with the following settings:

- Static IP: 192.168.1.10
- Net mask: 255.255.255.0

Ensure the computer networking is configured with a static IP of `192.168.1.x` where `x` cannot be `0`, `10` or `255` to enable communication with the nController®. It is recommended once the initial connection has been made, to configure the *External Ethernet* port to the desired settings and connect the computer to that network rather than using the *Internal Ethernet*. See Section 10.3, “Networks” for details on configuring network settings.

An internet connection (external network) is not required for the product to function. However it does use the Network Timing Protocol (NTP) to maintain its clock accuracy.

9.1.1.2. Computer OS Compatibility

Ensure the Operating System of the laptop/computer supports multi-cast DNS (mDNS).

Table 19. Operating Systems Supporting mDNS

OS	Version	Additional Software Required
Windows	10 and higher	N/A
Windows	8 and lower	Apple Bonjour
MacOS	10.2 and higher	N/A
Linux	N/A	Avahi

mDNS is also operational when a Static IP is configured.

Manual IP Discovery

In the event that the computer does not support mDNS, the MAC address for the external network port is labeled on the exterior of the nController®.

Look for this MAC address in the DHCP server to determine which IP address was assigned to the nController® and navigate to 'http://<ip-address>' from a compatible web browser rather than the mDNS URL http://ncontroller-<serial_number>.local.

9.2. The Dashboard Tab

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

Information icons are placed above each gauge, button, and status indicator in the Operator Interface. These icons guide the technician to the corresponding section of the manual that explains each element in detail.

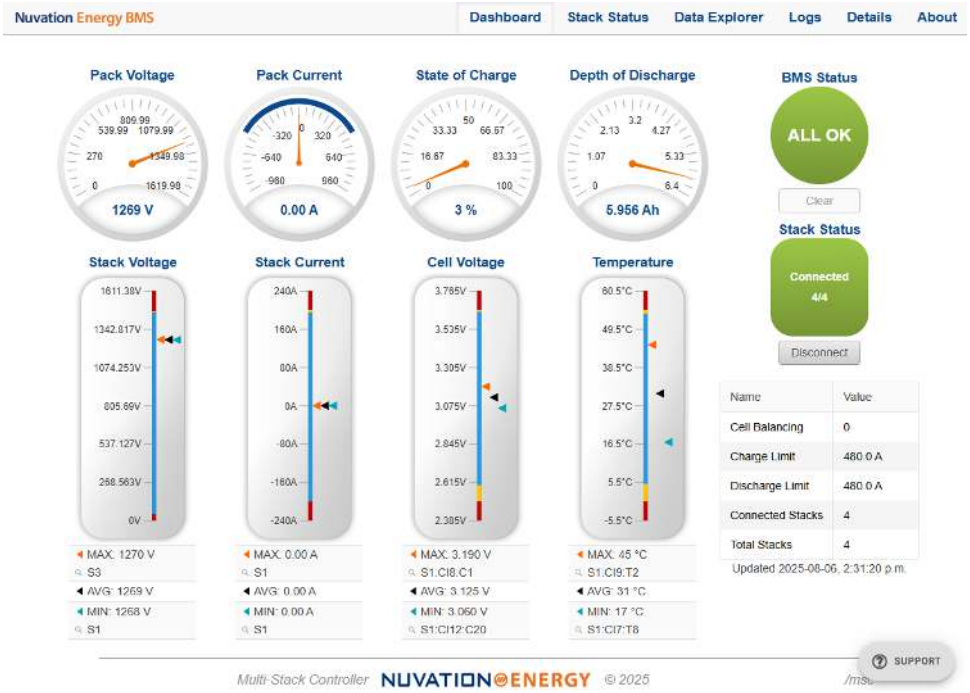


Figure 25. Nuvation Energy BMS Operator Interface Dashboard

9.2.1. Warnings and Faults

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

ALL OK	An ALL OK indicates that there are no faults or warning. This is the normal state for Nuvation Energy BMS.
Warning	A Warning indicates the state of the battery system has been detected outside of its normal operational range. The cause of the warning should be identified and a corrective action should be performed. For instance, if the warning is a thermistor temperature measurement has become too hot, the battery system should be cooled to bring the measurement back into the normal operational range.

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

9.2.2. Pack Voltage

The pack voltage radial gauge shows the average stack voltage of the stacks connected to the common DC bus.

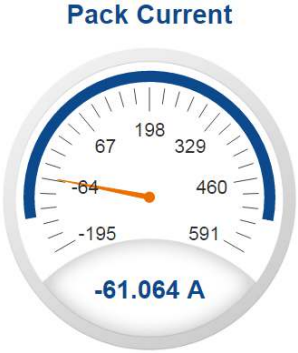
If no stacks are connected, a value of 0 V is displayed.

9.2.3. Pack Current

The pack current radial gauge shows the battery pack current which is the addition of current from each stack that is connected to the common DC bus. The maximum charge current limit and the maximum discharge current limit is also shown. The acceptable current range is visualized on the gauge by the blue arc. An absence of the blue arc indicates the battery pack cannot be charged or discharged in its present condition.

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

If no stacks are connected, a value of 0 A is displayed.



9.2.4. State-of-Charge

The State-of-Charge radial gauge shows the battery pack's State-of-Charge, which is an average State-of-Charge of the stacks connected to the common DC bus. The battery pack is empty when the State-of-Charge value is 0% and full when the State-of-Charge value is 100%.

If no stacks are connected, a value of 0% is displayed.

9.2.5. Depth-of-Discharge

The Depth-of-Discharge radial gauge shows how much energy has been taken out of the battery pack. It is the sum of all stacks connected to the common DC bus. 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 pack to fill it back up to 100% State-of-Charge.

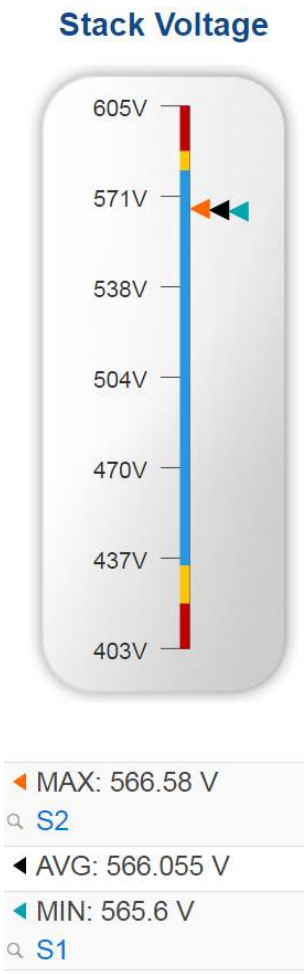
If no stacks are connected, a value of 0 Ah is displayed.

9.2.6. Stack Voltage

The stack voltage bar gauge shows the maximum, minimum, and average stack voltage measurements for all installed stacks within the battery pack.

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

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

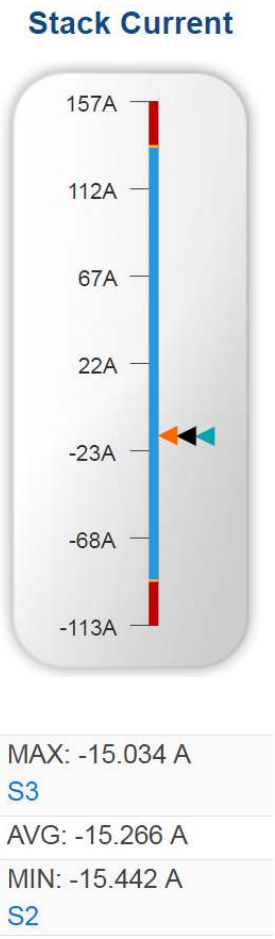


9.2.7. Stack Current

The stack current bar gauge shows the maximum, minimum, and average stack current measurements for all installed stacks within the battery pack.

The high stack discharge current and high stack charge current warning and fault thresholds are visualized on the gauge with yellow and red segments. The blue segment depicts the acceptable stack current range.

The maximum and minimum stack location in the pack and their current value are shown below the gauge, along with the average stack current value.



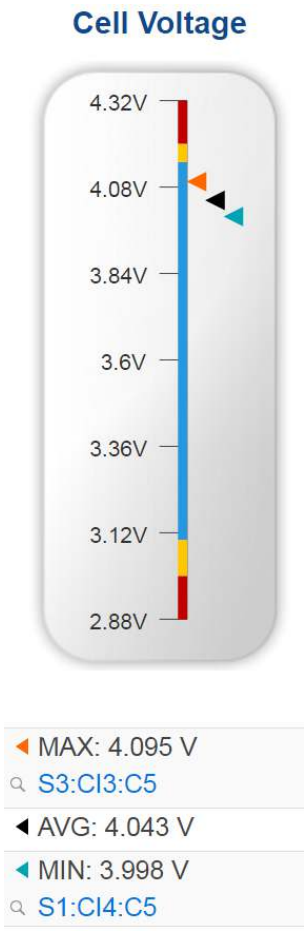
9.2.8. Cell Voltage

The cell voltage bar gauge shows the maximum, minimum, and average cell voltage measurements within the pack. Only data from installed stacks is aggregated.

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 pack and their voltage values are shown below the gauge, along with the average cell voltage value.



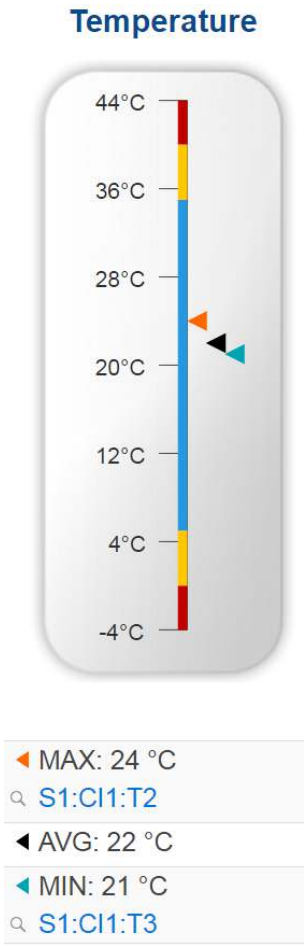
9.2.9. Cell Temperature

The temperature bar gauge shows the maximum, minimum, and average cell temperature measurements within the pack. Only data from installed stacks is aggregated.

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 pack and their temperature values are shown below the gauge, along with the average cell temperature value.



9.2.10. Nuvation Energy BMS Status

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

9.2.10.1. Operation Status

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

Figure 26. Three 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 the Section 9.3, "The Stack Status Tab" tab where the overall fault status as well as the fault status of each stack is displayed.

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

9.2.10.2. Connection State

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

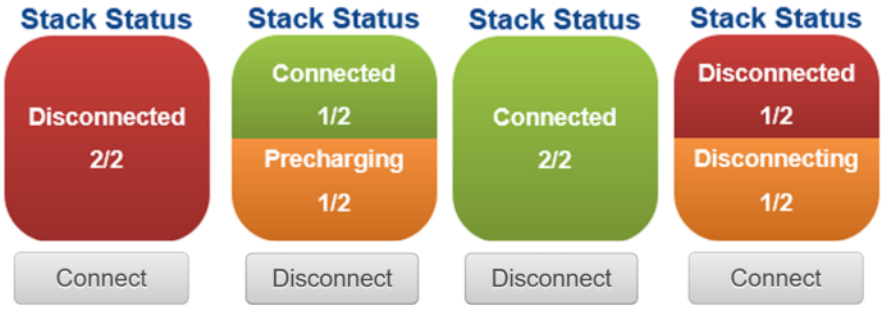


Figure 27. Four Nuvation Energy BMS Connection States

Stack Status of `Disconnected` in a red square indicates the Nuvation Energy BMS contactors are open, and the battery stack is unavailable to be charged or discharged.

`Pre-charging` in an orange square 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.

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

`Disconnecting` in an orange square indicates the Nuvation Energy BMS contactors are not yet opened so that the controller & PCS have time to ramp down power to avoid breaking under load, and the battery stack is unavailable 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.

9.2.10.3. Information Table

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

Name	Value
Cells Balancing	70
Charge Limit	-129.064 A
Discharge Limit	528 A
Connected Stacks	4
Total Stacks	4

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.

9.2.10.4. Last Update

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

If the communication with a Nuvation Energy BMS is lost, a notification banner appears at the top of the display screen. The information shown on the Dashboard represents the last data received and is no longer recent.

9.3. The Stack Status Tab

The Stack Status tab contains a detailed view for each installed stack in the Nuvation Energy BMS. The status of each stack is graphically represented on this page as shown below.

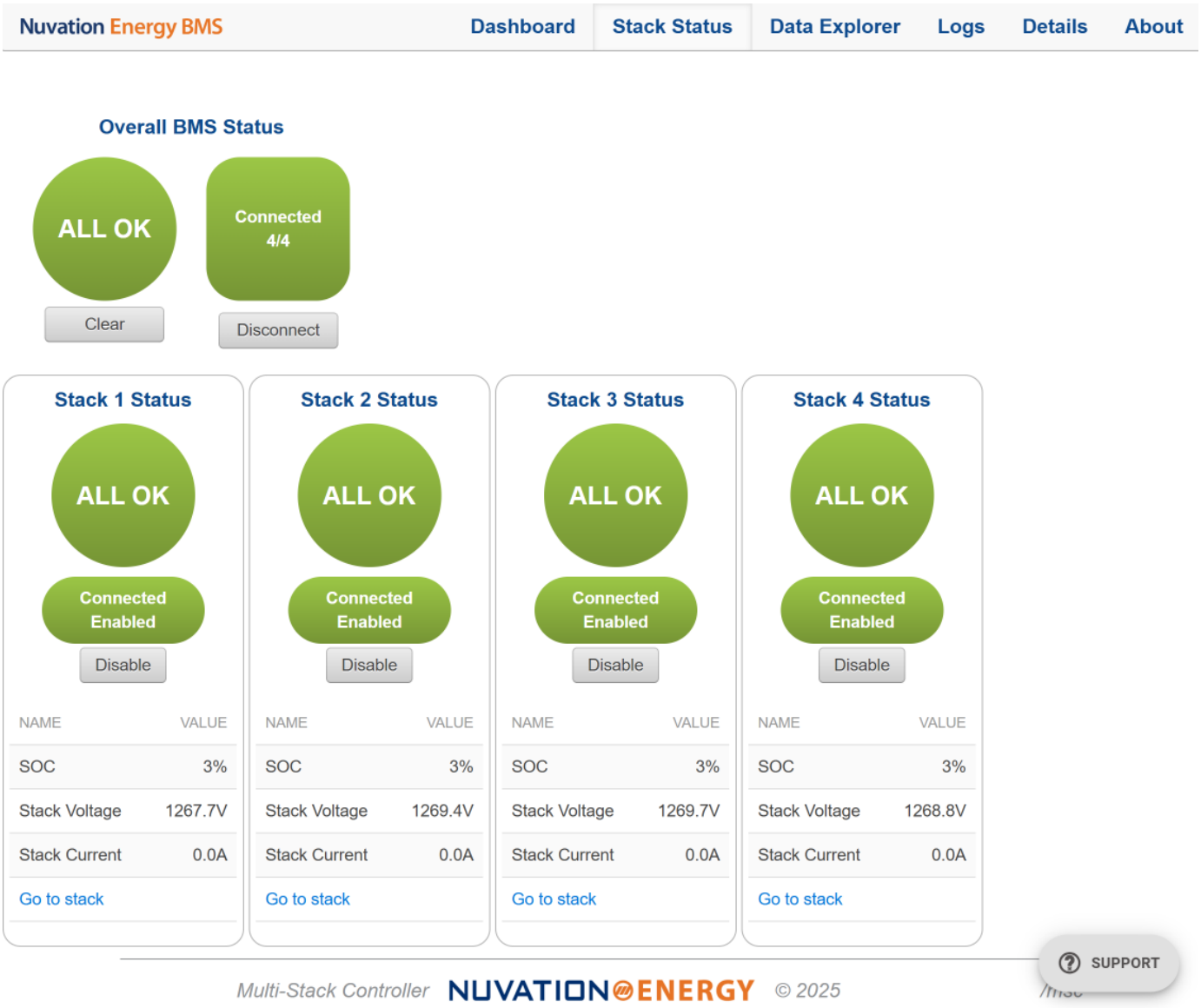


Figure 28. Multi-Stack Operator Interface Stack Status Tab Screenshot

The following information is available on each stack status:

- Overall stack status (OK/Warning/Fault/COM Fault/Service Lockout)
- Whether the stack is Enabled or Disabled
- Whether the stack is connected or disconnected to the DC bus.
- Stack measurements for SoC, voltage, and current
- Link to navigate to the stack operator interface

Figure 29. Multi-Stack Operator Interface Support Button

The SUPPORT button can be used to direct the operator to the Nuvation Energy website to contact Support.

9.3.1. Pack Connection/Status

The overall controller operation and connection status is displayed in the upper left corner of the screen. The behavior of this graphic is the same as described in the dashboard Section 9.2.10, "Nuvation Energy BMS Status". The BMS statuses of the pack or any stack is clickable to navigate to the Safety Accordion for details of all warnings and faults for the pack or a specific stack. A connect button is available when automatic pack connection has been enabled. When manual connection of a pack is configured, this connect button is removed.

9.3.2. Stack Enable and Connection

The *connected* and *enable* state of each stack is displayed in the red/green oval. A grey button labelled *Enable* or *Disable* is located below this status. The button will toggle the enable state of a stack. When a stack is changed from *enabled* to *disabled* state, the stack is immediately disconnected from the DC bus. When a non-faulted stack is toggled from *disabled* to *enabled*, there will be one of two possible outcomes:

1. If pack auto connection is enabled, the stack is considered a candidate for connecting to the pack.
2. If pack manual connection is configured, a connect button will appear on the stack status.

Please contact support@nuvationenergy.com for further details.

9.3.3. Stack Service Lockout

If a stack was to enter its *Service Lockout* state (refer to *Operator Interface Manual: Single-Stack* for details), the stack status will be updated as shown below.

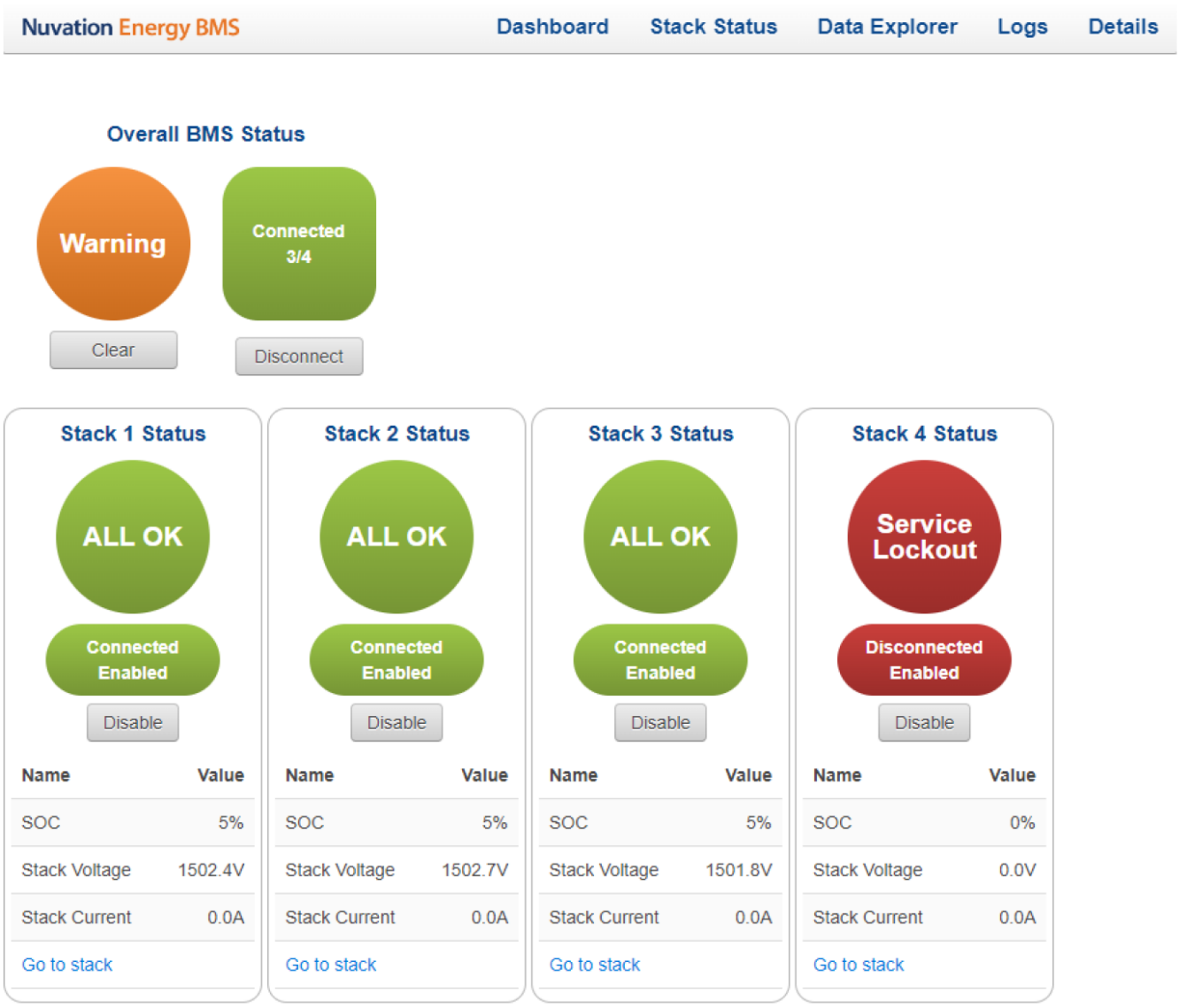


Figure 30. Stack in Service Lockout

9.3.4. Stack COM Fault

If there is a communication failure with a stack (i.e. the nController® loses communication with the stack), the stack status will be updated as shown below.

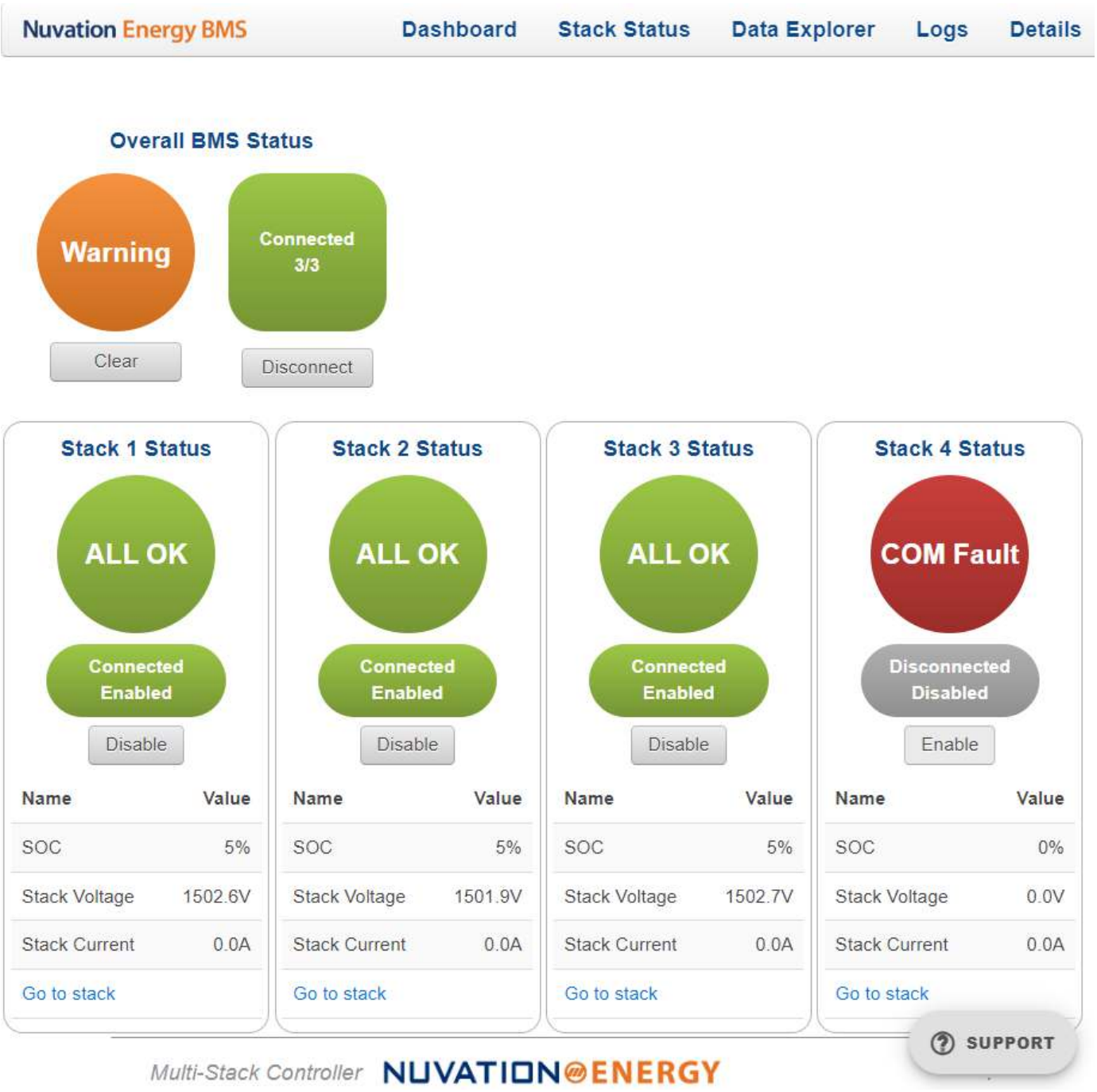


Figure 31. Stack with COM Fault

9.4. The Data Explorer Tab

The data explorer tab allows read-only access of the nController® information including pack and stack data and configuration.

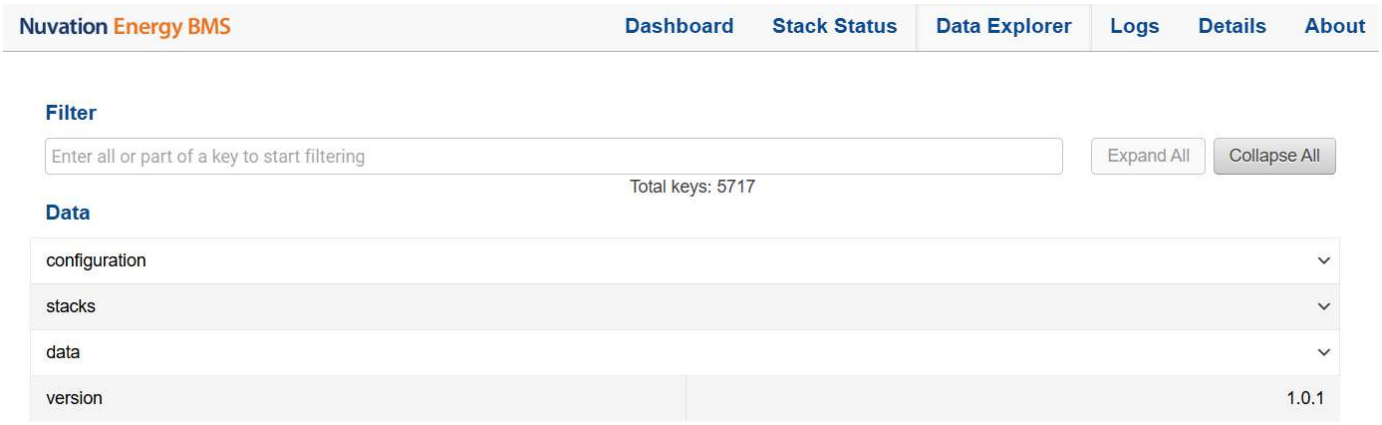


Figure 32. Data Explorer Screenshot

An alphanumerical search box can be used to filter through the data. The number of filtered keys appears at the bottom of the search box. The accordion can be expanded by clicking on the `Expand All` button to show the filtered keys along with their values. Clicking on the `Collapse All` button will collapse all accordions.

The `Expand All` button is disabled when the search yields too many keys. Filtering must be done before expansion.

Please contact support@nuvationenergy.com for details on the explorer keys.

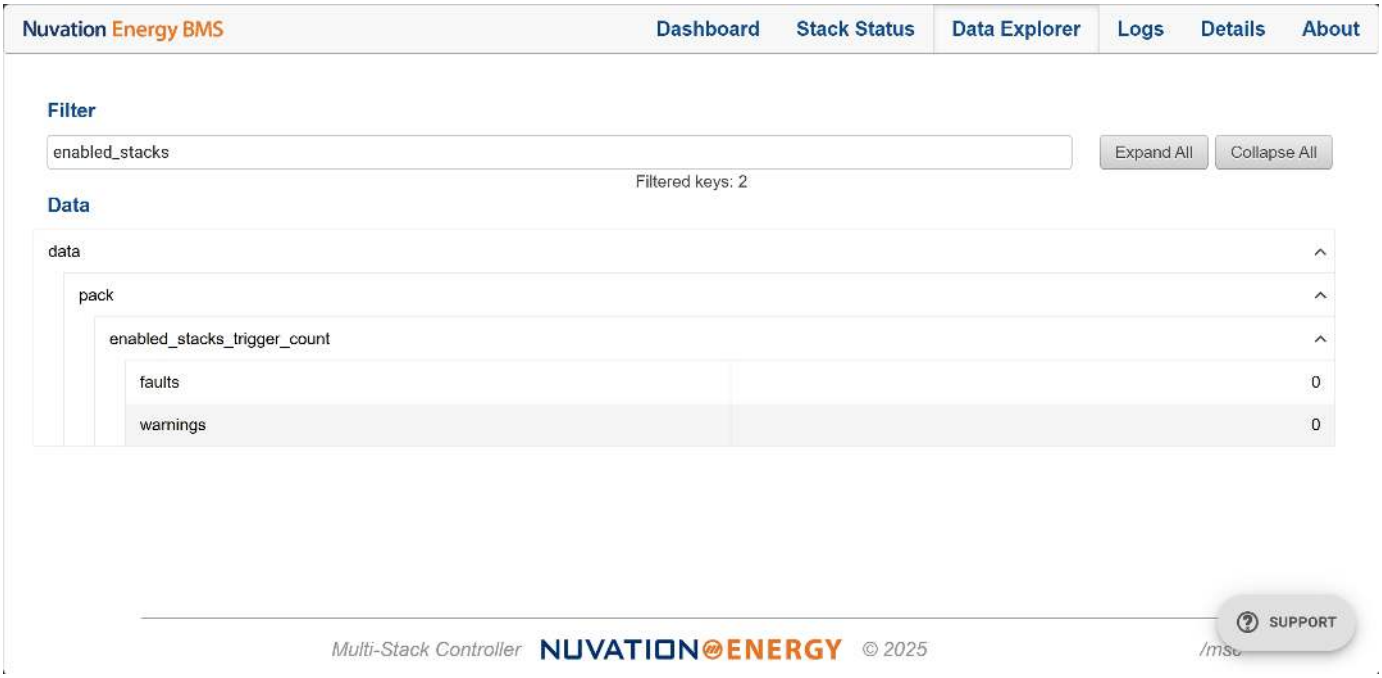


Figure 33. Data Explorer Filter

9.5. The Logs Tab

The logs tab can be used to download a csv file of the data measured by the nController® within a specific time range.

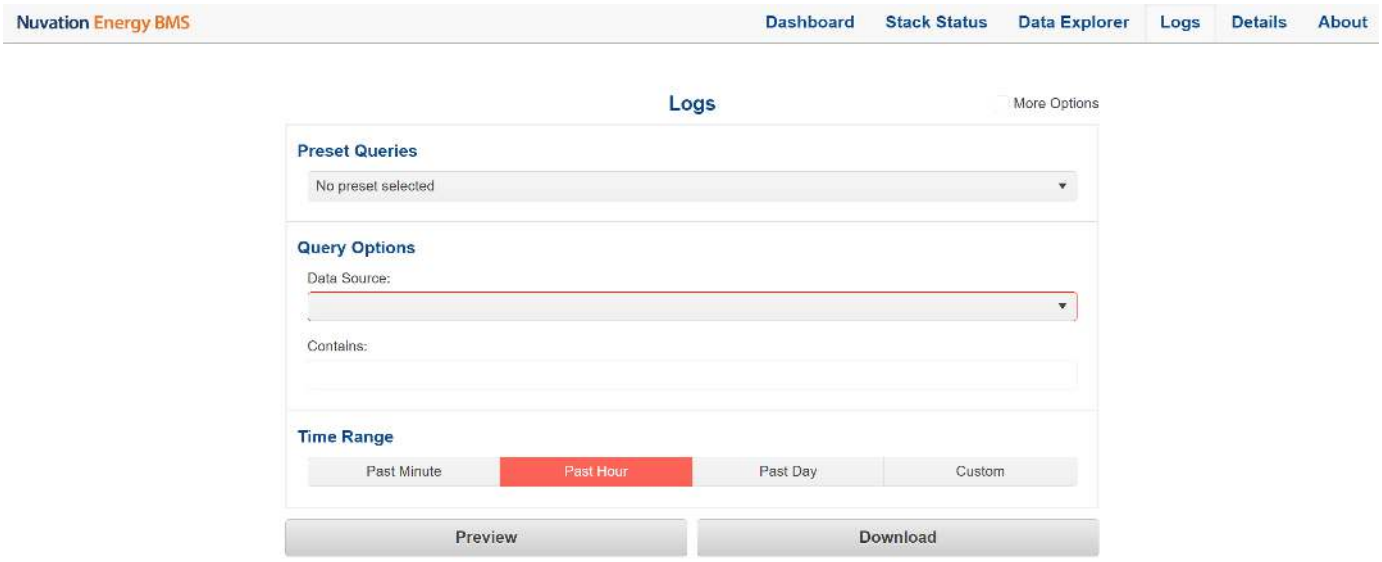


Figure 34. Logs Tab Screenshot

The following query options are available:

- All Measurements
- Aggregate 1 Minute Measurements
- All Text

Additionally, upon pressing "More Options" in the top right of this Operator Interface, more search features will be presented as seen in the following:

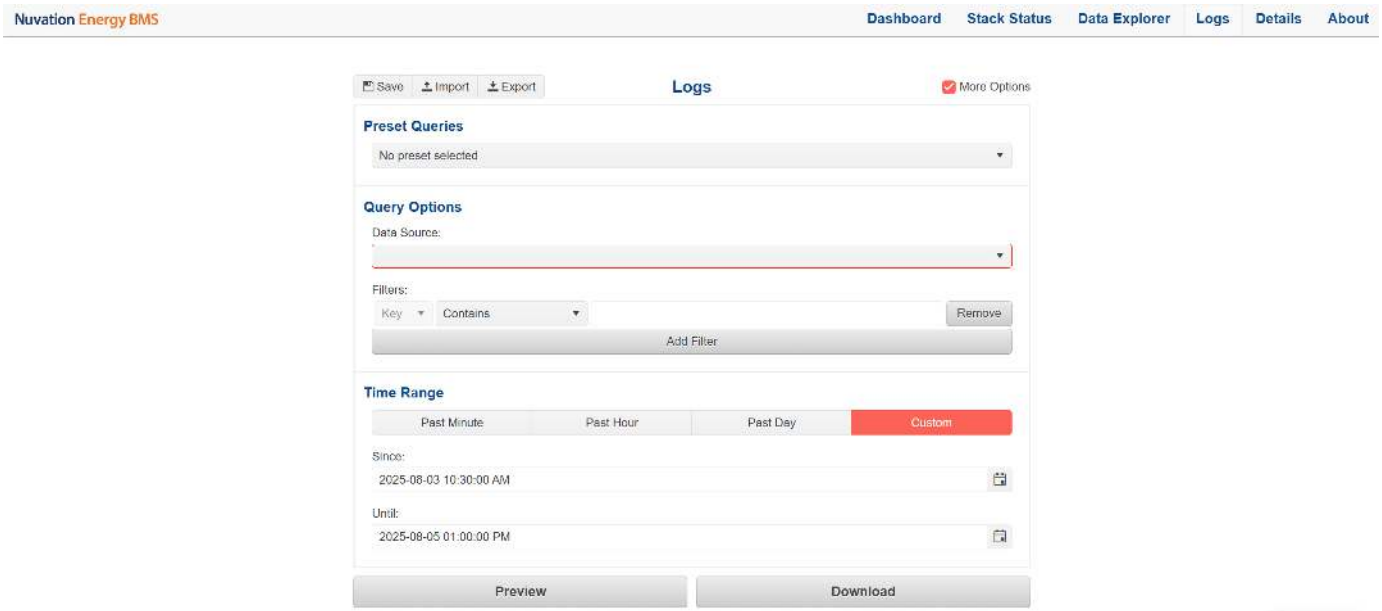


Figure 35. Logs Filtering

The filtering tool allows users to filter through the dataset using entered keys and then retrieve the filtered dataset. The available operations using this filtering function are: equals, contains, begins with, ends with, does not equal, does not contain, does not begin with, does not end with.

Furthermore, the `save`, `import`, and `export` buttons that appear on the top left of the Operator Interface allow the user to directly interact with the log query formatted as a JSON.

To download the data, choose from the time range options such as: past minute, past hour, past day and custom. In order to set a custom time range press on the timestamps and manually changing them to the desired dates, alternatively, pressing the calendar button for a visual representation. Clicking the `Download` button will download the csv file with the data for the selected dates. The format of the csv files will depend on the query, refer to Table 20, "Log File Format".

Table 20. Log File Format

Query	csv columns (time in milliseconds unix format)	Description	Retention period
All Measurements	time, key, value	Instantaneous data	7 days
Aggregate 1 Minute Measurements	time, key, average, max, min, count	1 minute data aggregates	Minimum 1 year, larger systems have shorter retention periods
All Text	time, key, value	Text data	Minimum 1 year, larger systems have shorter retention periods

For more information on the `key` column please contact support@nuvationenergy.com.

Downloaded files can be very large. It is recommended to download smaller time periods.

9.6. The Details Tab

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

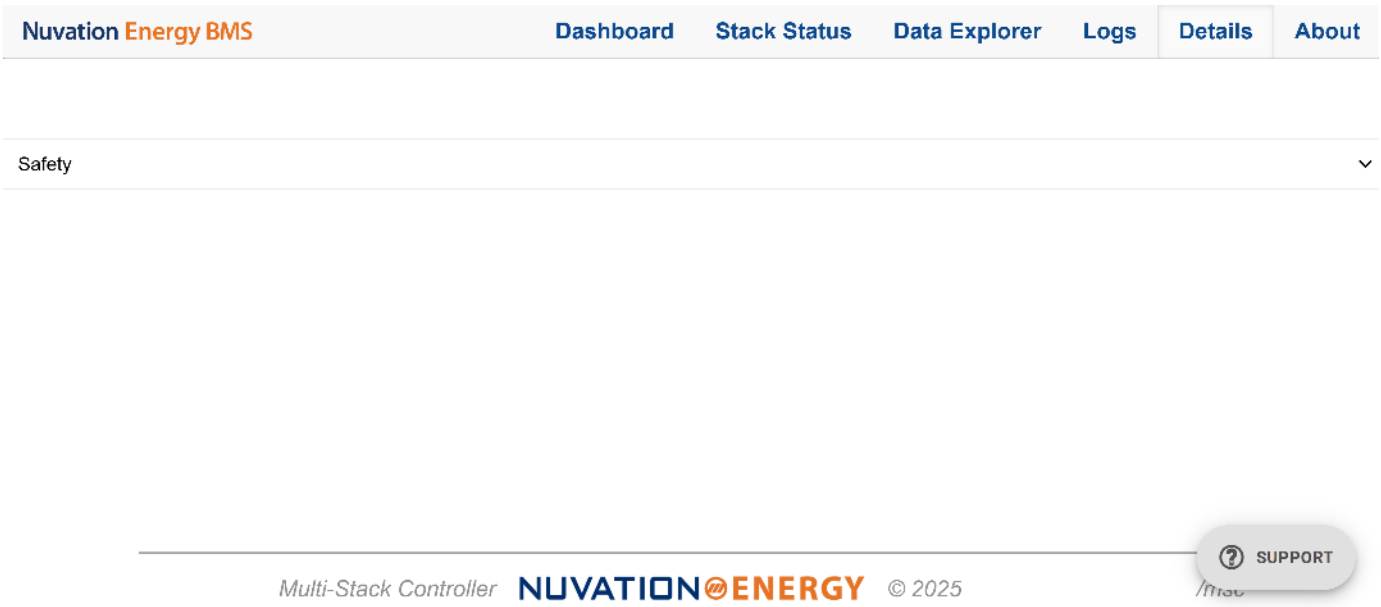


Figure 36. Nuvation Energy BMS Operator Interface Details Tab Screenshot

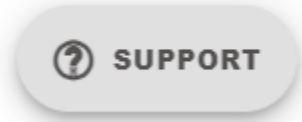


Figure 37. Operator Interface Support Button

The SUPPORT button can be used to direct the operator to the Nuvation Energy website to contact Support.

9.6.1. Safety

The safety accordion contains a summary list of the number of Nuvation Energy BMS faults and warnings active in the battery pack well as the overall status of the battery pack. An active fault is shown as `Tripped`. An active warning or user trigger is shown as `Triggered`. An fault or warning that has not completed its Self Check is shown as `Checking`. In normal operation, all warnings and faults should be clear and the battery stack can be charged and discharged.

Some faults and warnings at the pack level are due to stack level faults and warnings. To see a summary of the faults and warnings for all the stacks, navigate to the Stack Status Tab.

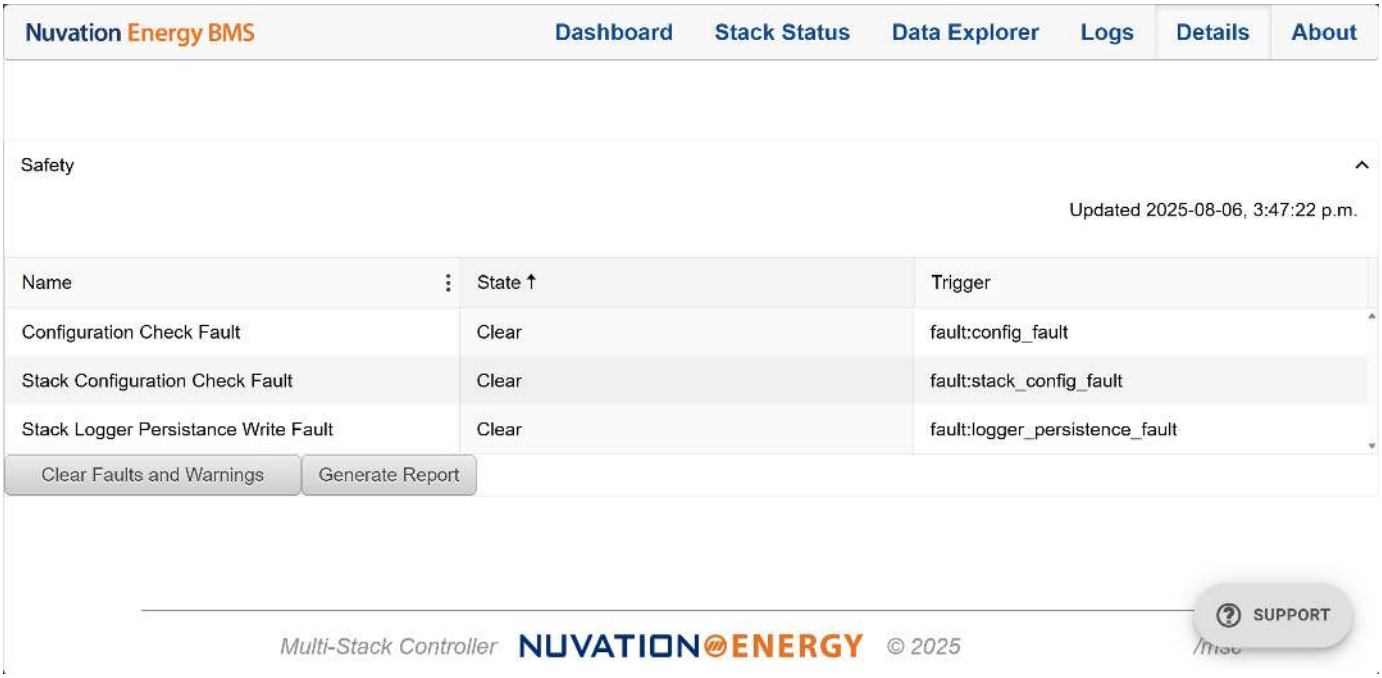


Figure 38. Safety Accordion in Details Tab

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.

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

10. Using the Platform Interface for the nController®

10.1. Accessing the Platform Interface via PC or Laptop

The Platform Interface accessible by navigating to http://ncontroller-<serial number>.local/platform and enables configuration and management of the nController®.

This URL can be accessed via a compatible computer.

Replace <serial number> with the nController® serial number - this can be found on a label on the exterior of the product. Below is an example of a product label, with the relevant serial number listed beside the field "SN".

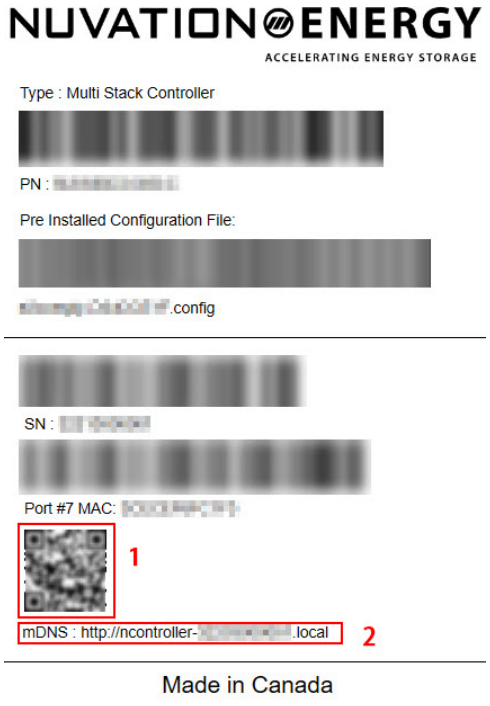


Figure 39. Sample Product Label

The above product label is an example, and the actual label will be different.

The Platform Interface currently supports the most recent versions of Mozilla Firefox and Google Chrome. Other browsers such as Internet Explorer are not supported.

Five main pages can be accessed by using the menu on the left side of the page:

- Functions
- Networks
- Backups

- Settings
- Logs

10.2. Functions

The Functions page is responsible for installing and upgrading application software.

It is highly recommended to only install/upgrade software under guidance from Nuvation Energy. Incorrectly installing/upgrading software could render the nController® inoperable.

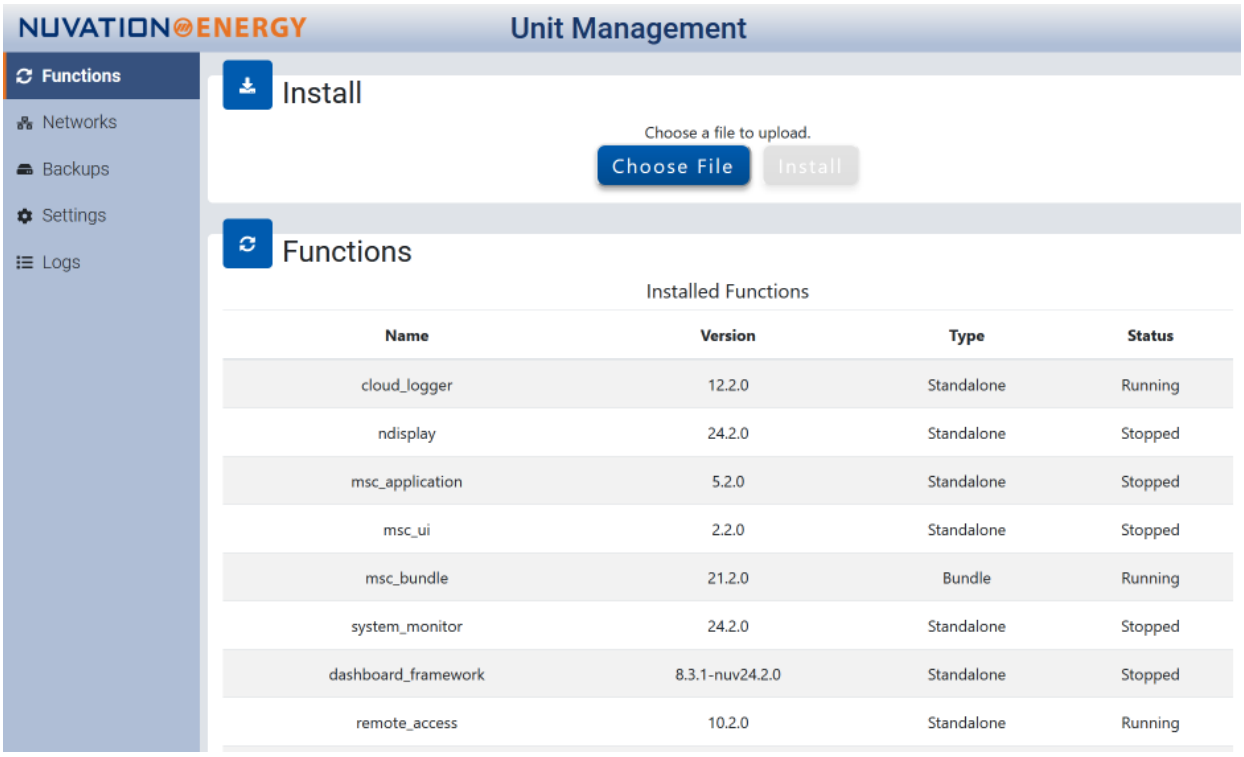


Figure 40. Nuvation Energy Platform Interface Function

The Functions card displays a list of all functions currently installed along with their respective versions.

It is normal for functions of type `Standalone` to display the `Stopped` status if one or more functions of type `Bundle` are present.

10.2.1. Installing a Function

1. Use the `Choose File` button to select a file with the extension `.fn`, `.fns`, or `.fnz`.
2. Click `Install` to install the function.

10.2.2. Upgrading a Function

1. Software may be upgraded in place by installing a newer version without uninstalling the older version.

10.3. Networks

The networks page shows the current network status of the nController® and allows for configuration of the network interfaces.

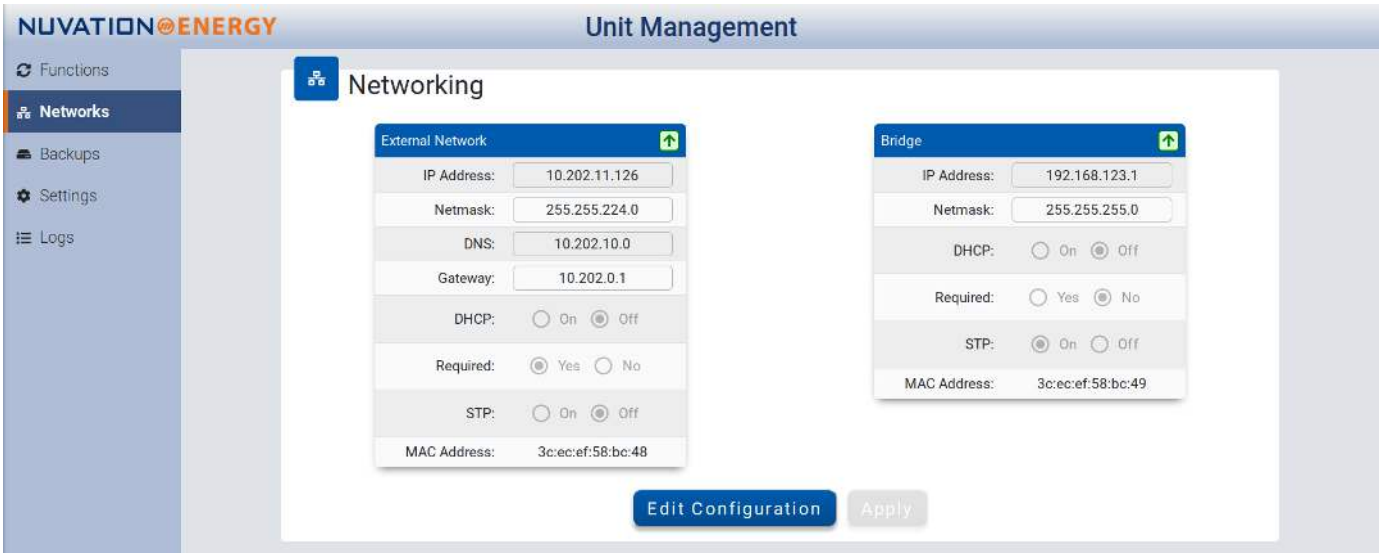


Figure 41. Nuvation Energy Platform Interface Networks

10.3.1. Networking

There are two configuration cards on this page:

- `External Network`: Controls the External Ethernet network on the nController®
- `Bridge`: Controls the Internal Ethernet network on the nController®

Each card shows the following information:

- `IP Address`: The current IP of the nController® on that network. Displays `Unknown` if no address is assigned.
- `Netmask`: The current netmask of the connected network. Displays `Unknown` if no address is assigned.
- `DHCP`: Whether DHCP will be used to acquire an address. Displays `On` for yes, and `Off` for no.
- `Required`: Whether the network interface is required to be up for proper operation. The nController® will wait for up to 2 minutes during power-up for interfaces marked 'required' to come up before continuing with system startup.
- `STP`: Spanning Tree Protocol. STP protects inadvertent loops within the network between grouped ports of the nController®. When enabled, a delay of 30 seconds occurs between a network interface gaining carrier and beginning to forward traffic.
- `MAC Address`: The MAC address of the nController® on the network. This address is not modifiable.
- *Arrow in the header*: A green up-arrow indicates the network interface has a carrier. A red down-arrow indicates no carrier.

If DHCP is disabled on the External Network, the following options will become available:

- `DNS`: The nameserver address to use for hostname lookups. If no DNS is available, set to `0.0.0.0` to disable.
- `Gateway`: The gateway address to access the Internet from this network. If no gateway is available, set to `0.0.0.0` to disable.

To communicate with the nController® while the gateway is set to 0.0.0.0, the nController® must be on the same subnet as the gateway.

Clicking the `Edit Configuration` button switches from showing the current status to showing the configured values. Values can be edited in the fields directly. The field will change from green to red if an invalid value is entered. Click `Apply` to apply and save the configuration.

The Platform Interface only supports configuring IPv4 networks. Operation of the nController® on IPv6-only networks is not supported.

The DNS server will receive queries for Internet addresses (for example NTP server addresses), so the DNS server should forward queries to root nameservers for proper operation.

If 2 or more networks overlap with each other, the message "Error: Conflicting Networks" will appear. This may cause undesirable operation.

When applying External network settings involving DHCP, the old IP address will not be released, and this may be reflected by the status IP address not matching the configured value. This ensures that the device will always be reachable. A reboot of the device will release the old address.

10.3.2. Configuration

For the External network settings, the IP address and other corresponding information are automatically assigned by the DHCP server. For the Internal network settings, it is recommended to keep the default parameters which are listed as follows:

- IP Address: 192.168.1.10
- Netmask: 255.255.255.0

10.4. Backups

The Backups page is responsible for creating and restoring a state for the nController®. That state includes configured settings, installed functions, and all logged data at the time of the backup creation.

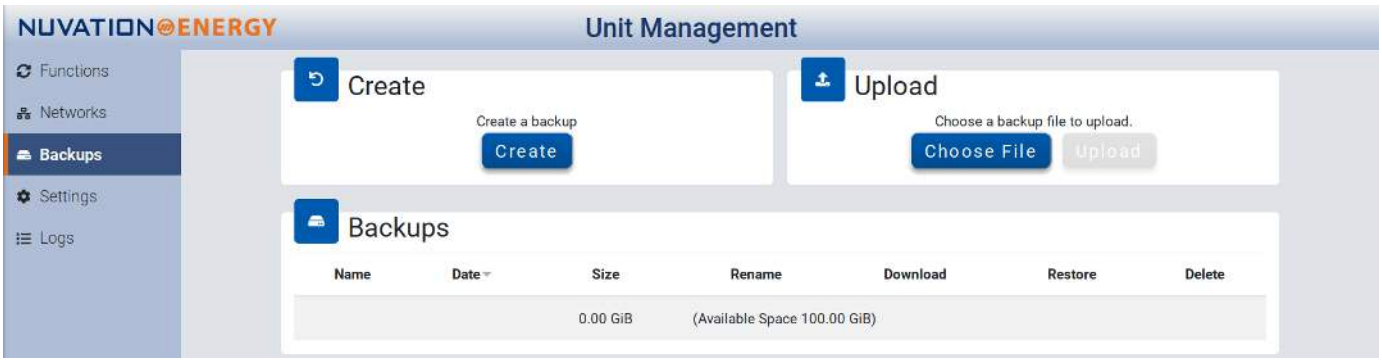


Figure 42. Nuvation Energy Platform Interface Backups

10.4.1. Create a System Backup

To create a backup of the current state of the system, click on `Create`. After a few minutes, a new backup file will be displayed under Backups with a name, creation date and size. To rename the file, click on `Rename` and input the name when prompted.

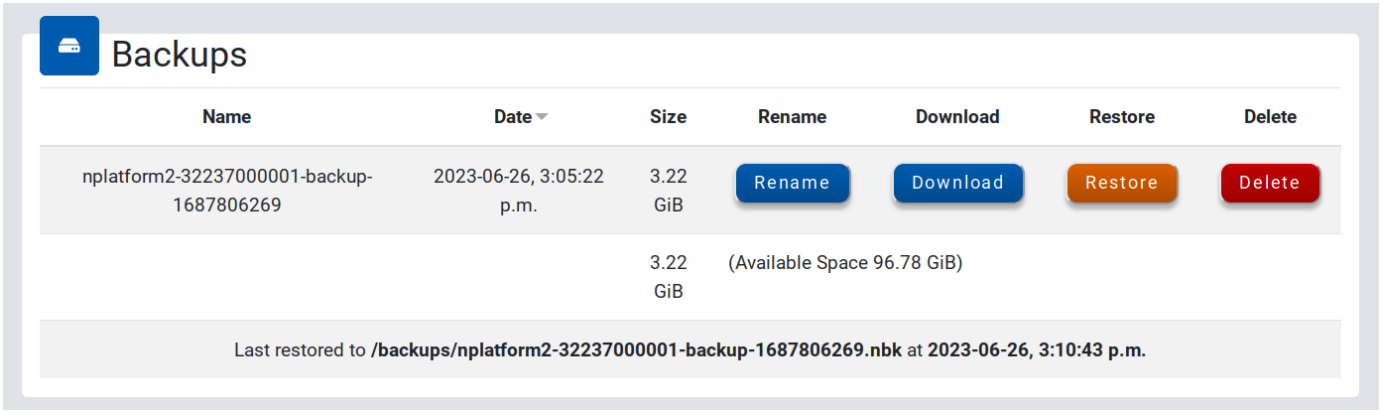


Figure 43. Nuvation Energy Platform Interface Backup File

A copy of the backup file can be downloaded on a compatible computer by clicking the `Download` button. At any time, a backup file can be deleted by clicking the `Delete` button.

10.4.2. Upload a Backup File

To upload an existing backup file, click on `Choose file` and select a `.nbk` file, then click the `Upload` button.

These files are relatively large and might take time to upload and download to the system.

10.4.3. Backup Restore

To restore the nController® to a previous state, click the `Restore` button that corresponds to the `.nbk` file with the desired state.

Restoring will delete all current data on the device. Other backups will not be deleted.

If restoring a backup that contains different network settings, you may have to navigate your browser to the new address if this does not happen automatically.

10.5. Settings

The settings page is responsible for the following:

- Upgrading the nController®
- Factory Resetting the nController®
- Rebooting and Powering off the nController®
- Setting Date, Time, and Timezone
- Importing and Exporting System Configuration Files

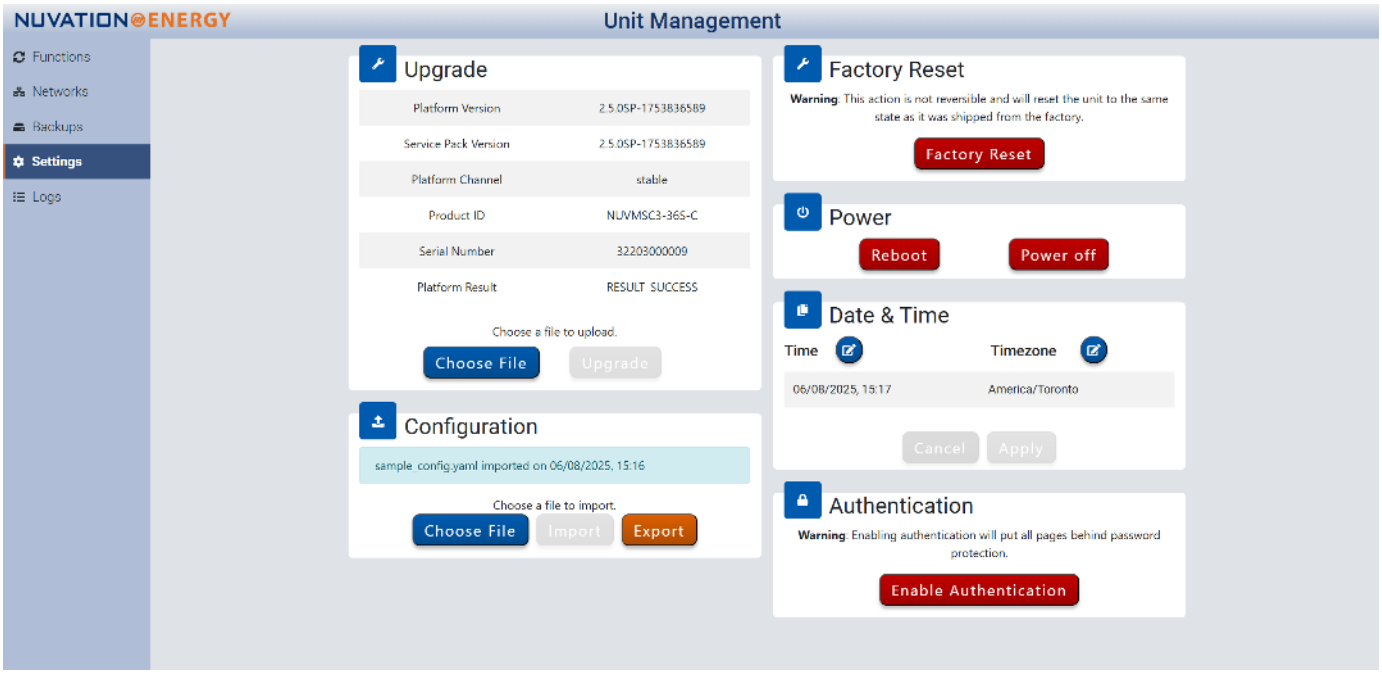


Figure 44. Nuvation Energy Platform Interface Settings

The above screenshot of the settings page is an example, the actual page will be different.

10.5.1. Upgrading the nController®

It is strongly recommended to only upgrade software under guidance from Nuvation Energy. Incorrectly upgrading software could render the nController® inoperable.

To upgrade the nController®, click the `Choose File` button to select a file with an extension of `.nup` or `.nosp`. Then, click `Upgrade` to upgrade the unit.

It is always recommended to create a backup before upgrading.

The upgrade process may take a couple minutes, so please wait for the upgrade

process to complete. The page will automatically refresh once the upgrade is complete.

Downgrading the nController® is not an accessible feature. To revert to a previous version, please use the backup/restore feature. Please contact support@nuvationenergy.com for assistance with downgrading.

10.5.2. Factory Reset the System

It is strongly recommended to only factory reset the unit under guidance from Nuvation Energy. This action is not reversible and will reset the unit to the same state as it was shipped from the factory. The unit will be restored to the same software package it was shipped with, using a backup file created at the factory.

To reset the nController®, click the `Factory Reset` button.

The reset process may take a few minutes, so please wait for it to complete. The page will automatically refresh once the reset is complete. However, the process will reset all network settings, so the nController® may no longer be reachable without adjusting the computer's network settings.

10.5.3. Rebooting the System

To reboot the nController®, click on the `Reboot` button and wait until the unit has been rebooted.

The Platform Interface will not be functional while the nController® is rebooting.

10.5.4. Powering off the System

To power off the nController®, click on the `Power off` button. Alternatively, pressing the physical power button on the unit will have the same effect. Following a shutdown, the physical power button can be pressed to restart the unit.

Before removing power from the nController®, ensure that the unit has been powered off either through the Platform Interface or the physical power button. Abruptly removing power while the unit is still on may lead to internal file corruption or damage causing the unit to become inoperable.

10.5.5. Setting the Date, Time, and Timezone

The Timezone and Date/Time are individually configurable.

Note: These date and time settings will be overwritten by the NTP server if it is set up and connected. See Section 10.5.5.1, "NTP Client Configuration" for more details.

Setting the Date and Time

1. Click the blue edit-button to the right of the `Time` label.
2. Select the date and time by clicking on the field that is shown.
3. Click `Apply` to save the changes or `Cancel` to discard the changes.

Setting the Timezone

1. Click on the blue edit-button to the right of the `Timezone` label
2. Select the desired timezone from the dropdown list.
3. Click `Apply` to save the changes or `Cancel` to discard the changes.

10.5.5.1. NTP Client Configuration

The nController® runs an NTP client to maintain clock accuracy. By default, this client is connected to servers in the pool.ntp.org domain and requires an internet connection to function.

For deployments where internet access is not available or customers require use of a specific NTP server, an alternative NTP server IP address can be configured.

In these cases, it is recommended to either:

1. Allow NTP traffic from the internet to the nController® to ensure accurate time synchronization, or
2. Set up an accessible internal NTP server and contact Nuvation Support to configure the product to use that NTP server

10.5.5.2. Coin Cell Battery for Time Keeping

The nController® includes a coin cell battery that maintains the system clock when the device is powered off or when no NTP server is accessible. This ensures the system maintains accurate time between power cycles without requiring immediate NTP synchronization upon startup.

The coin cell lifespan is 3 years if the device is unpowered, and 10 years if the device is powered. Once the coin cell is depleted, the product will need to re-synchronize time after being powered off with an NTP server, or be manually updated through the nController® interface.

10.5.6. Configuration Import and Export

Configuration files are `YAML` files that contain settings to be uploaded to the system.

Please contact support@nuvationenergy.com for more information on configuration files.

To upload a configuration file:

1. Click the `Choose File` button.
2. Select a `YAML` configuration file.

3. Click the `Import` button. A notification box will appear indicating the configuration was uploaded.

> To get the configuration file currently uploaded on the system. Click the `Export` button.

10.5.7. Authentication

The enabling of authentication on the Platform Interface will require users to login with a username and password. Additionally with authentication enabled, all traffic will be encrypted with HTTPS using Basic Authentication.

How to enable/disable authentication

Authentication can be enabled or disabled by administrators in the settings page `platform/settings`.

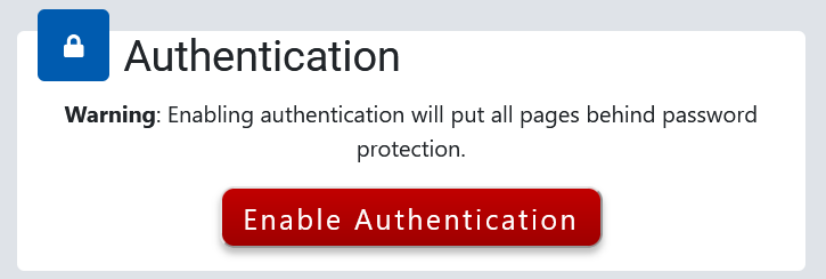


Figure 45. Platform Interface Enable Authentication Button

1. Click on the `Enable Authentication` button.
2. Set up a password. Requirements for the password are listed below. The username will be `admin`.
3. Authentication will be enabled and an admin user will be prompted to login.
4. Once authentication is enabled it can be disabled after logging in.

> Disabling authentication clears the current password.

Figure 46. Platform Interface Disable Authentication Button

Password requirements

1. Password should be at least 8 characters long.
2. Password must contain at least one lowercase letter (a-z).
3. Password must contain at least one uppercase letter (A-Z).
4. Password must contain at least one number (0-9).

5. Password must contain at least one special character (!@#$%^&*-_+/*).

When are passwords required

When authentication is enabled, the Platform Interface will require a password for all pages and API requests.

What should I do if I forget my password?

The nController® can be factory reset to remove the password if it was forgotten. This action is not reversible and will reset the unit to the same state as it was shipped from the factory. The unit will be restored to the same software package it was shipped with, using a backup file created at the factory. See: Factory Reset the System

It is not possible to retrieve the password once it has been set. Please contact support@nuvationenergy.com for further assistance in case the password is lost.

10.6. Logs

The logs page allows debugging information to be downloaded from the nController®. These logs can allow Nuvation Energy to more easily assist with support.

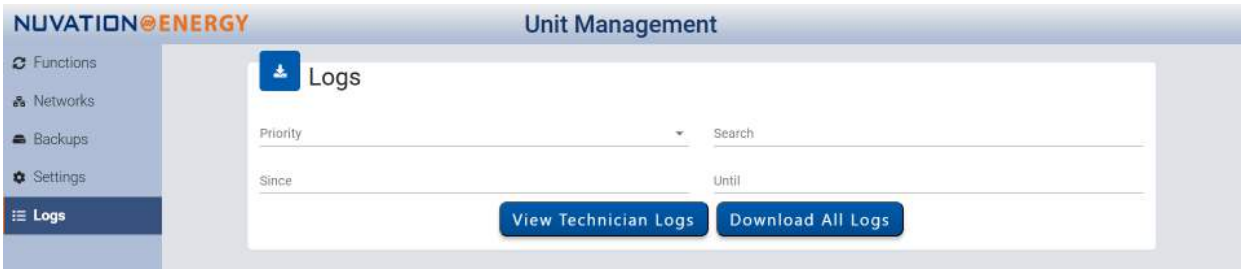


Figure 47. Nuvation Energy Platform Interface Logs

10.6.1. Downloading Logs

Set the `Priority`, `Search`, `Since`, and `Until` options as requested by Nuvation Energy support and click `Download All Logs`. Save the resulting `.logx` file to your computer so it can be relayed to Nuvation Energy support. Setting the query options and clicking the `View Technician Logs` button will allow the user to preview and download public log messages.

11. SunSpec Energy Storage Models Structure and Nomenclature

This section is a clarification of terms used to describe SunSpec Energy Storage Models. It is used to understand the terminology in the spreadsheet presented in the previous section.

11.1. Points

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

For example, the SunSpec 802 model has the `Evt1` point which is of type `bitfield32`. In this case, the point spans 2 Modbus registers and so a request to read this point must read 2 Modbus registers.

11.2. Repeating SunSpec models

The number of the SunSpec models 804 and 805 will vary depending on the stack and cell interface counts in the system. To ensure an accurate SunSpec model, the nController® must be configured with the following parameters:

- Maximum number of installed stacks
- Maximum number of Cell Interface modules per stack
- Maximum number of cells per Cell Interface

For example, a four-stack system with four Cell Interface modules per stack will have four 804 models and sixteen 805 models.

These parameters are pre-configured for the maximum size of the system. Please contact support@nuvationenergy.com in case any of the above parameters are changed.

11.3. Fixed/Repeating Blocks

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

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

For a multi-stack system, the number of repeating blocks will be determined by the maximum

number of stacks/strings, Cell Interface modules, and installed cells configured on the system:

- Stack repeating blocks are in models 803 and 804.
- Cell Interface repeating blocks are in models 804 and 805.
- Cell repeating blocks are in model 805.

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

11.4. Bitfields and Enumerations

Several points implemented by the nController® are bitfields and enumerations. These points often specify status information or are used for control. For example, the bitfields `EvtVnd1` and `EvtVnd2` from the 802 model contain fault and warning statuses for the nController® respectively. Other 802 points such as `SetOp` is read-write and is used to connect or disconnect the battery stacks. Details on 800 series bitfields and enums implemented by the nController® can be found in the *Nuvation-Energy-Multi-Stack-Controller-Sunspec-Modbus-Examples-r1.1.xlsx* Excel document.

11.5. Unimplemented Points

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

Table 21. Unimplemented Point Values

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

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

11.6. Scale Factors

All SunSpec points are integer values (signed or unsigned). To account for different range values beyond the data size (i.e. greater than 65535 for an unsigned 16 bit value) or some fractional value (i.e. 1.1), some SunSpec points have scale factors associated with them. The scale factor is another point within the model which contains a signed integer exponent of base 10 that scales a corresponding point value. For example, a scale factor of 2 would result in multiplying the corresponding point by 100. Likewise a scale factor of -3 would result in a scale factor of 0.001.

11.7. Diagnostic and Logging Data Rate Limits

In the following table, the 'Limit' defined is not a maximum. Software support is possible for more than the limits, but functionality around control loops, data rates, and guarantees on specific features may not be met with larger values on the limits. For diagnostics and logging data rate limits, the advertised data rates are:

Table 22. Diagnostic and Logging Data Rate Limits

Field	Max Data Rate (points/s)	Stack Scan Rate (s)	Cell Scan Rate (s)	Thermistor Scan Rate (s)	Points/Scan per Stack
Absolute Maximum Data Rates	14000	-	-	-	-
1-7 stack, 480 cells, 240 thermistors	-	1.0	2.0	8.0	1867
8 stacks, 480 cells, 240 thermistors	-	1.0	3.0	8.0	14936
12 stacks, 480 cells, 240 thermistors	-	1.0	4.0	16.0	22404
16 stacks, 480 cells, 240 thermistors	-	1.0	6.0	16.0	29872

12. Modbus Protocol Support

The nController® provides support through a Modbus TCP server. The nController® implements Information Models defined by the SunSpec Energy Storage Models to create the Modbus register mappings.

The exact Modbus mappings of points and addresses in CSV format can be downloaded in a web browser by navigating to http://ncontroller-<serial number>.local/sunspec/map/sunspec_map.csv.

12.1. Modbus TCP

This protocol is used for communications over TCP/IP networks. All register data is transmitted as big endian (most significant byte first).

12.2. Implemented SunSpec Energy Storage Models

The SunSpec Models and Modbus maps contains a number of "models" that can be implemented by vendors to describe an energy asset at various levels of detail.

The models implemented by nController® are described in the sections below.

Additional details regarding SunSpec specifications and models are available at: https://sunspec.org/sunspec-specifications/

SunSpec information Model files can be found at: https://github.com/sunspec/models

12.2.1. Common Model

This model primarily contains manufacturer and product-model identification information. Refer to the resource linked above for more information.

Table 23, "Common Model Points" describes the points of the Common Model as implemented in the nController®.

Table 23. Common Model Points

Point Name	Address	Description	Note
SunSpec_ID	0	'SunS' Identifier	Set to 0x53756e53
ID	2	Identifies Common Model Block	Set to 0x0001
L	3	Length of block	Set to 66
Mn	4	Device Manufacturer	Set to "Nuvation Energy"
Md	20	Device Model Number	Set to "nController®"
Opt	36	Options	Set to nController® ID
Vr	44	Version Information	Set to Platform version
SN	52	Device Serial Number	nController® SN
DA	68	Device Address	Set to 0x1

12.2.2. 701 (DER AC Measurement Model)

This model is used to describe a distributed energy resource. The DER AC Measurement information model primarily contains general data of the ESS at the highest level which includes status and alarm information. All mandatory and most optional points are implemented.

Relevant AC components.

Table 24. Relevant AC Component Registers

Field	Description
W	Total active power which is positive for DER generation and negative for absorption.
VA	Total apparent power.
Var	Total reactive power.
PF	Power factor for which the sign of power factor should be the sign of active power.
A	Total AC current.
LLV	Line to line AC voltage as an average of active phases.
LNV	Line to neutral AC voltage as an average of active phases.
Hz	AC frequency.

12.2.3. 702 (DER Capacity Model)

The DER Capacity information model contains additional information regarding the power ratings for a distributed energy resource. Note that this model has read-only values. This model is also applied to the ESS, which corresponds to the PCS and battery bank on-site.

12.2.4. 703 (DER Enter Service Model)

The System Model-Specific Data fields are unique to each device and are required to be set prior to the device being placed into service. These fields may include information such as the device's name, serial number, and operating mode.

Each data field is identified by a unique register address and data type, which allows for easy integration with different types of hardware and software platforms. The SunSpec Model 703 provides a standardized and interoperable data model for entering DER systems into service, and enables the integration of different types of DER components such as inverters, energy storage systems, and smart controllers.

12.2.5. 704 (DER AC Controls Model)

The Inverter Model-Specific Data fields provide information on the AC side of the grid, including AC power output, AC voltage, AC current, AC frequency, power factor, and other operational and control settings. The Meter Model-Specific Data fields provide information on the AC power flow, including AC

voltage, AC current, AC power, power factor, and other operational and control settings. The SunSpec Model 704 provides a standardized and interoperable data model for monitoring and controlling DER systems on the AC side of the grid.

12.2.6. 711 (DER Frequency Droop Model)

Droop control is not available through this model in the nController®. Any droop features should be configured in the PCS separately from the nController®.

12.2.7. 713 (DER Storage Capacity Model)

The battery model-specific data fields provide information on the current state and capacity of the DER energy storage system, including the current SOC, the current charging or discharging current, the battery voltage, and the temperature. These data fields allow for the monitoring and control of the energy storage system, including charging and discharging operations.

Table 25. Capacitor SOC/SOH Registers

Field	Description
SoC	State of charge of the DER storage.
SoH	State of health of the DER storage.

12.2.8. 714 (DER DC Measurement Model)

The module model-specific data fields provide information on the DC voltage, DC current, DC power output, and temperature. These data fields allow for the monitoring of the DC side of the DER system, and provide information on the available power output of the photovoltaic modules.

Table 26. Relevant DC Component Registers

Field	Description
DCA	Total DC current for all ports.
DCW	Total DC power for all ports.
Prt.DCA	DC current for the port.
Prt.DCV	DC voltage for the port.
Prt.DCW	DC power for the port.

12.2.9. 715 (DER Control Model)

The DER control model-specific data fields provide basic control of the PCS part of the DER components. Only two points are implemented:

1. `OpCtl`: it allows the switching of the system into ON or OFF modes. The OFF mode ensures no power flow through the system, see table below for more details
2. `AlarmReset`: it is used to reset any latched alarms in the system

Table 27. Enum for point OpCtl

Enumeration Value	Function
0	Disables power flow by setting the system policy to offline
1, 2, 3	Enables the system by setting the system policy to the configured default policy

12.2.10. 801 (Energy Storage Base Model)

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

12.2.11. 802 (Battery Base Model)

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

The Modbus address of this model is 40094.

12.2.12. 803 (Lithium-Ion Battery Model)

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

12.2.13. 804 (Lithium-Ion String Model)

This model describes a lithium-ion battery stack and cell interfaces. This provides a communication interface with the individual stacks along with statistics about their cell interfaces. All mandatory points are implemented.

12.2.14. 805 (Lithium-Ion Module Model)

This model describes individual cells within a lithium-ion battery stack cell interface. It summarizes the cells balancing states, voltages, and cell temperature statistics in the cell interface. All mandatory points are implemented.

12.2.15. Nuvation Energy Model

This model implements custom fields that are applicable to Nuvation Energy equipment and do not currently exist in the set of SunSpec standard models.


```
{
    "group": {
        "desc": "Nuvation Energy distributed energy resource vendor model",
        "label": "Nuvation Energy DER",
```

```
        "name": "nuv_der",
        "points": [
            {
                "desc": "Model identifier",
                "label": "Model ID",
                "mandatory": "M",
                "name": "ID",
                "static": "S",
                "type": "uint16",
                "value": 61000,
                "size": 1
            },
            {
                "desc": "Model length",
                "label": "Model Length",
                "mandatory": "M",
                "name": "L",
                "static": "S",
                "type": "uint16",
                "value": 17,
                "size": 1
            },
            {
                "desc": "Amount of energy that can be absorbed",
                "label": "Energy Absorption Capacity",
                "name": "AbsCapWh",
                "type": "uint32",
                "sf": "Wh_SF",
                "size": 2,
                "units": "Wh"
            },
            {
                "desc": "Amount of energy available for injection",
                "label": "Energy Injection Capacity",
                "name": "InjCapWh",
                "type": "uint32",
                "sf": "Wh_SF",
                "size": 2,
                "units": "Wh"
            },
            {
                "desc": "Energy scale factor",
                "label": "Energy Scale Factor",
                "name": "Wh_SF",
                "static": "S",
                "size": 1,
                "type": "sunssf"
            },
```

```
            {
                "desc": "Watchdog Set timer",
                "label": "Watchdog Set timer",
                "name": "WatchdogSet",
                "type": "uint16",
                "sf": "Watchdog_SF",
                "size": 1,
                "units": "Secs",
                "access": "RW"
            },
            {
                "desc": "Watchdog FB timer",
                "label": "Watchdog FB timer",
                "name": "WatchdogFB",
                "type": "uint16",
                "sf": "Watchdog_SF",
                "size": 1,
                "units": "Secs"
            },
            {
                "desc": "Clear Fault",
                "label": "Clear Fault",
                "name": "ClrFault",
                "type": "uint16",
                "size": 1,
                "access": "RW"
            },
            {
                "desc": "Recharge maint OK (0: Not allowed; 1: Allowed)",
                "label": "Recharge maint ok",
                "name": "MaintMode",
                "type": "uint16",
                "size": 1,
                "access": "RW"
            },
            {
                "desc": "System status word",
                "label": "System status word",
                "name": "SysStatus",
                "type": "uint32",
                "size": 2
            },
            {
                "desc": "Frequency Set Point",
                "label": "Frequency Set Point",
                "name": "Fset",
                "type": "uint16",
                "sf": "Hz_SF",
```

```
            "size": 1,
            "units": "Hz",
            "access": "RW"
        },
        {
            "desc": "Rated Frequency",
            "label": "Rated Frequency",
            "name": "Frated",
            "type": "uint16",
            "sf": "Hz_SF",
            "size": 1,
            "units": "Hz"
        },
        {
            "desc": "Number of cells being balanced",
            "label": "Number of cells being balanced",
            "name": "NCellBal",
            "type": "uint16",
            "size": 1
        },
        {
            "desc": "Frequency scale factor",
            "label": "Frequency Scale Factor",
            "name": "Hz_SF",
            "static": "S",
            "size": 1,
            "type": "sunssf"
        },
        {
            "desc": "Watchdog scale factor",
            "label": "Watchdog Scale Factor",
            "name": "Watchdog_SF",
            "static": "S",
            "size": 1,
            "type": "sunssf"
        },
        {
            "desc": "Set the DER mode",
            "label": "Set the DER Mode",
            "name": "SetDERMode",
            "size": 1,
            "symbols": [
                {
                    "desc": "The DER is operating as part of a larger grid.",
                    "label": "Grid Attached",
                    "name": "GRID_ATTACHED",
                    "value": 0
                },
```

```
                {
                    "desc": "The DER is providing the grid.",
                    "label": "Islanded",
                    "name": "ISLANDED",
                    "value": 1
                }
            ],
            "type": "uint16",
            "access": "RW"
        },
        {
            "access": "RW",
            "desc": "Trigger a fast frequency policy response.",
            "label": "FFR trigger response",
            "name": "FFRTrigger",
            "size": 1,
            "type": "uint16",
            "units": "Pct"
        },
        {
            "desc": "Enable response in fast frequency response policy.",
            "label": "Enable response",
            "name": "FFRArmed",
            "size": 1,
            "symbols": [
                {
                    "desc": "The response in FFR policy is disabled",
                    "label": "Disable FFR response",
                    "name": "FFRDisable",
                    "value": 0
                },
                {
                    "desc": "The response in FFR policy is enabled",
                    "label": "Enable FFR response",
                    "name": "FFREnable",
                    "value": 1
                }
            ],
            "type": "uint16",
            "access": "RW"
        },
        {
            "desc": "Switch to different policies.",
            "label": "Policy Switch",
            "name": "SelectPolicy",
            "size": 1,
            "symbols": [
                {
```

```
                    "desc": "Switch to External Control",
                    "label": "External Control",
                    "name": "ExternalControl",
                    "value": 0
                },
                {
                    "desc": "Switch to Manual",
                    "label": "Manual",
                    "name": "Manual",
                    "value": 1
                },
                {
                    "desc": "Switch to Offline",
                    "label": "Offline",
                    "name": "Offline",
                    "value": 2
                },
                {
                    "desc": "Switch to Energy Dispatch",
                    "label": "Energy Dispatch",
                    "name": "EnergyDispatch",
                    "value": 3
                },
                {
                    "desc": "Switch to Fast Frequency Response",
                    "label": "Fast Frequency Response",
                    "name": "FastFrequencyResponse",
                    "value": 4
                },
                {
                    "desc": "Switch to Target Capacity",
                    "label": "Target Capacity",
                    "name": "TargetCapacity",
                    "value": 5
                },
                {
                    "desc": "Switch to Energy Dispatch Target Capacity",
                    "label": "Energy Dispatch Target Capacity",
                    "name": "EnergyDispatchTargetCapacity",
                    "value": 6
                },
                {
                    "desc": "Switch to Test Pattern",
                    "label": "Test Pattern",
                    "name": "TestPattern",
                    "value": 7
                }
            ],
```

```
                "type": "uint16",
                "access": "RW"
            },
            {
                "desc": "FFR Policy Status",
                "label": "FFR Status",
                "name": "FFRStatus",
                "size": 1,
                "symbols": [
                    {
                        "name": "DISABLED",
                        "value": 0
                    },
                    {
                        "name": "READY",
                        "value": 1
                    },
                    {
                        "name": "RESPONSE",
                        "value": 2
                    },
                    {
                        "name": "REST",
                        "value": 3
                    },
                    {
                        "name": "RECOVERY",
                        "value": 4
                    }
                ],
                "type": "enum16"
                }
        ],
        "type": "group"
    },
    "id": 61000
}
```


Additional models will be included above when future Modbus map updates occur

12.2.16. End Model

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

12.3. Operational Cases for SunSpec Modbus Interface

There are two main operational cases for the control of nController® over its SunSpec interface:

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

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

12.3.1. External Controller Communicating Over SunSpec Modbus Interface

An external controller typically polls SunSpec points at a rate of 1 Hz. This controller reads data points required to manage current flow in the system. The following table summarizes the most important points an external controller may want to read.

Table 28. SunSpec Points Read by an External Controller

Model	Block	Point Name	Address	Scale Factor	Purpose
802	Fixed	CtrlHb	89	No	Heartbeat counter incremented every second
802	Fixed	Evt1	96	No	Bit field of all faults/warnings
802	Fixed	V	104	Yes	External DC voltage of the battery system
802	Fixed	A	114	Yes	Total DC current of the battery system
802	Fixed	AChaMax	115	Yes	Instantaneous maximum DC charge current
802	Fixed	ADisChaMax	116	Yes	Instantaneous maximum DC discharge current

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

Table 29. SunSpec Points Written to by an External Controller

Model	Block	Point Name	Address	Purpose
801	Fixed	AlmRst	90	Clears all latched alarms in the nController®
802	Fixed	SetOp	120	Commands nController® to connect/disconnect the battery

12.3.2. External Nuvation Energy BMS Monitoring Over SunSpec Interface

An external data logger may want to access a variety of data from the nController®. In general, a

data logger will not actively manage nController®; normally, it will not initiate actions such as connecting a battery stack to the DC voltage bus or clearing faults. A data logger should connect to one of the read-only Modbus connections (if available) to allow the writable Modbus connection to be available for separate external control functions. The following table contains the SunSpec Energy Storage Models Points exposed by the nController® that could be collected for logging purposes.

Table 30. Length Details

Model	Start Address	Length	Number of Models
start	0	2	1
Common	2	68	1
802	70	64	1
803	134	28 + 32 x S	1
804	162 + 32 x S	48 + 16 x CI	S
805	162 + 80 x S + 16 x S x CI	44 + 4 x C	S x CI
End	162 + 80 x S + 16 x S x CI + S x CI x (44 + 4 x C)	3	1

S = Number of Stacks on the system, CI = Number of Cell Interface modules per stack, C = Number of cells per Cell Interface.

Table 31. SunSpec Points Read by External Data Logger

Model	Block	Point Name	Address	Scale Factor	Purpose
802	Fixed	SoC	81	Yes	BMS State of Charge
802	Fixed	CtrlHb	89	No	BMS Heartbeat counter incremented every second
802	Fixed	Evt1	96	No	Bit field of all faults/warnings of a nController®
802	Fixed	V	104	Yes	External DC voltage of the battery system
802	Fixed	SetOp	120	No	BMS requested connection state of all stacks/strings
802	Fixed	CellVMax	107	Yes	Maximum cell voltage measured
802	Fixed	CellVMaxStr	108	No	Module/String location of maximum cell voltage
802	Fixed	CellVMin	110	Yes	Minimum cell voltage measured
802	Fixed	CellVMinStr	111	No	Module/String location of minimum cell voltage
803	Fixed	ModTmpMax	138	Yes	Maximum module temperature
803	Fixed	ModTmpMaxStr	139	No	Module/String location for maximum module temperature
803	Fixed	ModTmpMin	141	Yes	Minimum module temperature

Model	Block	Point Name	Address	Scale Factor	Purpose
803	Fixed	ModTmpMinStr	142	No	Module/String location for minimum module temperature
802	Fixed	A	114	Yes	Total DC current of the battery system
803	Fixed	StrAMax	150	Yes	Largest DC current reported by a stack/string
803	Fixed	StrAMin	152	Yes	Smallest DC current reported by a stack/string
803	Repeat	StrSoC	166 +Index	No	State of charge for a stack/string
803	Repeat	StrSoH	167 +Index	Yes	State of health for a stack/string
803	Repeat	string.StrA	200 +Index	Yes	Current of a stack/string
803	Repeat	string.StrCellVMax	169 +Index	Yes	Maximum cell voltage of a stack/string
803	Repeat	string.StrCellVMin	171 +Index	Yes	Minimum cell voltage of a stack/string
803	Repeat	string.StrCellVMaxMod	170 +Index	No	Location of min/max cell voltages of a stack/string
803	Repeat	string.StrModTmpMax	174 +Index	Yes	Maximum module temperature of a stack/string
803	Repeat	string.StrModTmpMin	176 +Index	Yes	Minimum module temperature of a stack/string
803	Repeat	string.StrModTmpMaxMod	175 +Index	No	Location of min/max module temperatures of a stack/string
803	Repeat	string.StrEvt1	182 +Index	No	Alarms warnings and status bitfield of a stack/string
804	Repeat	lithium_ion_string_module.ModCellVAvg	804_start_address +55 +Index	Yes	Average voltage for all cells in the module
805	Repeat	lithium-ion-module-cell.CellV	805_start_address +44 +Index	Yes	Cell terminal voltage
805	Repeat	lithium-ion-module-cell.CellTmp	805_start_address +45 +Index	Yes	Cell temperature

In the Repeating block addresses used in the above table, the term Index for the 803 model is `Index = Stack Index * Length of Repeating block`. For the 804 model, `Index = Cell Interface Index * Length of Repeating block`. For the 805 model, `Index = Cell Index * Length of Repeating block`. See Table 30, "Length Details" for the value of `804_start_address` and `805_start_address`.

By definition, the 803, 804 and 805 Repeating blocks are 16 Modbus registers in length.

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

12.4. Accessing SunSpec Energy Storage Models

SunSpec Energy Storage Models are located contiguously in the Modbus address space starting at a base address of `0`.

The Common Model is always located first in this space. The End Model is always last and is used to denote the end of SunSpec Modbus registers. Each model located between the Common Model and the End Model has a numeric identifier as well as a length.

A handy tool that can be used to explore the SunSpec Modbus registers for nController® is `modpoll.exe`.

It is available for free download at http://www.modbusdriver.com/modpoll.html.

Using `modpoll.exe`, the Common Model can be polled from a using the following command (assuming the device has an IP address of `192.168.1.10`)

Polling example with nController® IP address of `192.168.1.10`

```
modpoll -m tcp -0 -r 0 -c 70 192.168.1.10

modpoll 3.10 - FieldTalk(tm) Modbus(R) Master Simulator
Copyright (c) 2002-2021 proconX Pty Ltd
Visit https://www.modbusdriver.com for Modbus libraries and tools.

Protocol configuration: MODBUS/TCP, FC3
Slave configuration...: address = 1, start reference = 0 (PDU), count = 70
Communication.........: 192.168.1.21, port 502, t/o 1.00 s, poll rate 1000 ms
Data type.............: 16-bit register, output (holding) register table

-- Polling slave... (Ctrl-C to stop)
[0]: 21365
[1]: 28243
[2]: 1
[3]: 66
.
.
.
[68]: 1
[69]: -32768
```

13. Configurable Modbus

In addition to the SunSpec implementation, the nController® provides a 'configurable_modbus' feature that enables read/write access to the nController® key-space through the Modbus TCP interface on port 519. It allows a Modbus TCP client to retrieve real-time data from the various sub-systems of the nController®. Note that the definition of a key-space was provided in Section 7.2, "nController® Device Configuration".

Please contact support@nuvationenergy.com for more information related to key-space selection and data available on the nController®

Individual Modbus points can be configured via the access map, using the configuration list 'func:configurable_modbus:api:1:configuration:staged:access_map'.

Upon importing a valid configuration file, a new CSV file containing the Modbus point details is generated. It is available for download through the endpoint 'http://<ip_address>/configurable_modbus/access_map/download'.

The following describes the configuration fields of an access map entry.

Table 32. Configurable Modbus Access Map Configuration

Access map entry key	Description	Input
'data_key'	The nController® primitive key from which to retrieve data from when the associated Modbus address is requested.	String of the nController® primitive key.
'data_type'	The expected data type stored at the primitive key.	uint16, sint16, uint32, sint32, uint64, sint64, float32, float64.
'scale_factor'	Factor with which to scale the retrieved data-key value.	Non-zero integer, default is 1.
'access'	Read and write access of the register	"RW"/"R".

The current data types following the format `<sign-mode><numeric-type><number-of-bits>`.

- `sign-type`: The prefix 'u' indicates that the integer type is unsigned. Otherwise it is signed.
- `numeric-type`: 'int' to describe integer type, 'float' to describe floating-point type.
- `number-of-bits`: Number of bits to represent the value. For a N-bit data type, (N/16) consecutive register addresses are used for the Modbus point.

Modbus point addresses are not configurable. Access map entries are assigned sequential addresses, starting from zero, according to their order in the list.

Additional configuration fields are available to define how the payload will be delivered to the Modbus client. These fields are detailed in the following table.

Table 33. Configurable Modbus general configuration

Configuration key	Description	Options
'func:configurable_modbus:api:1:configuration:active:byte_order'	Set the endianess of the Modbus payload byte order.	'big-endian', 'little-endian'
'func:configurable_modbus:api:1:configuration:active:word_order'	Set the endianess of the Modbus payload word order.	'big-endian', 'little-endian'

The Modbus TCP server will not start if the configured access map is empty.

The configuration must be valid. Any errors will be detailed in the downloadable access map CSV file.

14. Troubleshooting

14.1. Faults

When a pack level fault occurs, all stacks are disconnected. The following sections describe the different faults and the conditions that trigger them. In general, all warnings have a similar trigger condition as their corresponding fault. The following discussion will focus on the term fault and all descriptions can be applied to the compatible warning. For faults observed at the stack level please refer to the *Troubleshooting* section in the BMS level *Product Manual*.

Please contact support@nuvationenergy.com for details of the configuration and operation of any of the below triggers.

14.1.1. Ready Stacks

This fault represents a configurable minimum limit of how many stacks must be ready and still have the pack remain connected and manage the battery power.

`faults:stacks_ready`

- Fault indicating that the minimum number of ready stacks for the pack has not been satisfied

Refer the `Stack Status` page (Section 9.3, "The Stack Status Tab") on the Operator Interface to observe which stacks have been either disabled, are in Service Lockout, or have faulted.

14.1.2. BMS Firmware Mismatch

`warnings:stacks_bms_version`

- Warning indicating that the nController® has read a stack-level BMS firmware version different than the expected. Perform a firmware upgrade on the affected stacks.

14.1.3. Current Imbalance

`faults:current_imbalance`

- Fault indicating that the current difference between the stack with the highest current and the stack with the lowest current is greater than the configured threshold.

14.1.4. Configuration Fault

`faults:config_fault`

- Fault indicating that no configuration file is loaded or a configuration file failed to load.

The configuration fault does not have a corresponding warning and is not configurable.

14.1.5. Stack Configuration Fault

`faults:stack_config_fault`

- Fault indicating that a configuration file is loaded but a stack IP address is missing or an incorrect Modbus or HTTP ports were set up.

The stack configuration fault does not have a corresponding warning and is not configurable.

14.1.6. Logger Persistence

`faults:logger_persistence_fault`

- Fault indicating one or more stacks failed to save battery maintenance details to persistent storage.

The logger persistence fault does not have a corresponding warning and is not configurable.

14.1.7. Invalid Configurable Registers

`faults:invalid_configurable_registers`

- Fault indicating that one or more configured stack register entry is invalid.

14.2. Lost/Forgotten IP Address

The nController® is resolvable using mDNS via a compatible computer. Refer to Section 9.1.1, "External Computer Requirements" for details.

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

14.2.1. Wireshark (Windows/Linux)

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

14.2.2. Netdiscover (Linux only)

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

In the event the IP address cannot be discovered, a factory reset operation must be carried out to restore the BMS to its default IP configuration.

14.3. Incorrect Clock Time on nController®

If the reported product time does not match UTC, please contact support@nuvationenergy.com for assistance. To resolve this, the Nuvation Support team will need to configure the NTP client IP address on the nController®.

Appendix A: Operating Limits

nController® Compact Operating Limits

Exceeding the maximum ratings will damage the module.

Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
		Power Specifications				
+Vin	Input Voltage	-	11.4	12	12.6	V DC
	Input Current	+Vin = 12 V DC	-	7.5	12.5	A DC
		Ethernet Specifications				
ETH RJ45: 1-4	Ethernet Connection Speed	10BASE-T 100BASE-TX 1000BASE-T	10	-	1000	Mb/s
ETH RJ45: 5,7	Ethernet Connection Speed	1GBASE-T 10GBASE-T	1	-	10	Gb/s
ETH Twisted_Pair: 1-4	Ethernet Cable Rating	-	Cat 5e	-	Cat 6	
ETH Twisted_Pair: 5,7	Ethernet Cable Rating	-	Cat 6	-	-	
ETH SFP+: 6,8	SFP+ Port Speed	-	1	-	10	Gb/s
ETH_Connector	Ethernet jack rating	-	-	Cat6	-	

Environmental Conditions

Symbol	Parameter	Conditions	Min	Typ	Max	Units
		Thermal Specifications				
T_a	Operating Temperature	-	5	25	40	°C
	Storage Temperature	-	-40	25	70	°C
		Humidity Specifications				
RH	Operational RH	Non-Condensing	8	-	90	%
	Storage RH	Non-Condensing	5	-	95	%
		Shock and Vibration Specifications				
Vertical	Vertical Shock/Vibration	-	-	-	10	m/s^2
Longitudinal	Longitudinal Shock/Vibration	-	-	-	10	m/s^2
Transverse	Transverse Shock/Vibration	-	-	-	10	m/s^2

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Pulse Vibration	On each axis	-	-	-	245	m/s^2

If the nController® is stored at temperatures below 5 °C, it must be warmed up in a 20 °C or warmer environment for 45 minutes before applying power. Powering the unit below 5 °C may impact data logging or cause other unexpected behaviour.

Standards and Certifications

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

The following directives and standards apply to the nController®:

- EMC/EMI: 2014/30/EU (EMC Directive)
- Electromagnetic Compatibility Regulations 2016
- FCC Part 15 Subpart B
- ICES-003
- VCCI 32-1
- AS/NZS CISPR 32
- BS/EN55032
- BS/EN55035
- BS/EN 61000-3-2
- BS/EN 61000-3-3
- BS/EN 61000-4-2
- BS/EN 61000-4-3
- BS/EN 61000-4-4
- BS/EN 61000-4-5
- BS/EN 61000-4-6
- BS/EN 61000-4-8
- BS/EN 61000-4-11
- Green Environment: 2011/65/EU (RoHS Directive)
- EC 1907/2006 (REACH)
- 2012/19/EU (WEEE Directive)
- Product Safety: 2014/35/EU (LVD Directive)
- Electrical Equipment (Safety) Regulations 2016
- UL/CSA 62368-1 (USA and Canada)
- IEC 62368-1

nController® Rack Mount Operating Limits

Exceeding the maximum ratings will damage the module.

Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
		Power Specifications				
$+V_{in}$	Input Voltage	-	100	-	240	V AC
	Input Frequency	-	50	-	60	Hz
	Input Current	V_{in} = 120 V AC	0.41	0.83	1.25	A AC
		V_{in} = 240 V AC	0.2	0.41	0.62	A AC
		Ethernet Specifications				
RJ45 Port 1-9	Connection Speed	10BASE-T 100BASE-TX 1000BASE-T	10	-	1000	Mb/s
	Twisted-pair cable rating	-	Cat 5e	-	Cat 6	
	Ethernet jack rating	-	-	Cat6	-	
RJ45 Port 10-11	Connection Speed	1GBASE-T 10GBASE-T	1	-	10	Gb/s
	Twisted-paid cable rating	-	Cat 6	-	-	
	Ethernet jack rating	-	-	Cat6	-	
SFP+ Port 12-13	SFP+ Port Speed	-	1	-	10	Gb/s

Systems involving more than 10 Ethernet connected ports for equipment will require an external network Ethernet switch to be connected to the nController®.

This external switch is not provided. An industrial grade, un-managed switch is recommended.

Environmental Conditions

Symbol	Parameter	Conditions	Min	Max	Units
		Thermal Specifications			
T_a	Operating Temperature	-	5	45	°C
	Storage Temperature	-	-40	70	°C
		Humidity Specifications			
RH	Operational Relative Humidity	Non-Condensing	8	90	%
	Storage Relative Humidity	Non-Condensing	5	95	%

If the nController® is stored at temperatures below 5 °C, it must be warmed up in a

20 °C or warmer environment for 45 minutes before applying power.

Powering the unit below 5 °C may impact data logging or cause other unexpected behaviour.

The nController® unit should not be shipped while installed in a rack.

Regulatory Compliance

Standard	Name
	Electromagnetic Emissions
FCC Class B	US Federal electromagnetic radiation limits
EN 55032 Class B	European Electromagnetic compliance testing of multimedia equipment
EN 61000-3-2/3-3	European Electromagnetic limits for harmonic current emissions
CISPR 32 Class B	International Electromagnetic compatibility of multimedia equipment
	Electromagnetic Immunity
EN 55024/CISPR 24	European information technology equipment immunity characteristics
	Safety
CSA/EN/IEC/UL 60950-1 Compliant	Information technology equipment safety general requirements
CE Marking	Compliant with European Union (EU) directives and regulations

Appendix B: Ordering Information

This section provides orderable part numbers for Nuvation Energy's offerings of nController® modules and related accessories.

Product Part Number	Product Name
NUVNC-3C-01S	nController®, Compact, single stack
NUVNC-3C-02S	nController®, Compact, up to 2 stacks
NUVNC-3C-04S	nController®, Compact, up to 4 stacks
NUVNC-3C-06S	nController®, Compact, up to 6 stacks
NUVNC-3C-08S	nController®, Compact, up to 8 stacks
NUVNC-3C-10S	nController®, Compact, up to 10 stacks
NUVNC-3C-12S	nController®, Compact, up to 12 stacks
NUVNC-3C-14S	nController®, Compact, up to 14 stacks
NUVNC-3C-16S	nController®, Compact, up to 16 stacks
NUVNC-3R-01S	nController®, Rack Mount, single stack
NUVNC-3R-02S	nController®, Rack Mount, up to 2 stacks
NUVNC-3R-04S	nController®, Rack Mount, up to 4 stacks
NUVNC-3R-06S	nController®, Rack Mount, up to 6 stacks
NUVNC-3R-08S	nController®, Rack Mount, up to 8 stacks
NUVNC-3R-10S	nController®, Rack Mount, up to 10 stacks
NUVNC-3R-12S	nController®, Rack Mount, up to 12 stacks
NUVNC-3R-14S	nController®, Rack Mount, up to 14 stacks
NUVNC-3R-16S	nController®, Rack Mount, up to 16 stacks

Depending on the region the product is shipped to, either a NEMA 5-15P or CEE 7/7 12V power connector is included in the box.

Appendix C: List of Supported Equipment

Supported Equipment

Below is a non-inclusive list of equipment and vendors that ensure the integration of the nController® with different energy assets depending on the topology of the site.

Battery Management System

Manufacturer	Product	Version	Supported
Nuvation Energy	Low-Voltage BMS and G4 High-Voltage BMS	Ampere 17.12	No
Nuvation Energy	Low-Voltage BMS and G4 High-Voltage BMS	Babbage 18.08	No
Nuvation Energy	Low-Voltage BMS and G4 High-Voltage BMS	Curie 19.11	Yes
Nuvation Energy	Low-Voltage BMS and G4 High-Voltage BMS	Descartes 21.4	Yes
Nuvation Energy	G5 High-Voltage BMS	Faraday	Yes
Nuvation Energy	G5 High-Voltage BMS	Faraday Update 1	Yes

Power Conversion System

Below is a list of Power Conversion System which are supported with a break down of which features are available in the nController®. The status can be described as follows:

- N/A - Not applicable either because of a lack of feature availability on the Power Conversion System or it does not apply to the model
- Yes - feature is supported by both the Power Conversion System and the nController®
- No - feature is not supported by the nController®

Manufacturer	Product	Version	P/Q	Low Power/Stand by	Islanding Droop V/F	Islanding Non-Droop	Seamless Transfer
Sinexcel	PWS2-30k-NA/EX	N/A	Yes	No	No	No	No
LS Energy Solutions (LSES)	PowerBRiC	N/A	Yes	Yes	No	Yes	No
Dynapower	MPS-125, CPS-1500	N/A	Yes	Yes	No	No	No
EPC	PD250, PD500	4.5.0	Yes	Yes	No	No	No
EPC	PD250, PD500	4.6.0	Yes	Yes	Yes	No	Yes

Manufacturer	Product	Version	P/Q	Low Power/Stand by	Islanding Droop V/F	Islanding Non-Droop	Seamless Transfer
Trystar	OZPCS-RS40	N/A	Yes	Yes	Yes	N/A	Yes

Feeder Protection Relays

Manufacturer	Product	Version	Supported
Schweitzer Engineering Laboratories (SEL)	SEL-751, SEL-751A	N/A	Yes

Power Meters

Manufacturer	Product	Version	Supported
Continental Control Systems	WND-WR-MB	N/A	Yes
Circutor	CVM-C10	N/A	Yes
Schneider	LV430491	N/A	Yes

General Purpose Input/Output

Manufacturer	Product	Version	Supported
Brainboxes	ED-588	N/A	Yes
RLH	Smart IO device	N/A	Yes

Solar Charge Controllers

Manufacturer	Product	Version	Supported
Alencon	SPOT with PODD	N/A	Yes

Supported UPS Devices

The following UPS devices have been tested and are supported with Nuvation Energy products:

- APC SRT3000RMXLA
- APC BR1000MS
- CPS CP1500PFCLCD
- CPS CP1350PFCLCD

Nuvation Energy guarantees product compatability with the above family models.

Excluding the UPS devices mentioned above, following family models are likely to be compatible, however have not been thoroughly tested by Nuvation Energy:

- APC Smart-UPS family models
- Other APC Back-UPS family models
- CPS CP*PFCLCD family models
- CPS OR*PFCRT* family models
- CPS BRG*AVRLCD family models
- CPS CP*AVRLCD family models
- CPS CP*AVR* family models

Nuvation Energy **does not** guarantee product compatability with the above family models.

The nController® can communicate with UPSes via USB and Ethernet.

Supported Display Devices

Nuvation Energy products are configured to support a display before shipment. If you wish to configure a display after shipment, please contact support@nuvationenergy.com. The following touchscreen devices have been tested and are supported with Nuvation Energy products:

- Acer UT241Y
- Dell P2418HT
- Zhixanda GC1016-C

Display hotplugging is not supported. Users must either connect the display before device startup or connect the display and reboot the device.

Specification for compatible displays supported by Nuvation Energy products:

- Display Connection: VGA
- Minimum Resolution: 1024 x 768
- Maximum Resolution: 1920 x 1200
- Touch Panel Connection: USB

Most touchscreens with USB HID devices with multi-touch are supported. Also most USB keyboards and mice are supported. Please contact support@nuvationenergy.com with a model and Nuvation Energy can attempt to determine if it will work prior to purchase.

Appendix D: Best Practices

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

Excess Cable Management

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

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

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

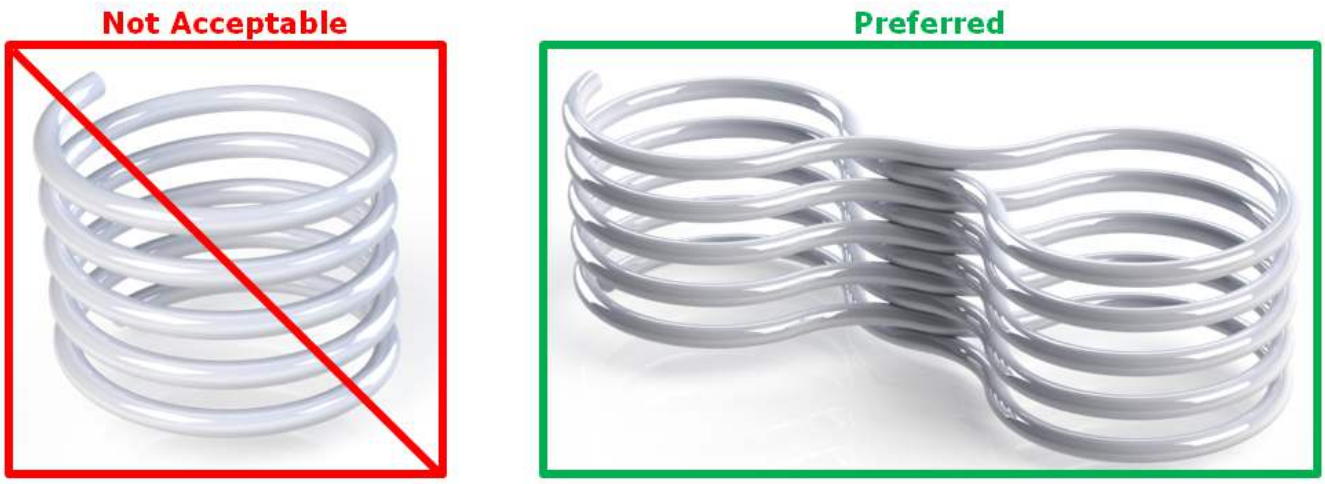


Figure 48. Excess Cable Management Examples

Security

This section is provided as guidance only and experts in security and the broader system must be consulted on any security decisions.

Security for the entire system and site must be considered, not just for individual Nuvation Energy products.

It is recommended evaluating each site and system to assess the risk level and impacts of the system not operating properly. Security restrictions protect against both accidental misuse and intentional

attacks. Each added layer of security will impact the ability to diagnose and resolve system problems and analyze system performance. The costs of system security should be proportional to the risk level of that system.

The sections below outline the best practices for maintaining a secure system.

Physical Security

Physical security measures are designed to deny unauthorized physical access to Nuvation Energy products and the larger systems. Physical security can include barriers, locks, access control, surveillance, guards, intrusion detection/alarms, and other physical security systems.

Ensuring all equipment is physically secure is the first and most important step in protecting the system. Below are some recommended best practices for the physical security of the products:

- Nuvation Energy products should be physically secured in a locked enclosure, room, or building to restrict access. This physically secured area will be referred to as the 'secure zone'.
- The 'secure zone' access should be restricted to authorized personnel only.
- Authorized personnel should be trained to operate the equipment and follow the security process.
- Any unauthorized personnel should be supervised at all times.

Outside the products themselves, access to equipment and connections should also be secured, such as:

- Cells/battery modules
- PCS/inverters
- SCADA systems
- UPS/emergency power equipment
- High and low power cables and measurement wires
- Communication cables (i.e. Ethernet, USB, Linkbus, etc.)
- Networking equipment (i.e. routers, switches, transceivers, etc.)
- Buttons/control panels (i.e. E-stop, touchscreens, etc.)
- Any other critical equipment/connections that might compromise the site

Network Security

The networking on Nuvation Energy products uses Ethernet-based TCP/IP communications. Throughout this section, references to the 'controller' apply to Multi-Stack Controller, Nuvation Energy nController® and Energy Management System products, and all these terms may be used interchangeably. A network security analysis for any third party equipment on the network should be conducted in consultation with the equipments' manufacturer. Below are some recommended best practices for network security of Nuvation Energy products:

- Nuvation Energy products should be on an isolated network where only trusted equipment can operate, and trusted personnel can access. This network will be referred to as the 'secure

network'.

- The 'secure network' should be within the 'secure zone' (see the Physical Security for details)
- The 'secure network' should be established through either a:
  - Physically isolated network (i.e. no connection to any other network, otherwise known as 'air gapped')
  - Firewall isolated network (i.e. router, smart switch, or other equipment with packet filtering to the 'secure network')
- The nController® should be used to isolate the stack BMSs from the site network through the nController® 'Internal/Bridge' network. These two networks must be isolated on separate subnetworks with separated IP address ranges.

An example of a 'secure network' topology with a router based firewall, Nuvation Energy nController®, and Nuvation Energy stack BMS units isolated on the 'Internal/Bridge' network is below:

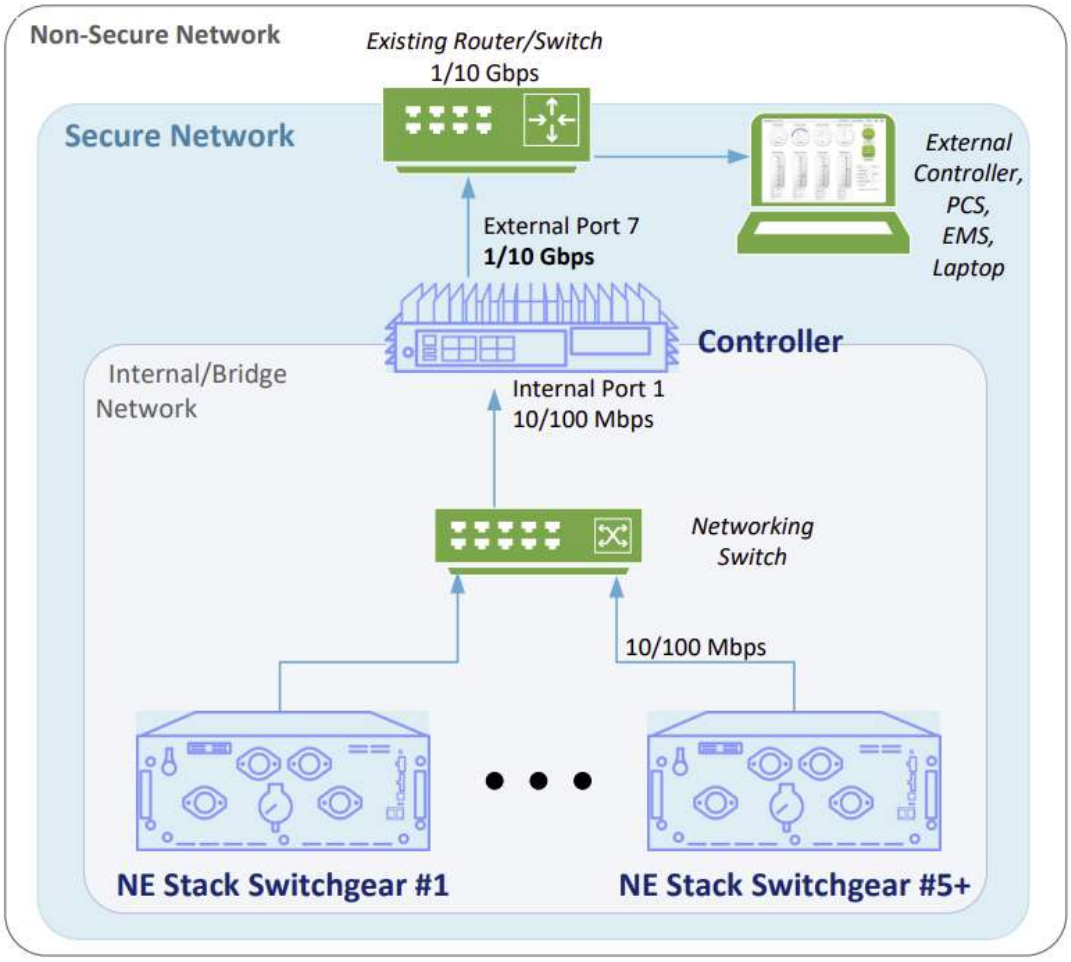


Figure 49. Networking Configuration for a nController® with Secure and Internal Network

Inbound Protocols and Ports

All the open ports listening on the nController® with the network protocols are listed below. Unless

specified, the protocols are not encrypted or authenticated.

- TCP Port 80 (HTTP)
- TCP Port 502/519 (Modbus)
- UDP Port 5355 (LLMNR)
- UDP Port 5353 (mDNS)
- TCP Port 443 (HTTPS - encrypted)
- TCP Port 22 (SSH - encrypted/authenticated)
- TCP Port 3493 (NUT)

Outbound Protocols

All Nuvation Energy products implement the essential outbound services for proper operation with modern networking equipment, listed below. Unless specified, the protocols are not encrypted or authenticated.

- Broadcast on network segment (ARP, STP)
- UDP Port 67/68 (DHCP)

The nController® has the following additional services listed below. Unless specified, the protocols are not encrypted or authenticated.

- UDP/TCP Port 53 (DNS)
- UDP Port 5355 (LLMNR)
- UDP Port 5353 (mDNS)
- UDP Port 123 (NTP)
- UDP Port 1194 (VPN - Nuvation Energy support only, encrypted/authenticated)
- TCP Port 443 (HTTPS/WSS - Nuvation Energy Cloud Services https://nuvation.energy, encrypted)
- TCP Port 3493 (NUT)

Blocking outbound protocols can be done in a similar way to inbound protocols (i.e. firewalls). For more information on the above services and to configure or disable services, contact support@nuvationenergy.com. Some services such as mDNS cannot be disabled.

Operator Interface Unlock Password

The Operator Interface for both single and multi-stack systems can be configured with a password which restricts some features in the products. The unlock password protects against accidental misuse of the products during normal operation.

The Operator Interface uses HTTP which does not encrypt connections and requires a secured network to protect against malicious intent.

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.