$LiFePO_4$ – MPLHP-5125528 Battery System

Operation and Maintenance Manual

Read this manual carefully before starting the installation of the battery system.

Retain these instructions for reference.

History of Version Upgrade

Version	Date	Change
V1.0	25/09/2020	First edition
V1.1	08/10/2020	Updates on HMI, Tools, BMS Configuration
V2.0	11/05/2020	Update BMS, HMI, Error code
V3.0	03/08/2021	Update to BMS, HMI, Error code
V4.0	06/03/2021	Second edition
V4.1	8/19/2021	Updated system diagram and images
V4.2	11/4/2021	
V4.3	3/22/2022	Updated to reflect SPI Comm changes
V4.4	9/12/2022	Updated file name, and removed all NESP references
V4.5	12/1/2022	Added Startup procedure and Updated HMI screens, alarm parameters,
V4.6	1/30/2023	Updated system images, file name and format

Contents

Important Safety Instructions

Please read and follow these instructions!

The following precautions are intended to ensure your safety, extend the service life of your product, and prevent property damage. Before installing this product, be sure to read all safety instructions in this document for proper installation.

The system location shall address and minimize personnel exposure to electrical hazards through effective equipment operation, design, specification, and installation. All electrical work shall be done in accordance with latest local electrical, building, fire and other codes, standards, regulations, or utility requirements as applicable to the installation, by qualified service personnel who has been appropriately trained and authorized in accordance with the related instructions and appropriate practices.

NESP Series is a high-voltage LFP lithium battery system. When dealing with the battery system, it is important to follow all safety recommendations.

The following warnings, safety instructions and notes are given as safety measures for the user as well as measures to prevent damage to the product or parts of the connected machines. Warnings, safety notes, and notes that are generally valid when working with the NESP battery system are summarized.

Safety Precautions

The following precautions provide general safety guidelines that should be followed when working with or near the High Voltage Lithium Battery System. Complete safety parameters and procedures are site-specific and should be developed by the customer for the installation site.

Review and refer to all safety warnings and cautions in this manual before installation.

Only authorized, adequately trained electrical operators should be able to access the system.

Depending on the location. Consult local codes and applicable rules and regulations to determine permit requirements. If required, mark enclosures appropriately before beginning work.

Qualified Personnel

The personnel must be thoroughly familiar with all the warnings and installation procedures described in the installation instructions!

Only qualified personnel with valid proof or certificate of electrical knowledge with code requirements, safety standards, and experienced in the type of work may work on electrical circuits and equipment.

Only qualified personnel who are familiar with the batteries and safety precautions should perform installation or maintenance of the battery.

Only authorized, trained technicians should perform annual preventive maintenance. Do not allow unauthorized personnel to contact the batteries.

Safe Electrical Work

All live electrical work requires a live work permit. A qualified person shall verify the equipment is de-energized and proper Lockout/Tag out procedures implemented prior to beginning electrical work.

When work is performed near energized overhead power cables, equipment such as boom, mast, crane, or its load shall never be permitted within evaluated distance limit from the power cables.

A site electrical installation, even if considered as provisional, must be planned and made in a proper manner using materials and industrial electrical components in order to ensure the proper functioning of the equipment and employees' integrity.

Safe Battery Handling

Please be aware that a battery presents a risk of electrical shock including high short-circuit current.

Follow all safety precautions while operating the batteries.

Do not smoke or use fire near batteries!

Do not use organic solvent to wash batteries!

Do not dispose of the batteries in a fire, or it could be exploded!

Do not dismantle batteries, it contains electrolyte that can do harm to the skin and eyes! Do not put

tools or any metal parts on the top of the batteries!

Remove watches, rings, and other metallic accessories!

Use only insulated tools to avoid inadvertent short circuits!

Disconnect charging source and load before connecting or disconnecting terminals!

Use proper lifting means when moving batteries and wear all appropriate safety clothing and equipment!

Keep 0.5m away from heat sources or any places may occur sparks (such as breakers, fuse box, etc.)!

The risk of local overheating such as direct sunlight over the battery rack should be avoided!

Batteries must be handled, transported, and recycled or discarded in accordance with federal, state, and local regulations!

Warning Signs Table

 Danger	 High Voltage Shock Hazard	 Arc Flash Hazard	 Read the manual
 Warning	 Fire Hazard	 Pinch Point	
 Caution	 Static Sensitive	 No Smoking	

1. Scope

This manual stipulates system specifications and detailed steps and attentions during installation of Narada MPLHP high-voltage lithium battery system.

2. Definitions

2.1 **Cell:** The basic unit of lithium iron phosphate battery consisting of positive, negative electrodes and electrolyte, with rated voltage of 3.2V and rated capacity of 55Ah.

2.2 **Module:** The NLHP51255 module with rated voltage of 51.2V and rated capacity of 55Ah, is composed of 55 Ah cells.

2.3 **Rack:** Several modules and control boxes are connected in series through electrical connectors, delivers voltage up to 512V (10 or 9 Pcs of 51.2NESP55 modules) in rated voltage and 55 Ah in rated capacity.

2.4 **Cabinet:** The rack enclosure that contains the battery system components (Modules and Control box).

2.5 **Control box:** Is maintenance free and provides isolation and protection for single rack (multiple battery modules). It integrates the BCU, High voltage management unit, circuit breakers, main contactors, pre-charge resistors, fuses, current sensors and switching power supply.

2.6 **BMS:** Battery Management System, is a collection of electronic devices used to monitor, evaluate, and protect battery operating parameters. It consists of BMU, BCU, Control box, BAMS, HMI and other components. It has 3 levels that control and monitor information related to operational status, battery cells, battery racks, and battery system units, such as battery voltage, current, temperature, and protection, etc., evaluating and calculating the state of charge (SOC) and state of health (SOH).

2.7 **BMU:** Battery Management Unit, the first rank of BMS (Module BMS). It is responsible for cell voltage and temperature acquisition, balancing management, real-time cell monitoring and upward communication.

2.8 **BCU:** Battery Cluster Management Unit, the second rank of BMS (Rack BMS). It is responsible for the current collection of the battery string. It integrates multiple CAN communication circuits and multiple wet and dry contacts. It is responsible for communicating with the managed BMUs, collecting information, alarms and protecting in case of overvoltage/ undervoltage/ overcurrent /short circuit /over temperature of the battery string. The information is sent to the next level BAMS, enabling the BAMS to resolve the problems of the lower-level system (BMU and battery) to ensure safe, reliable, and efficient operation of the battery management system.

2.9 **BAMS:** Battery Administration Management System, the third level of BMS (System BMS), composed of Battery Administration Management Unit (BAU) and HMI.

2.10 BAU: Battery Administration Management Unit.

2.11 HMI: Human Machine Interface, enabling data reading and parameter setting.

3. Acronyms and Abbreviations

The following acronyms and abbreviations are used in this manual.

Abbreviations	Full Name
BMS	Battery Management System
BMU	Battery Management Unit (Module level)
BCU	Battery Cluster Management Unit (String level)
BAMS	Battery Administration Management System (HMI and BAU)
BAU	Battery Administration Management Unit (System level)
HMI	Human Machine Interface
PPE	Personal Protection Equipment
EHS	Environmental Health and Safety
LFP	Lithium iron phosphate
BAT	Battery
SOC	State of Charge
SOH	State of Health
UVR	Under Voltage Release

4. Product Description

4.1 Introduction

4.1.1 MPLHP 55Ah battery system is a high-voltage high power lithium (LFP) system which is primarily used in emergency power supply, and data center applications. Both the lithium-ion (LFP) batteries and the BMS use a standard modular design.

4.2 Features

4.2.1 **Modular design:** The battery module and BMS designed to have uniform standard modular design. Flexible configuration allows for different quantities of battery modules in series providing multiple battery voltage options to match your UPS. Modular design makes the system easy to assemble, maintain and install.

4.2.2 **High safety:** The grouping structure, ventilation and thermal management design ensures the temperature consistency of each cell in each battery module during operation. Redundant protection system ensures the unit safety.

4.2.3 **Long-life design:** Long-life and high-quality cells are automatically selected during production, thus the consistency of the cells in grouping is ensured. The combination of passive and active balancing of the battery modules ensures the consistency of each cell during system operation, leading to extended battery life and improved system safety and reliability.

4.2.4 **Smart BMS:** System data is collected and managed in a systematic manner, through data interaction between BMS and monitoring system, enabling rapid response. The BMS ensures the battery is always running properly through real time monitoring, automatically balancing, automatically scanning protection and power data requests.

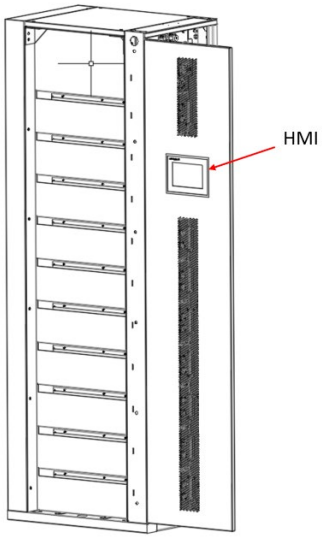
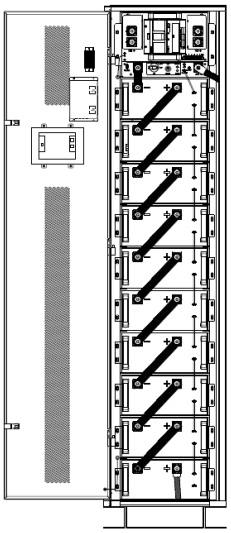
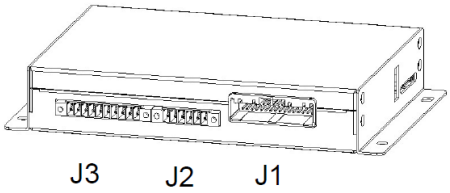
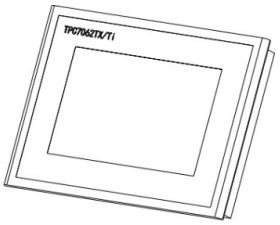
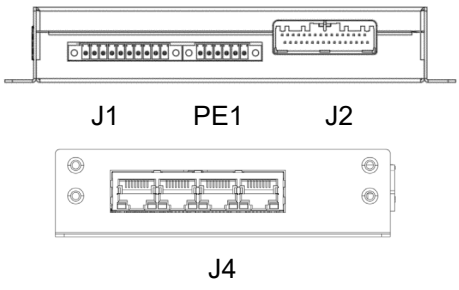
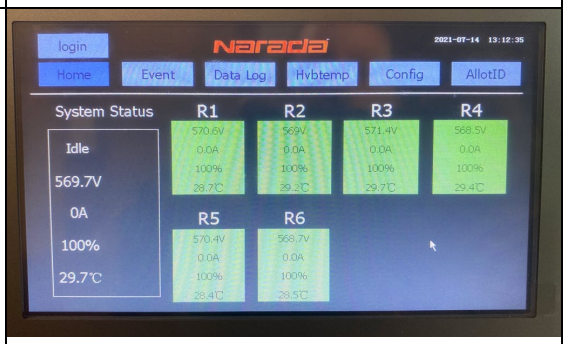
4.3 BMS

4.3.1 The BMS is based on 3 Level architecture, which consists of BMU, BCU, and BAMS, the parameters of BMS are as below.

Table 4-1 Specifications of BMS Components

Unit Level	Unit Name	Specifications
Module Level	BMU	• Battery type: High Rate LFP • Voltage detection range: 0.5-5.0V • Voltage acquisition of cells in strings: 16 • Voltage sampling accuracy: 0.1% or ≤5mV • Temperature sampling accuracy: ±2℃ • Balance type: Active balance • Balance current: ≤2.5A • Communication interface: CAN2.0 • Supply voltage: 20-28Vdc (typical 24Vdc)
Rack Level	BCU	• Max BMU number: 10 • Current sampling accuracy: $\pm(1\%\mathrm{FS}+1\%\mathrm{RD})$ • Voltage sampling interval: 100ms • Communication interface: RS 485*0, CAN*3 • Supply voltage: 20-28Vdc (typical 24Vdc) • High voltage detection: 0-900 Vdc, Accuracy: 0.5% • Insulation resistance detection: 100K-5MΩ, Accuracy ≤10%
System Level	BAU/HMI	• Communication interface: RS 485*3, CAN*2, Ethernet1 • Supply voltage: 20-28Vdc (typical 24Vdc)

4.3.2 The locations and interfaces of BAU and HMI are shown as below.

BAMS-Front	BAMS-Rear
	
BAU- Interface side	**HMI- Interface side**
	
BAU Interface- Front	**HMI Panel-Front**
	

4.3.3 There are several interfaces in the BAU, namely J1 as Power and Communication Port and dry contact 1 and 2, J3 for dry contacts 3 and 4 and J4 as Ethernet Communication Port.

4.3.4 When the BMS system is in a normal operating state, the BAU dry contact outputs are closed. For alarm or failure status, the dry contact is open. The dry contacts can be connected to < 60VDC.

4.3.5 J1 and J3 power communication port pin out – refer to cable drawing LHP-CCOM-J1J3

4.3.6 When the BMS system is in normal state, the BAU dry contact outputs a closed signal, and the BAU output breaks when the BMS system fails. This dry contact can only be connected to the <DC60V signal system.

5. Battery Systems Operation

5.1 System Diagram

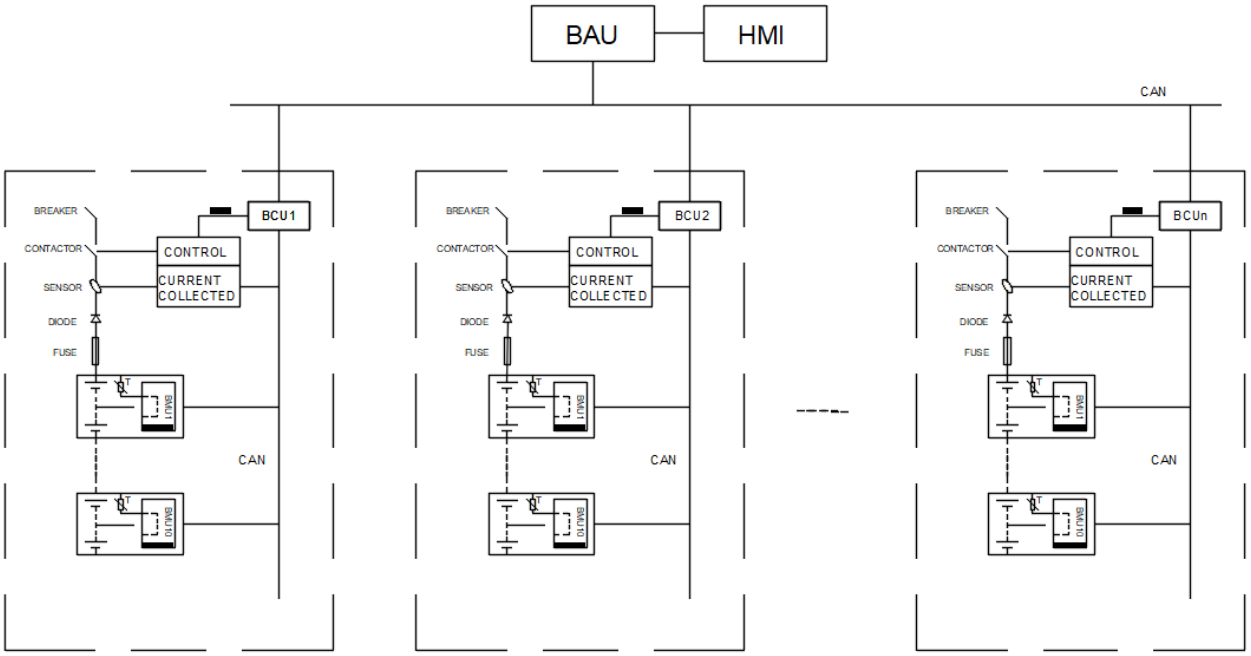


Fig 5.1 System topology

5.1.1 In Figure 5.1, the whole battery system is composed of multiple battery racks, BAMS, and HMI. Each battery rack is composed of multiple battery modules and a control box connected in series. Each battery module is equipped with a BMU to monitor the battery status.

5.1.2 Each battery rack functions as a complete subsystem of BMS. The battery management system directly detects and manages the entire battery rack operation, including basic battery operation information collection, capacity estimation, balancing between cells, and system operation state analysis, battery system fault diagnosis and protection, system policy control, system leakage detection, battery data monitoring and display, data communication, etc.

5.1.3 Multiple battery racks can be connected in parallel in order to expand the system capacity. The BAMS can communicate the racks with the outside world through HMI, SPI, and RS485.

5.2 Charge and Balance Procedure

5.2.1 **Soft Balance** – Preferred Method - Estimated time 24 hours.

5.2.1.1 This method can reduce the amount of time required for the cells to balance during the first charge after installation by avoiding frequent High Cell Voltage. However, it requires the UPS float voltage to be adjusted during the startup which is not always convenient. Set the initial UPS charge voltage to 550V. Charge at close to 0.5C (about 20 amps per string) and allow system voltage to reach UPS voltage. Check that Min/Max cell voltage differential (VPC) for each string is around 0.05VPC. **(Max VPC – Min VPC = Differential)**

5.2.1.2 Increase the UPS charge voltage to 570V

NOTE: The system is available for a discharge during this time and the charge contactor may open and close as needed to allow the system to balance.

5.2.2 **Hard Balance** – Timeframe - 24 to 48 hours.

5.2.2.1 This method is used when adjusting the UPS during startup more than once is not convenient. It may take longer for the cells to balance during the first charge after installation because of frequent High Cell Voltage. When an individual cell reaches the limit, the controller will open the charge contactor. The charge current will stop until the cell voltage drops and 1 hour has elapsed. This process happens at the rack level which means some racks may stop the charge while other racks are still charging.

5.2.2.2 Set the UPS charge voltage to 570V and allow system to charge and balance until the Min/Max Cell Voltage (VPC) differential is within 0.15V. (Max VPC – Min VPC = Differential)

NOTE: The system is available for a discharge during this time and the charge contactor may open and close as needed to allow the system to balance.

5.3 Balancing

The BMU automatically places a small load across the higher voltage cells to drain energy from them until the cell voltages are within 0.015V of each other. This process may take approximately 72 hours after the first start up. Racks will stop the charge for 1 hour for the individual rack when a high cell voltage (3.75V) is detected. The charge contactor will close again when the High cell recovery value (3.45V) has been reached AND 1 hour has elapsed. The rack is available for discharge during this time.

5.4 System Startup

5.4.1 **Main Control Box Power Disconnect Switch**

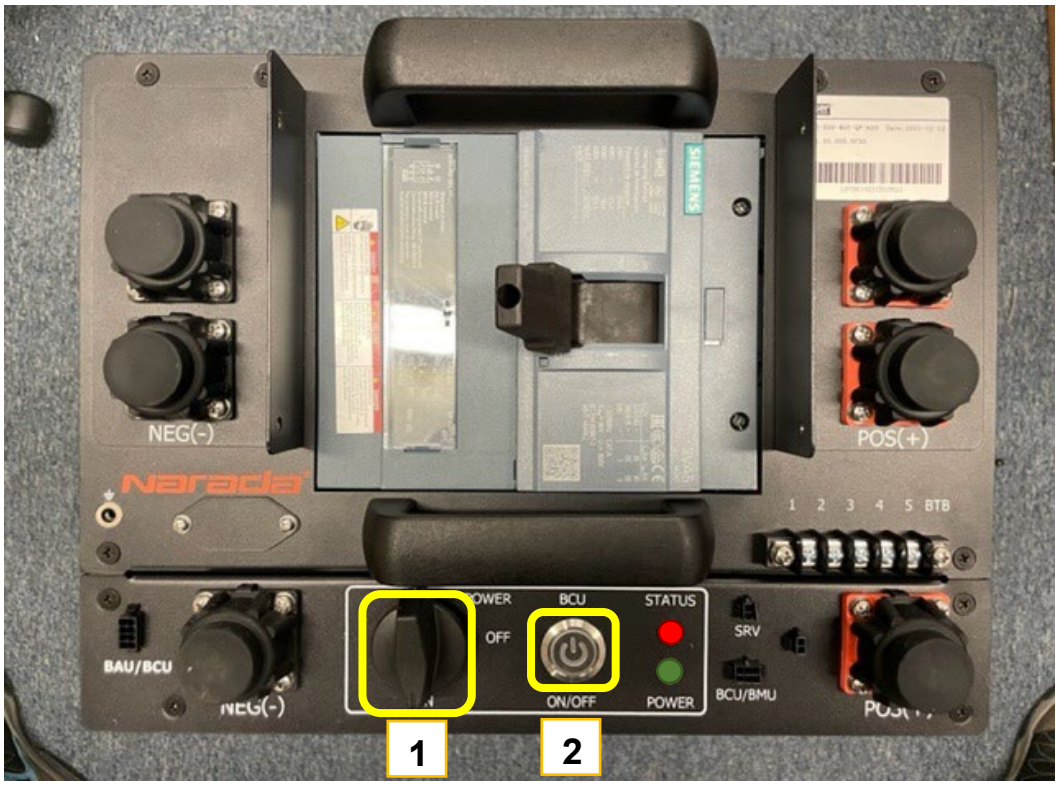
5.5.1.1 This switch can be found on the front of the control box on each string in the system. The black knob, shown in image below, controls main string level power. When in the “Off” position all BCU/BAU power will be disconnected, and both the “Status” light and “Power” will be off.

5.5.1.2 When the switch (1) is turned to the “On” the BCU of that string will now be getting the required voltage. However, the BAU and HMI screen will not be powered up

during this step. Completion of this step will give you a Green light for “Power” no light for “Status” signifying the system is powered on but not online.

5.5.1.3 To power the BAU and HMI, String 1 in the system will need to have the On/Off switch shown as #2 in image below depressed. Once pushed, the “Status” light will light up Red and “Power” light will remain green. This signifies a properly powered up system. You will hear a beep from the HMI and it will illuminate. Follow this procedure for all strings in the system to allow all BCU’s to communicate to the BAU/HMI.

5.5.1.3.1 Once the strings are enabled via the HMI (see Section 5.12) the contactors will close on each string, followed by the “Status” light turning green.



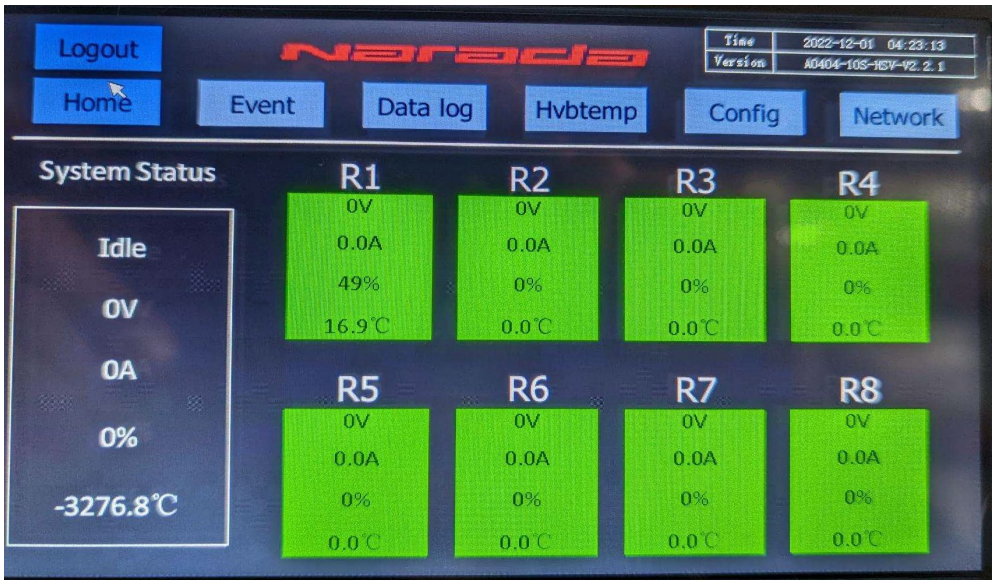
5.5 BMS Operations

This section introduces the functions and instructions of the human-machine interface (HMI).

5.5.1 Main Display

After the system is powered on, the home page will be shown on the screen automatically (as shown in the figure below). The home page displays 2 major categories:

- System Status
- Rack level Information



5.5.2 **Operation function:** with a click of the following buttons, the system will enter different pages for controlling the following functions:

button	Linked Interface
Login	Click the button to enter the user login page
Alarm	Click the button to enter the alarm data display page
Data Log	Click the button to enter the manual data storage interface
HVBTemp	Click the button to enter the control box temperature interface
Config	Click the button to enter the configuration interface
Network	Click the button to enter the Network and BAU time setting interface
R1	Click the button to enter the corresponding Rack data screen

5.5.3 **System status**: This portion displays the overall system status including voltage, current, SOC%, and temperature. When the system is not running, the status will show “Idle”.

5.5.4 **Rack status:** Each box displays the status of the voltage, current, SOC%, and temperature. If the green box turns red, it indicates there is a communication error or rack

failure.

5.5.5 **Alarms:** When any of the Rack blocks turns red, click the alarm button to check the alarm code. Refer to the following table for the detail description of the alarm parameters and contactor operation. There are 3 alarm levels (alarm, warning, critical).

5.5.6 Alarm parameters and Contactor operation

#	Parameter	Unit	Level	Trigger Duration	Recovery Duration	Charge Contactor Operation	Discharge Contactor Operation	HMI Rack Color
1	Total Voltage High	V	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Open	Closed	green
			Critical	1s	1s	Open	Open	Red
2	Cell Voltage High	mV	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Open	Closed	green
			Critical	1s	1s	Open	Open	Red
3	Total Voltage Low	V	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Closed	Closed	green
			Critical	1s	1s	Open	Open	Red
4	Cell Voltage Low	mV	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Closed	Closed	green
			Critical	1s	1s	Open	Open	Red
5	Discharge Temperature High	℃	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Closed	Closed	green
			Critical	1s	1s	Open	Open	Red
6	Discharge Temperature Low	℃	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Closed	Closed	green
			Critical	1s	1s	Open	Open	Red
7	Charge Temperature High	℃	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Open	Closed	green
			Critical	1s	1s	Open	Open	Red
8	Charge Temperature Low	℃	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Open	Closed	green
			Critical	1s	1s	Open	Open	Red
9	Charge Current High	A	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Open	Closed	green
			Critical	1s	1s	Open	Open	Red
10	Discharge Current High	A	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Closed	Closed	green
			Critical	1s	1s	Open	Open	Red
11	Insulation Low	Ω/V	1级	1s	1s	Closed	Closed	green
			2级	1s	1s	Closed	Closed	green
			3级	1s	1s	Open	Open	green
12	Control Box Temperature High	℃	Warning	1s	1s	Closed	Closed	green
			Alarm	1s	1s	Closed	Closed	green
			Critical	1s	1s	Open	Open	Red

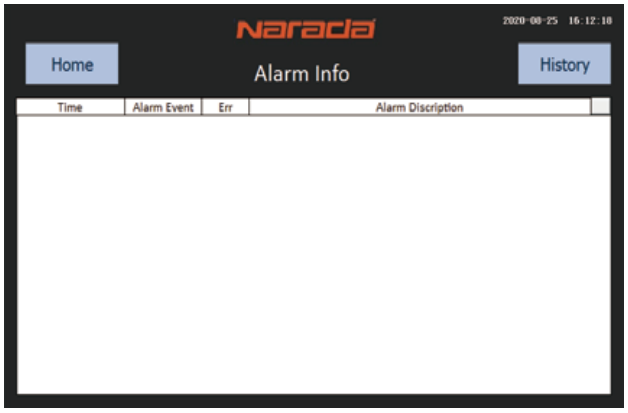
5.6 *Login for Administrator Operation

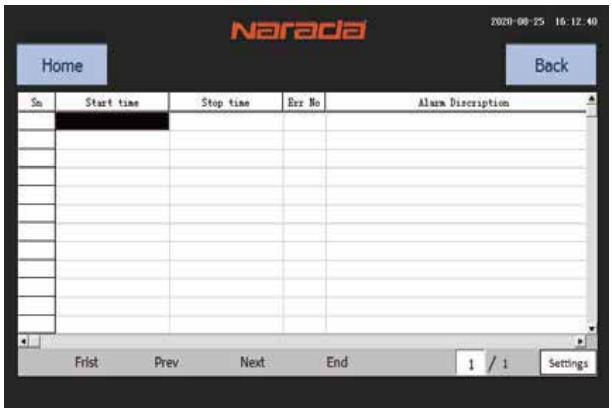
On the main page, click the login button in the upper left corner of the screen to enter the user login interface. Then enter the username and password to execute the administrator operation authority

5.7 Alarm Data Display

Click the Alarm button in the main interface to enter the alarm information page to check current and historical alarm information. The current alarm information page is shown as below.

Then click the History button to check the historical alarm information as shown in the following figure.





5.8 Manual Storage Interface

Obtain the administrator authority first by logging in and then click the Data Log button in the main interface to enter the manual storage page. In this page, you can determine the status of the USB, check storage and operation, and manually force the data logs to save to the USB.

"Normal" button in green means that the contact is normal. If "Normal" is in red, please check the contact of the USB flash drive. Data storage process can be performed after the contact is normal. Then click the "Refresh" button to store the data. "Data Log Completed" means that the storage is successful. Otherwise, check the USB flash drive.

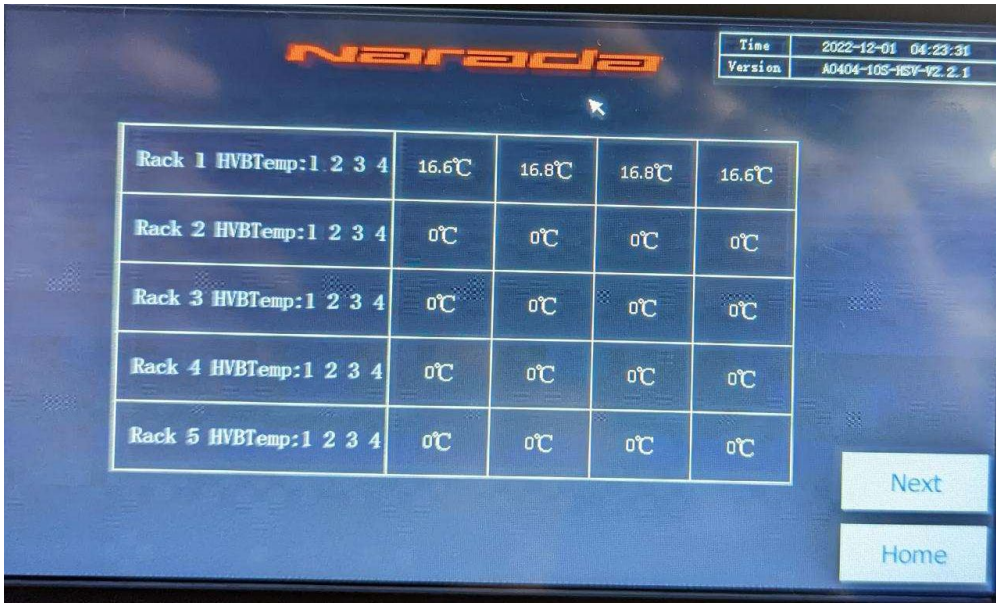
The data stored are Excel files organized within a folder on the USB which can be transferred to a laptop to download data files as needed. The files are organized by "Alarm", "Total State" and "Cluster" number (string number) and then within those folders by date and time in 24-hour

segments. Please remember to reinstall the USB after copying files.

Note: Please do not remove the USB flash drive during storage process, otherwise it may cause damage or data loss.

5.9 Temperature Interface

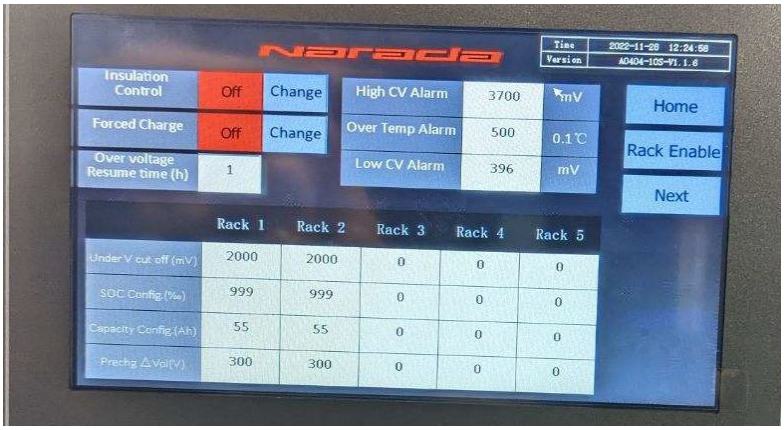
The interface displays the temperature values collected by control box. Click the Hvbtemp button in the main interface to enter the temperature interface page.



5.10 Configuration Interface

The maximum charge and discharge current are the recommended values by the current system. The “SOC Config” is generally not used. The “Delta voltage between Pre-charge and final” means that when the difference between the total voltage and the pre-charge voltage at the end of the grid connection is greater than this value, grid connection will fail.

The “Recharge” button is used to reconnect the racks after a full discharge has taken place and racks have been automatically disconnected due to low voltage. This is utilized as a worst-case scenario option when a discharge has completed to the point where the cabinet disconnects itself from the system. Under normal operation the UPS will be utilized to prevent the battery system from over-discharging and this button will not be needed.

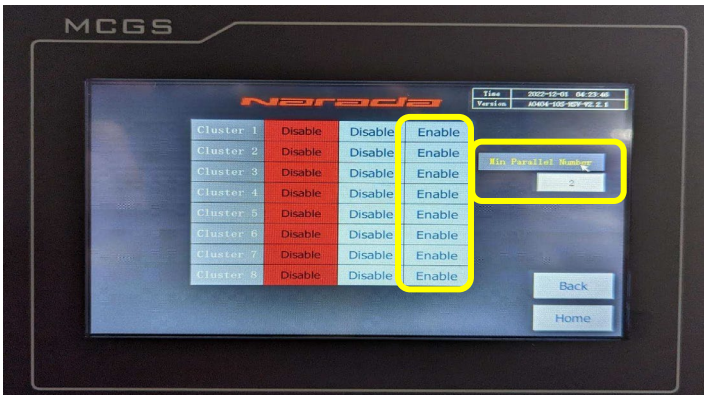


5.11 Rack Enable

5.11.1 Each rack needs to be enabled prior to operation. By default the racks are disabled as indicated on the screen below and both charge and discharge contactors are open as indicated by Red LED Status light on the front of the Control Box. Each Rack must be enabled by pressing the “Enable” buttons. Once the buttons are pressed contactors will make clicking sounds and will close if there are no active alarms. The Status LED will turn Green. This will indicate that the system is ready to operate.

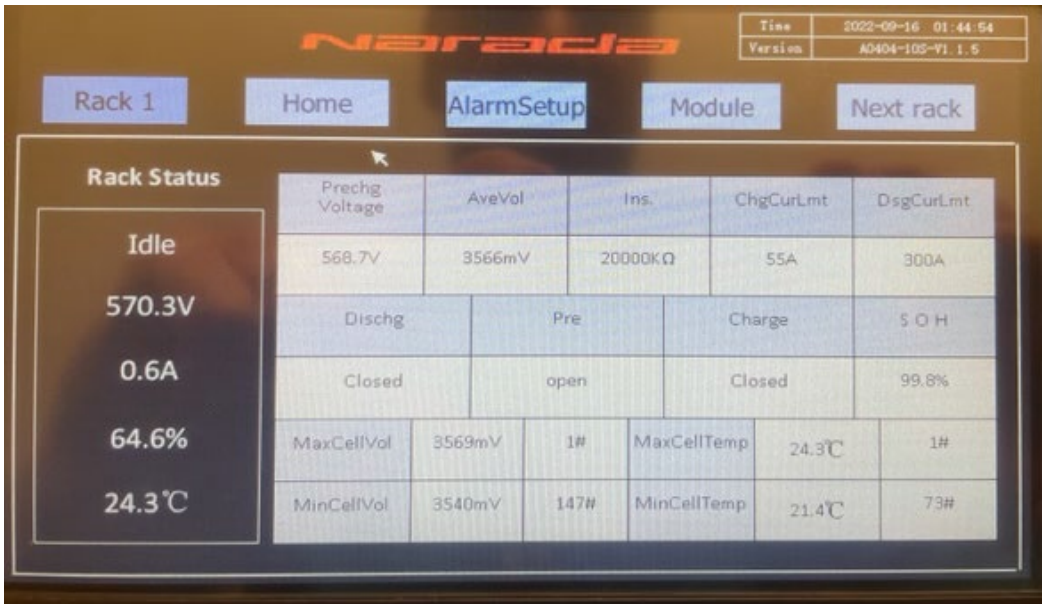
5.11.2 After the system has been fully configured and enabled, be sure to press ‘logout’ from the Home screen to avoid inadvertent setting changes by unqualified personnel.

5.11.3 **Minimum Parallel Number** setting represents a minimum number of racks the system needs to handle the total load during discharge. By default, it is set to half of total number of racks in the system.

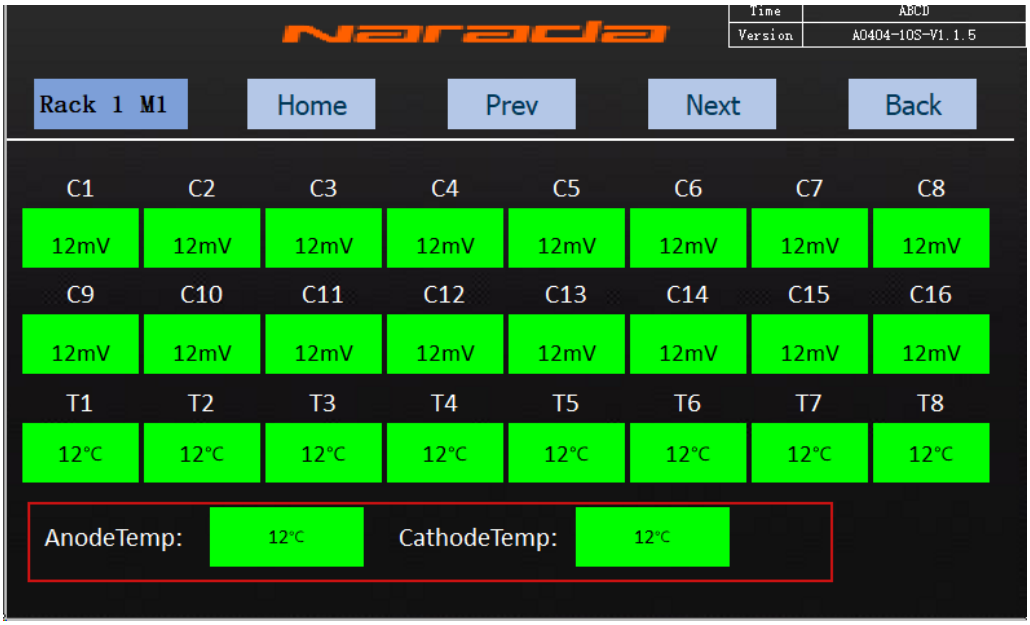


5.12 Single Rack Data Page

R1 to R8 represents the Rack 1 to Rack 8, and the data is displayed for the actual number of racks connected. For example: the RACK 1, click the R1 button to enter the data interface of Rack 1 and check the specific data. This interface contains the sampling information of the specific rack, including the max cell voltage, the min cell voltage, the charge and discharge status, SOC, SOH, max/min temperature and other information.



Click the Module button to enter the BMU information collection interface, which contains the cell voltage and temperature information collected by the BMU. RACK1 M1 shows the information collected by the first BMU, and RACK1 M2 is the information collected by the second BMU, so on and so forth.

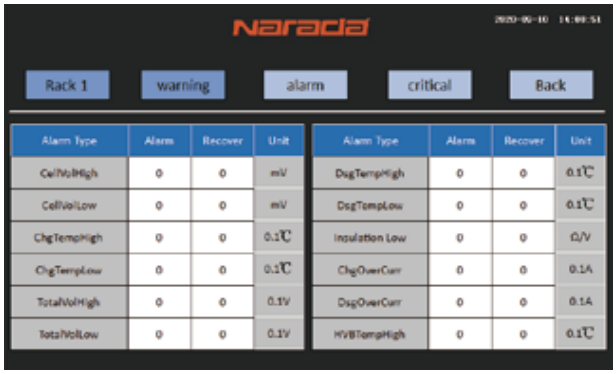


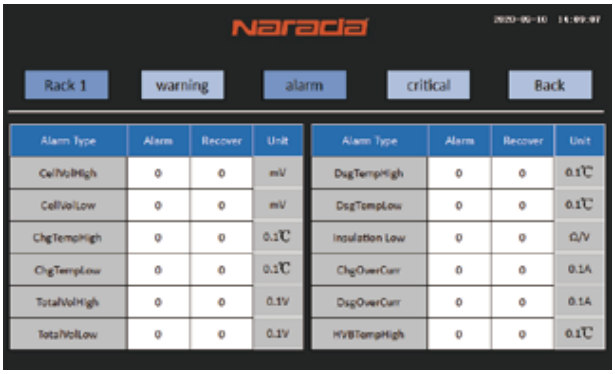
5.13 Threshold Parameter Setting

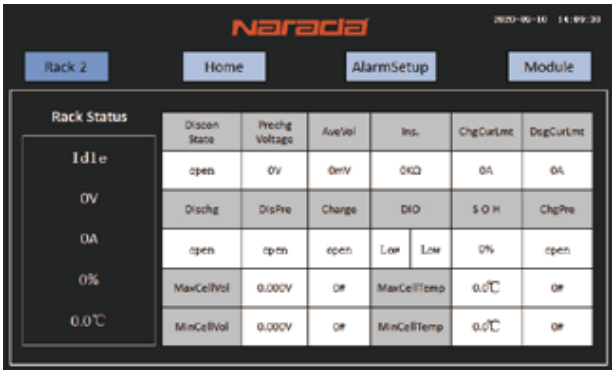
5.13.1 Click the AlarmSetup button to enter the threshold parameter setting page. On this page, you can set the first-level “Warning” threshold, the second-level “Alarm” threshold, and the third-level “Critical” threshold.

5.13.2 On the parameter setting page, you can click the screen to set the relevant parameters of the three level of alarm and recover thresholds. After entering the value, click the OK button. When the value in the dialog box changes to the set value, it proves that the setting has been successful.

5.13.3 The first-level warning thresholds in terms of cell over voltage, undervoltage, high temperature and other parameters can be set. When the parameters of a rack reach the alarm threshold, the alarm interface will report the alarm information. When the system parameter reaches the recovery threshold, the rack will automatically recover. The same is true for the second and third level threshold settings. In case that the third level “Critical” threshold is reached, the system protection mechanism will be triggered. When the third level alarm is recovered, the system needs to be powered on again, and then the system operation will return to normal.







5.14 Circuit Breaker Accessories

Circuit Breaker Accessories are used to check on the status of the system and to be able to remotely take the system off line by opening a breaker.

5.14.1 **Aux Contact** is used to check if the Circuit Breaker is in Open or Closed position.

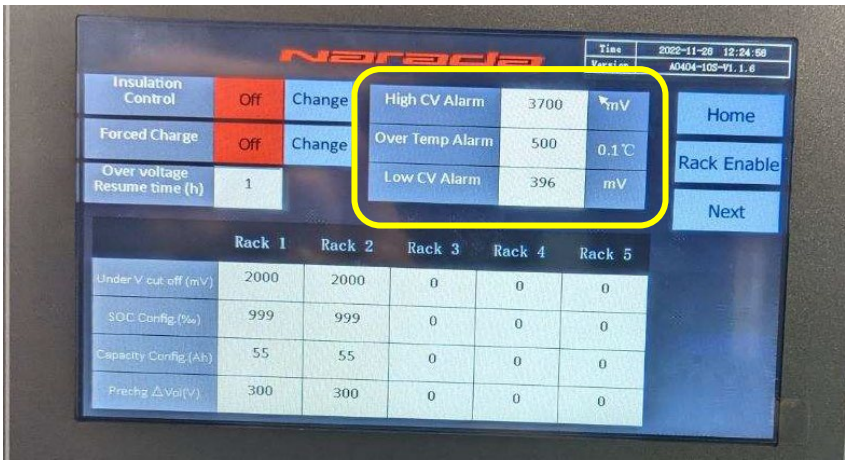
5.14.2 **UVR** – Under Voltage Release. UVR requires DC voltage (24V or 48V) to be constantly supplied to keep the breaker in the closed position. Once the Voltage is removed the UVR will open the breaker.

5.14.3 **Shunt Trip –** Woks opposite of UVR. Shunt trip mechanism does not require voltage to keep the breaker closed. When the voltage (24V or 48V) is supplied to the accessory the mechanism will open the breaker.

Note: It is typically a customer choice which accessory to use. Some customers may choose not to install any accessories.

5.15 Dry Contacts and E-Stop

Dry contacts allow Battery System to communicate with the UPS and enable the UPS to stop Charge and Discharge before BMS opens the contactors in the even the System reaches set Voltage and Temp values as shown under the Config tab on the HMI. Refer to the Installation Manual for more information.



5.16 BMS Automatic SOC Calibration

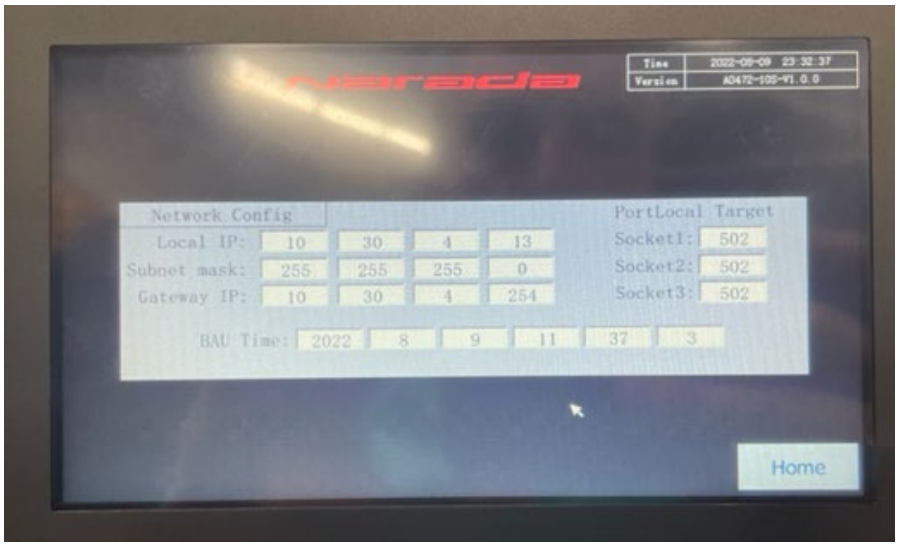
The battery system SOC is calibrated during a full charge and discharge cycle. The calibration process is automatic.

6. General Guidelines

6.1 BCU, BAU, BMU Configuration – See configuration manual for details

6.2 Ethernet Communication

6.2.1 After installation, wiring, and configuration are completed, check the communication status by connecting the Ethernet cable to the BAU to communicate via MODBUS to see whether the System BMS provides the data correctly. Press the Network Tab from the home screen to set the IP address.



6.2.2 The default IP address is:192.168.1.199 (May vary based on system – Part of startup procedure for commissioning) Port number: 502

6.3 Typical Protection Strategy

The basic protection strategy is outlined below (may vary based on application specific requirements):

6.3.1 Origins of signal for protection

a. Module/cell information based on BMS analysis and alarm trigger
b. BMS hardware fault
c. E-Stop - “Battery Off”

6.3.2 BMS sends signal to outside components via Modbus

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