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ACRONYMS

- BMS: Battery Management System
- CB: Circuit Breaker
- DG: Diesel Generator
- DDGG: Diesel Generators
- ECR: Engine Control Room
- EMS: Energy Management System
- ESS: Energy Storage System (including power unit, battery packs, transformer and circuit breaker)
- FSI: Fincantieri SI S.p.A.
- Grid Converter: DC/AC power module;
- HMI: Human Machine Interface
- HW: Hardware
- I/O: Input/Output
- LAN: Local Area Network
- LV: Low Voltage
- PLC: Programmable Logic Controller
- Power Unit: the assembly that is including the grid converters, relevant DC and AC disconnectors, fuses and filters.
- PMS: Power Management System
- RIO: Remote Input Output
- SG: Shaft generator
- SoC: State Of Charge (of battery)
- SW: Software
- SWBD: Main Switchboard

1. CONFIDENTIALITY OF INFORMATION

2. INTRODUCTION

This document is describing the EMS, its functionalities and operator interface.

3. SYSTEM DESCRIPTION

As schematized in the figure 1, the power plant and distribution system is including the following equipment:
- One main switchboard (SWBD) split into two sections;
- Three main diesel driven generators (DG1, DG2 and DG3);
- Two shaft generators (AA1 and AA2);
- Two Energy Storage Systems (ESS PORT and ESS STBD).

Each storage system is mainly consisting of (refer to Figure 1):

- One motorized Circuit Breaker (CB) for the connection to the MSBD;
- One LV transformer, with two secondary windings and with a premag system (to magnetize the trafo before connecting it to the MSBD);
- A Power Unit, that includes:
  - Two motorized AC disconnectors;
  - Two grid converters;
  - Two manual DC disconnectors;
  - An Energy Management System (EMS).
- Two Array of batteries (out of FSI scope of supply), each one consisting of eleven battery packs and a DC-precharge system.

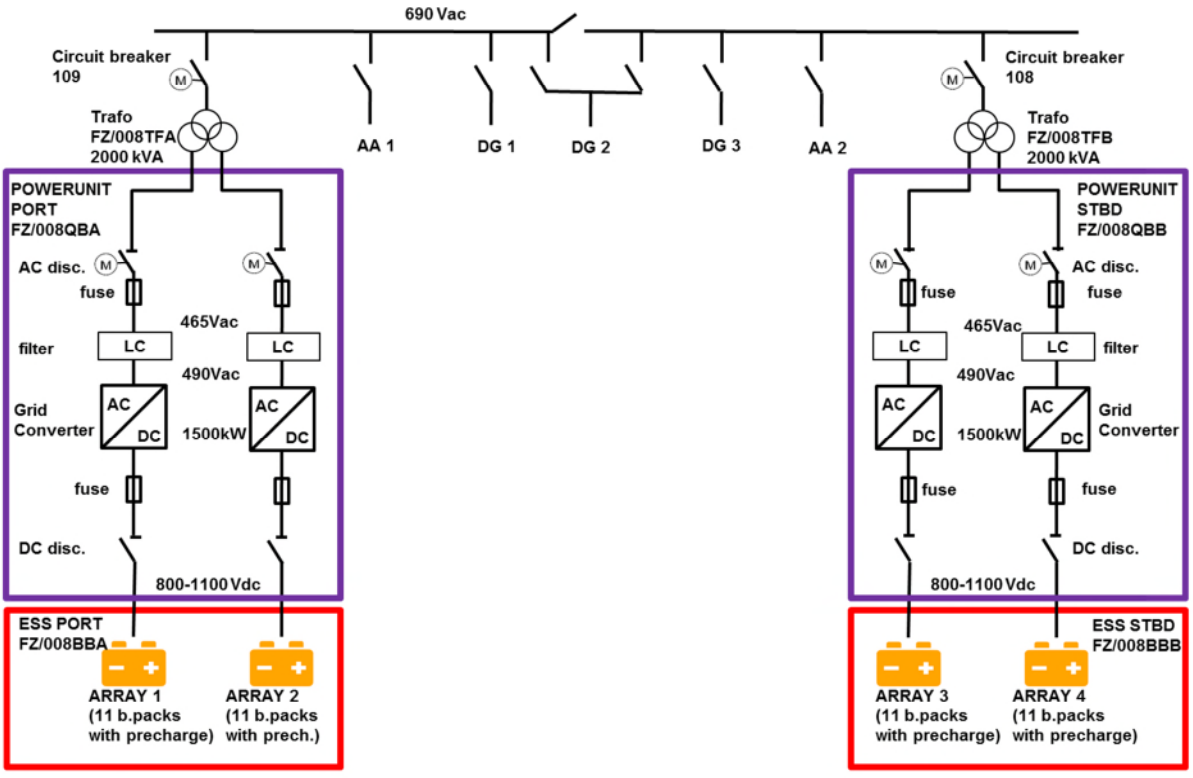


Figura 1 - Energy Storage basic configuration

4. EMS system architecture

The EMS is mainly composed of the following components:

- Power supply;
- PLC controller;
- Ethernet LAN Network;
- HMI local operator interface.

The following figure shows the system architecture and how the EMS components are split in two identical cabinets to be installed on port and starboard power units of the ship:

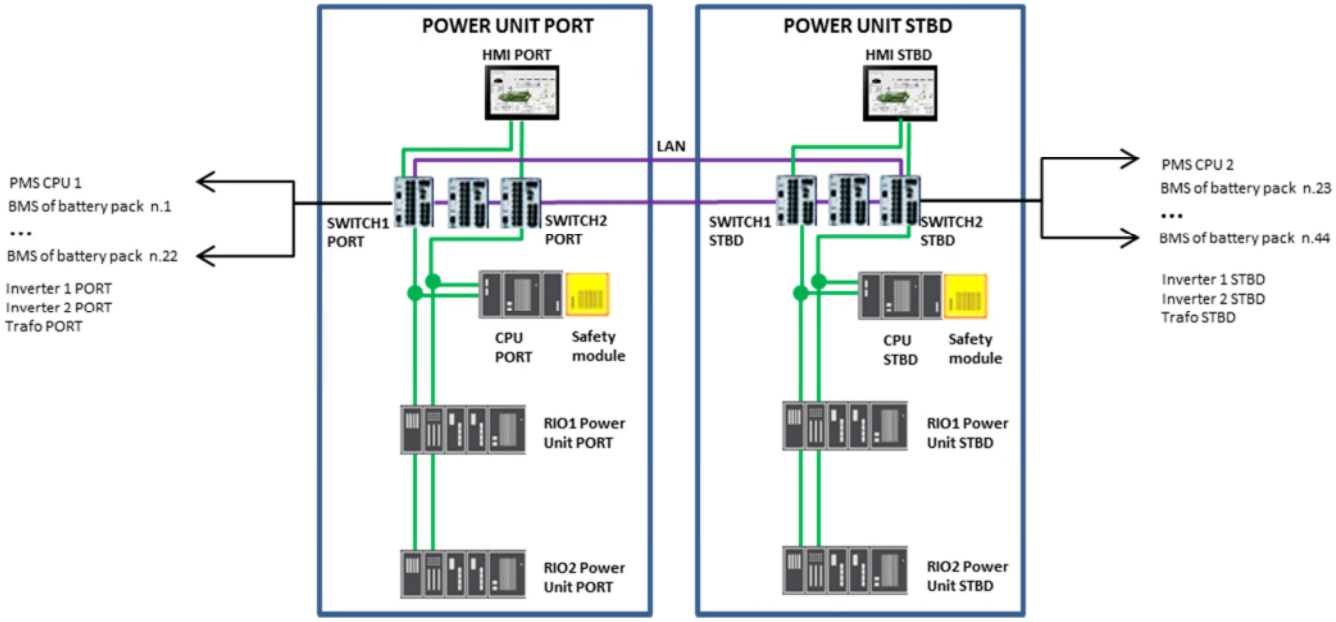


Figure 2 – EMS architecture

4.1. Power supply

The power unit receives a 230Vac from main switchboard and a 230Vac from UPS : the two power supplies are in redundancy so that, in case of failure of a power supply, the EMS and its components are fed by the other one.

4.2. PLC controller

The system is mainly consisting of foresees a CPU, two Remote Input Output (RIO) modules and a Safety Module.

4.3. LAN Network

There are two fiber optic LAN connections between Power Unit Port and Power Unit Stbd.
In each power unit, the EMS PLC CPU communicates via ethernet, by means of three 18-ports managed switches, with the following devices:

- 22 BMS ;
- PMS;
- 2 grid converters;
- Transformer's windings' temperatures acquisition module;
- HMI operator panels.

4.4. Human Machine Interface (HMI)

On each power unit door there is a 15" touch screen operator panel that performs HMI functions, allowing the operator to get detailed information for trouble shooting purposes and to tune parameters.

5. EMS software description

5.1. Alarms and warnings

EMS manages two levels of alarms fault and warning. Their meaning is :

- A warning is an alarm that indicates a potential unsafe condition or a reduction of functionality. It automatically clears when the condition itself is no longer present.
- A fault is an alarm that indicates an automatic shutdown of a device of the ESS. It can be for example the case of a trip of a grid converter or an automatic disconnection of a battery pack. Faults do not automatically clear: after fixing the root cause of the fault, the operator has to reset the failure from HMI or from PMS.

5.2. Power unit monitoring and control.

Only when the ship is in harbor the batteries can be used to release power to the network. In such situation PMS can set the batteries in "discharging" mode in one of the following modes:

- Only ESS: in case of short port stay PMS stops the diesel generators and the power plant is fed by the only batteries;
- ESS+diesel: in case of long port stay the power plant is fed by both the diesel generator(s) and the ESS.

The batteries are charged during the ship navigation.
PMS gives to EMS the commands (stop, start...) to define the Energy Storage Systems state (stop, running…) and the setpoints for their power release.
PMS takes care of providing a charging power setpoint that is compliant with the available power of the electrical plant.

5.3. ESS state

The ESS can be in one of the following states :

- ESS OFF state: situation in which the battery packs are disconnected, circuit breaker is open, AC disconnectors are open, trafo is not magnetized and DC bus voltage is zero;
- ESS Failure or Emergency stop state: situation similar to ESS OFF state, with the difference that, due to a failure condition, the system is not available to start;
- ESS ON state: situation in which the battery packs are connected, circuit breaker is closed, AC disconnectors are open, trafo is magnetized and DC bus voltage is at battery voltage level, ESS grid converters are stopped;
- ESS RUNNING state: situation in which the AC disconnectors are closed and the grid converters are running (synchronized with the main switchboard and modulating). In this state the ESS can be set in the following operating modes:
    - ✓ "ready/idle" state (no current);
    - ✓ "discharging" (positive current);
    - ✓ "charging" (negative current).

In normal ship operation the ESS is in running mode. The ESS is set in OFF state just in case of maintenance need or if the batteries aren't to be used for a long time.

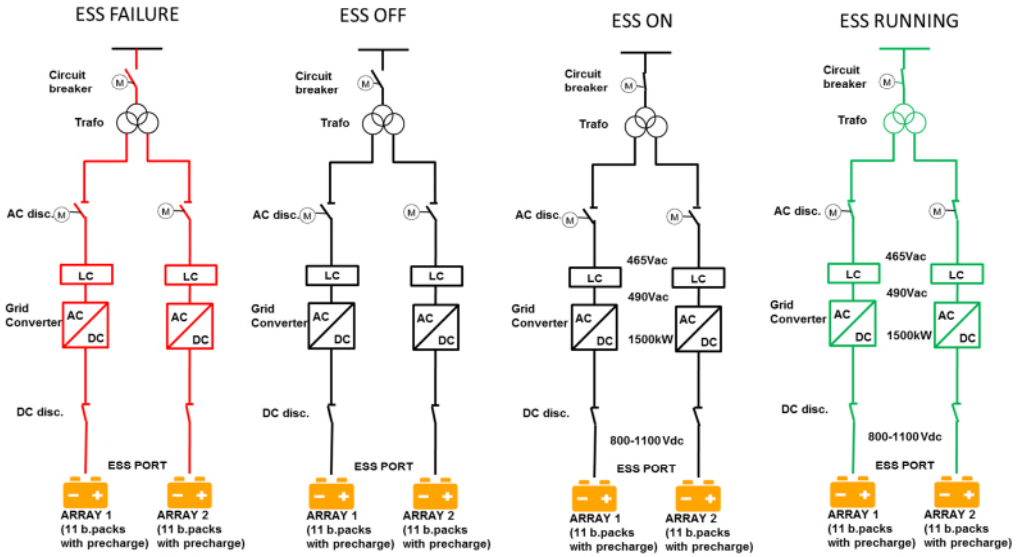
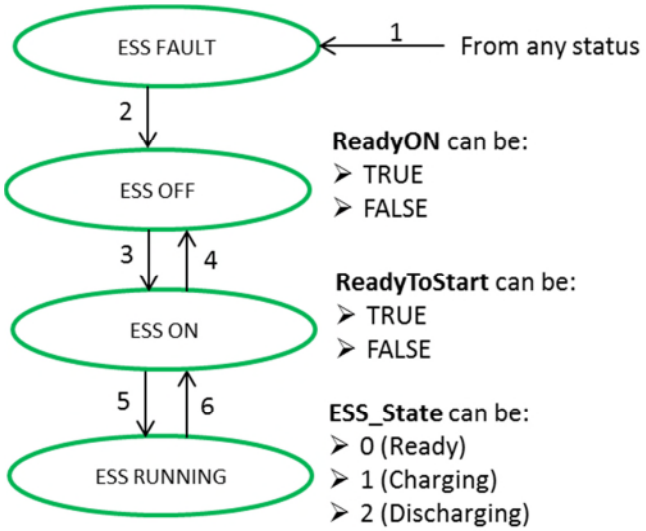


Figura 3- ESS state

5.4. ESS state transfers

ESS state transfers are normally controlled by PMS. EMS executes the state transfer requested by PMS if it's in the condition to do it (for example execution of a start command if in ready to start condition). Under certain conditions (for example a failure) EMS can change the ESS state by itself.
PMS is responsible to check the status of the power plant before providing a transfer command to EMS (f.e. diesel generators connection to network and load transfer to them before requiring EMS to stop the ESS).
The state transfers are shown on next figure:



Triggers for the state transfers are:

1) ESS Fault is TRUE OR Emergency Stop is TRUE;
2) Failure Reset from PMS or EMS is TRUE and no failures are present;
3) "ON conditions" are TRUE AND "ESS ON Command" from PMS is TRUE;
4) "OFF conditions" are TRUE AND "ESS OFF Command" from PMS is TRUE;
5) "Starting conditions" are TRUE AND "ESS Start Command" from PMS is TRUE;
6) "Stop conditions" are TRUE AND "ESS Stop Command" from PMS is TRUE.

The transfer conditions are monitored via a dedicated HMI's mimic.
If a state transfer is not initiated, the operator has to check in such mimic which condition is not verified.
If a state transfer is initiated but not successfully completed, then an alarm is communicated by EMS to PMS and the local HMI shows more detailed information about the checkpoint that was not passed.

5.4.1. ESS failure or emergency stop (1)

Initial state: any state
Trigger for state transition: A ESS fault or emergency stop.
Sequence:
ESS faults can be immediate or delayed. The IOlist column "PU alarm" is providing the information of which alarms are causing an immediate or delayed failure, in particular:

- Immediate ESS failure causes are identified with "FAILURE" description;
- Delayed ESS failure causes are identified with "FAILURE PREWARNING" description.

In case of ESS delayed failure, EMS generates a "failure prewarning alarm" and, after a delay (default=120 seconds) it stops the ESS. During the delay time the available power may be reduced, for example if a converter or an array is unavailable due to the failure. During the delay time the PMS evaluates if to start the first available genset and connect it to network before the power unit is totally stopped by EMS.
In case of fault the following actions are performed by EMS:

1) AC disconnectors opening;
2) Battery disconnection;
3) AC circuit breaker opening;

ESS enters fault condition that is retained by EMS and any "ESS ON command" is inhibited until the failure is solved and reset.

Final state: ESS fault or emergency stop state

5.4.1.1. ESS emergency stop

The ESS emergency stop is managed by the EMS safety module, while the other faults are managed by the PLC's CPU. Such solution allows total independency of the emergency stop actuation from the PLC controller.
The emergency stop can be initiated by :

- one of the three pushbuttons (at power unit door, at battery room entrance or in ECR). Each of them has two NC contacts. In case of incongruence of the two contacts a specific alarm is provided and the emergency stop is performed. After fixing the incongruence there is the need to push the emergency stop ON and OFF once again in order to align the two readings from the safety module.
- DC disconnector open status. DC disconnector opening causes an emergency stop. Anyhow, no maintenance inside power unit should be performed before having extracted all relevant battery packs PDM (refer to battery supplier manual) and before having blocked the AC circuit breaker in open position by means of its local control in the main switchboard,
- Emergency Shutdown System (ESD) command, initiated manually or automatically due to fire fighting system activation.

In case of emergency stop the following actions are performed by EMS:

- a quick stop command to the grid converters;
- (after a delay) an emergency stop command to the battery pack arrays;
- (after a delay) an AC circuit breaker open command.

5.4.2. ESS failure reset (2)

Initial state: ESS fault or emergency stop
Trigger for state transition: Manual reset from PMS or from HMI.
Sequence:
EMS receives a reset command from HMI (local) or from PMS (remote) and provides a reset command to all connected devices (grid converters, circuit breaker and battery packs). Before being able to reset a failure, the operator must fix its root cause.

Final state: ESS OFF.
Note: If a single battery pack is disconnected due to a fault, the operator has to check the failure locally, fix it, reset the BMS and provide a battery "connect" command to the single pack from the HMI.

5.4.3. ESS ON command (3)

Initial state: ESS OFF
Trigger for state transition: "ESS ON command" from PMS.
Sequence:
EMS receives an "ESS ON command" from PMS.
The ON procedure is initiated only if the "ON conditions" are verified. They are shown on relevant HMI page.
In case of ON command the following actions are performed by EMS:

1) Transformer premagnetization;
2) Precharge of DC-bus;
3) Connection of battery packs to DC-bus.

If the ON sequence is not concluded properly, EMS provides a warning "ESS ON sequence unsuccessful", and is automatically performing an OFF sequence in order to go back to initial OFF state and allow a new ON command tentative from PMS. If not possible to reach the OFF state either, ESS enters a fault condition.
The ON sequence is successful also in case some of the battery packs are not connected to DC-bus, since ESS can be started even with just one battery pack.
If some battery packs have not been connected by BMS during the ON sequence, the operator can connect them singularly from the local HMI. If even the single battery pack connect command is not executed by BMS, the reason can be that the single battery pack voltage is not aligned to the voltage of the connected battery packs: in such case repeat the manual command when, after battery charge or discharge, the battery pack voltage is at the connected packs voltage level. If even in such case the battery pack is not connecting then contact battery supplier for further trouble shooting.

Final state: ESS ON.

5.4.4. ESS OFF command (4)

Initial state: ESS ON
Trigger for state transition: "ESS OFF" command from PMS.
Sequence:
EMS receives an "ESS OFF command" from PMS.
The OFF procedure is initiated only if the "OFF conditions" are verified. They are shown on relevant HMI page.
In case of OFF command the following actions are performed by EMS:

1) Battery packs disconnections;
2) AC circuit breaker opening;

If the OFF sequence is not concluded properly, EMS provides a warning "ESS OFF sequence unsuccessful ", performs the ESS failure sequence (1) and enters the fault condition.
If the OFF sequence is concluded properly, EMS changes the ESS state to “ESS OFF”.

Final state: ESS OFF.

5.4.5. ESS start command (5)

Initial state: ESS ON
Trigger for state transition: "ESS start " command from PMS.
Sequence:
EMS receives an "ESS Start command" from PMS.
The start procedure is initiated only if the "start conditions" are verified. They are shown on relevant HMI page.
In case of start command the following actions are performed by EMS:

1) Grid converters start;
2) Closure of grid converters AC disconnectors;
3) Grid converters synchronization to network.

If the start sequence is not concluded properly, EMS provides a warning "ESS starting sequence unsuccessful" and allows a new starting tentative from PMS.
If the starting sequence is concluded properly, EMS changes the ESS state to “ESS running” and is ready to execute power setpoints from PMS. When ESS is running, it can be in ready/idle, discharging and charging mode depending on relevant PMS command. Such control modes have the following meanings:

- "ready/idle mode": EMS doesn't consider any power control from PMS and is releasing zero active power;
- "discharging mode": EMS can control the active power in isochronous or droop. In isochronous mode EMS receives an active power setpoint from PMS, while in droop mode it receives a droop frequency offset from PMS. If no diesel generators are on network, the control is automatically switched to droop;
- "charging mode": EMS follows an active power charging setpoint from PMS.

Final state: ESS running.

5.4.6. ESS stop command (6)

Initial state: ESS running
Trigger for state transition: "ESS stop" command from PMS.
Sequence:
EMS receives an "ESS Stop command" from PMS.
The start procedure is initiated only if the "stop conditions" are verified. They are shown on relevant HMI page.
In case of stop command the following actions are performed by EMS:

1) Grid converters stop;
2) Opening of grid converters AC disconnectors;

If the stopping sequence is not concluded properly (f.e. grid converters not stopping modulation), EMS provides a warning "ESS stop sequence unsuccessful", performs the ESS failure sequence (1) and enters the fault condition.
If the stopping sequence is concluded properly, EMS changes the ESS state to “ESS ON”.

Final state: ESS ON.

5.5. Power unit limitation to PMS power setpoint

EMS executes the power setpoint variations from PMS within the limit of its available power. Its available power can be limited for example due to current limit of the batteries, high or low SoC condition of a battery array, failure of a grid converters or failure conditions. PMS is always informed by EMS of the actual available power of each ESS.

5.6. Remaining time for battery charge / discharge

EMS informs PMS of the remaining time to reach the full charge or discharge of the batteries.

5.7. Support to network to prevent black-out

In case of frequency drop, the grid converters will, within their capability and if the power unit is set in running state by PMS, immediately support the network in order to avoid further voltage and frequency decrease. An alarm "UPS mode" is communicated by EMS to PMS till a generator is connected by PMS to the electrical network.
If a blackout condition is anyhow reached, the black-out resolution is managed by the emergency switchboard and by PMS without any grid converters contribution.

6. EMS operator manual

The EMS operator manual informs about how to operate locally from the power unit touch screen HMI.

The following instructions are provided by the manual:

- Navigator bar;
- Overview page;
- Alarm page;
- Alarm history page;
- Settings page;
- Logs page;
- Maintenance page;
- Sequences page;
- I/O status page;
- Trends page;
- Battery array page;
- Battery packs details page.

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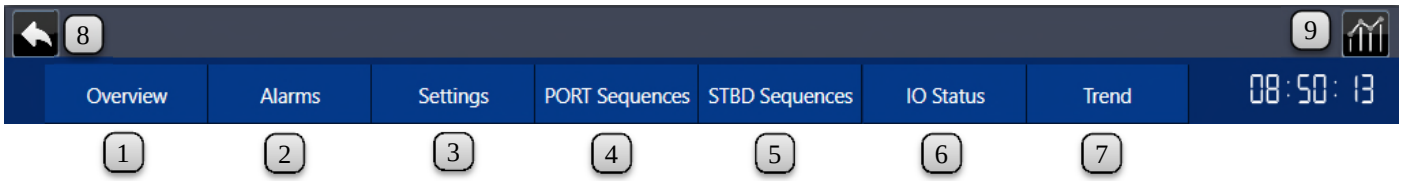
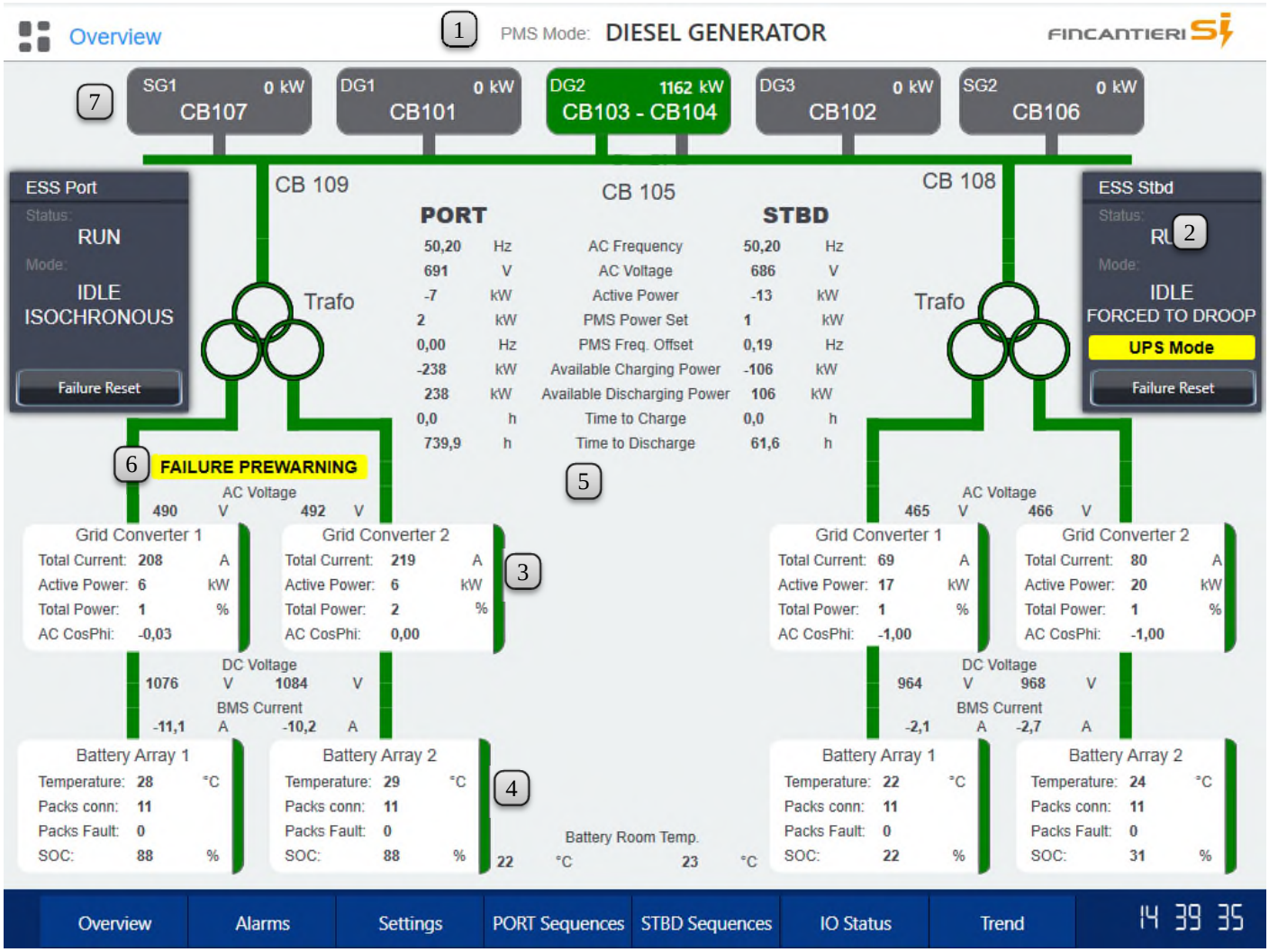
6.1. NAVIGATION BAR



1	Overview page: it represents both power units. From this page is possible to access relevant Transformers, Converters and Battery Array details.
2	Alarms page: In this page all active alarms are listed. When a new alarm occurs, the Alarms button starts blinking red and white until the alarm acknowledgement by the operator. From this page it's also possible to access to the alarms history.
3	Settings page: In this page we can find the plant's settings. A software maintainer password is required to modify them. A login dialog will appear if you try to edit data or show pages with insufficient privileges. Only if if you have enough privileges it's possible to access also the log and maintenance page.
4	PORT Sequences: In this page are displayed start conditions for all PORT's power unit sequences.
5	STBD Sequences: In this page are displayed start conditions for all STBD's power unit sequences.
6	IO Status: Show PLC, Safety modules and RIO status
7	Trend: Show data trend of signals received from PMS
8	BACK Icon: Visible only in some subpages, allows you to go back on the previous page
9	TREND Icon: Visible only in some subpages, allows you to show historical data for that object

6.2. OVERVIEW PAGE



1	POWER MANAGEMENT SYSTEM MODE: DIESEL GENERATOR SHAFT GENERATOR SHAFT GENERATOR 1 + DIESEL GENERATOR SHAFT GENERATOR 2 + DIESEL GENERATOR ONLY ENERGY STORAGE SYSTEM ENERGY STORAGE SYSTEM + DIESEL GENERATOR

2

EMS CONTROL PANEL:

STATUS	FAULT RUN ON OFF
MODE	ACTUAL MODE:

IDLE	IDLE STATUS, NO ACTIVE POWER FLOW.
CHARGING	CHARGING, ACTIVE POWER DRAIN FROM NETWORK
DISCHARGING	DISCHARGING, ACTIVE POWER FROM BATTERIES TO NETWORK

POWER MODE

ISOCHRONOUS	Work with fixed power setpoint from PMS
DROOP	Work with frequency offset from PMS
FORCED TO DROOP	Forced to work in droop mode if no diesel/shaft generator are connected
UPS MODE	This signal is visible when a converter detects a low network frequency. When it happens, the converters automatically switch to droop to support network and prevent backout. The UPS mode is automatically reset when a diesel/shaft generator is connected to network.

FAILURE RESET	Failure reset button. Need to be pressed to reset power unit failure status and/or battery packs failure status.

3

GRID CONVERTER INFORMATION:

VALUE	DESCRIPTION
Total Current [A]	TOTAL CURRENT FROM THE SINGLE CONVERTER
Active power [kW]	ACTIVE POWER FROM THE SINGLE CONVERTER
Total power [%]	TOTAL POWER % OF CONVERTER NOMINAL POWER
AC CosPhi	COSPHI
DC VOLTAGE [V]	ACTUAL VOLTAGE ON DC SIDE
AC VOLTAGE [V]	ACTUAL VOLTAGE ON AC SIDE

The bar at the side of the rectangle shows the Converter status;
RED: Failure active;
Yellow: Warning;
Green: Running
Light Gray: Ready to run
Dark Gray: Not ready to run

Click on the rectangle to open “Grid Converter” page.

4

BATTERY ARRAY INFORMATION:

VALUE	DESCRIPTION
TEMPERATURE [°C]	MAXIMUM CELL TEMPERATURE INSIDE ARRAY
PACKS CONN.	NUMBER OF PACKS CONNECTED
PACKS FAULT	NUMBER OF PACKS FAULTED
SOC [%]	STATE OF CHARGE
BMS CURRENT [A]	ACTUAL CURRENT FROM THE ARRAY

The bar at the side of the rectangle shows the Battery array status;
RED: Failure active;
Yellow: Warning;
Green: All available packs are connected;
Blinking Green & Gray: Not all available packs are still connected;
Gray: Ready

Click on the rectangle to open “Battery Array” page.

5

GENERAL INFORMATION:

VALUE	DESCRIPTION
AC FREQUENCY [HZ]	NETWORK FREQUENCY READ FROM CONVERTER. NOTE: THIS MEASUREMENT IS NOT RELIABLE IF THE AC CIRCUIT BREAKER IS OPEN.
AC VOLTAGE [V]	NETWORK VOLTAGE READ FROM CONVERTER. NOTE: THIS MEASUREMENT IS NOT RELIABLE IF THE AC CIRCUIT BREAKER IS OPEN.
ACTIVE POWER [KW]	ACTIVE POWER READ FROM PMS
PMS POWER SET [KW]	PMS ACTIVE POWER SETPOINT (ONLY ON ISOCHRONUS), NEGATIVE TO CHARGE AND POSITIVE TO DISCHARGE
PMS FREQ. OFFSET [HZ]	PMS FREQUENCY OFFSET (ONLY ON DROOP)
AVAILABLE CHARGING POWER [KW]	AVAILABLE CHARGING ACTIVE POWER CALCULATED BASED ON ACTUAL CHARGING CURRENT LIMITATION
AVAILABLE DISCHARGING POWER [KW]	AVAILABLE DISCHARGING ACTIVE POWER CALCULATED BASED ON ACTUAL DISCHARGING CURRENT LIMITATION
TIME TO CHARGE [H]	TIME TO COMPLETE CHARGE CALCULATED BASED ON ACTUAL SOC AND POWER SETPOINT FROM PMS.
TIME TO DISCHARGE [H]	TIME TO COMPLETE DISCHARGE CALCULATED BASED ON ACTUAL SOC AND POWER SETPOINT FROM PMS.

6

FAILURE PREWARNING

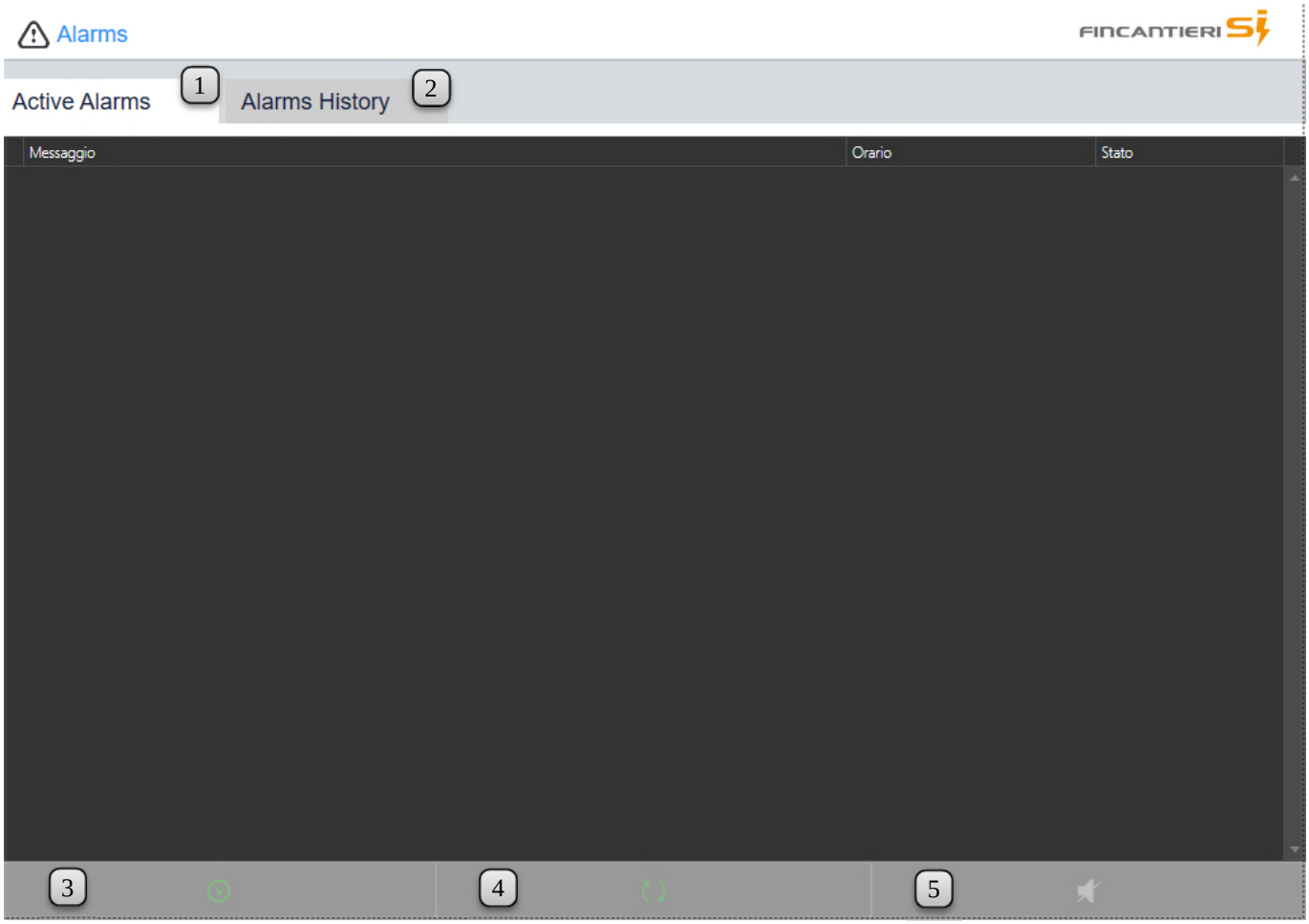
The text is visible if a failure prewarning is on course on the specific power unit.
The failure prewarning alarm is sent to PMS. After 2 minutes the power unit is automatically shut down by EMS.

7

GENERATORS AREA

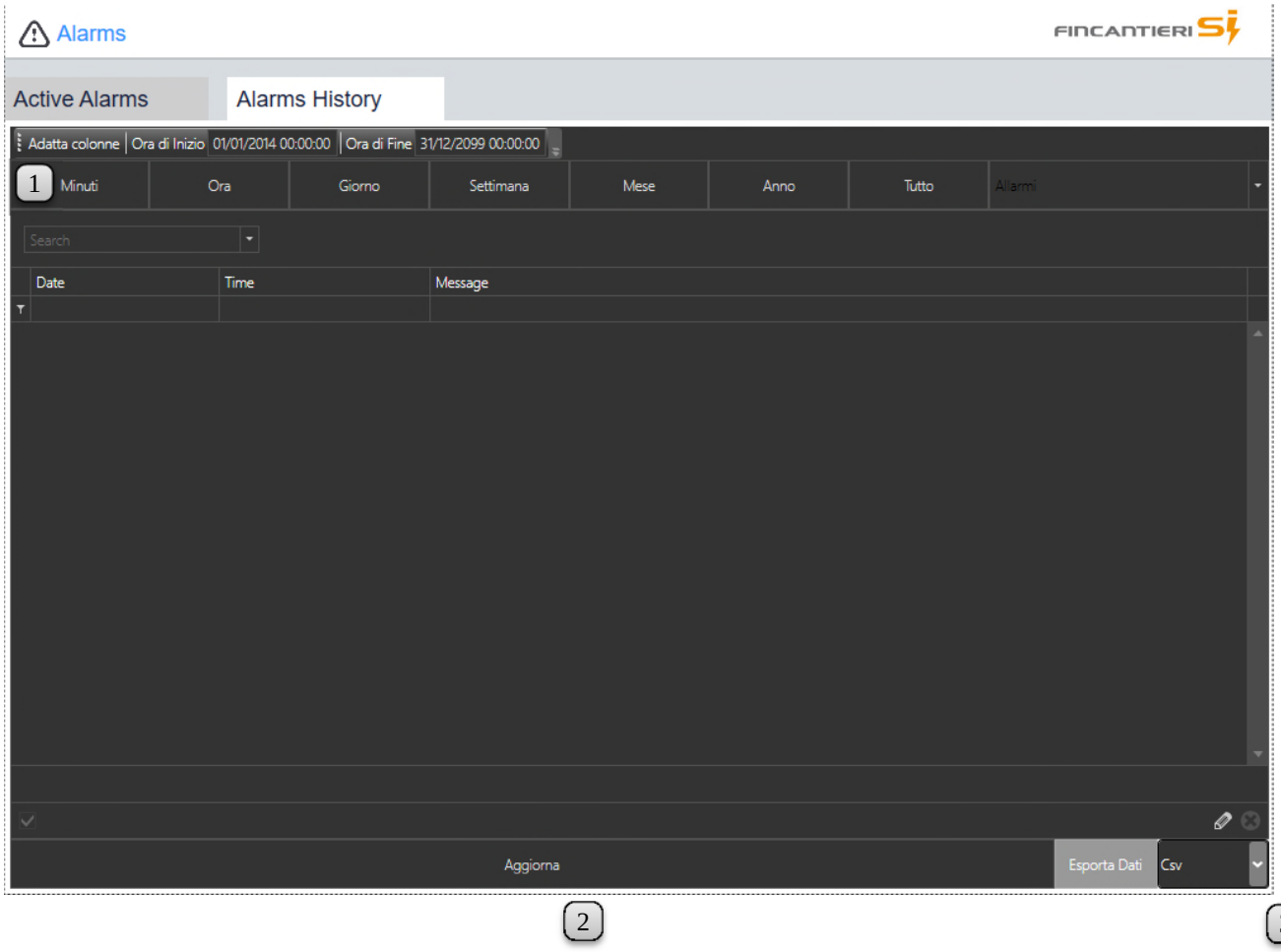
IN THIS AREA IT'S POSSIBLE TO SEE THE CIRCUIT BREAKER STATUS OF EACH DIESEL OR SHAFT GENERATOR AND THE TIE-BREAK STATUS. GREEN COLOR IS FOR CLOSED STATUS, DARK GRAY IF IT'S OPEN. FOR EACH GENERATOR, THE ACTIVE POWER IS INFORMED. SUCH DATA ARE ACQUIRED FROM PMS.

6.3. ALARMS PAGE



1	Show all active alarms. (White if selected). The alarms that are acknowledged are yellow if they are warnings and red if they are failures.
2	Show alarms history. (White if selected)
3	Acknowledge all active and unacknowledged alarms
4	Refresh active alarms list
5	Mute sound on unacknowledged alarms

6.4. ALARM HISTORY PAGE

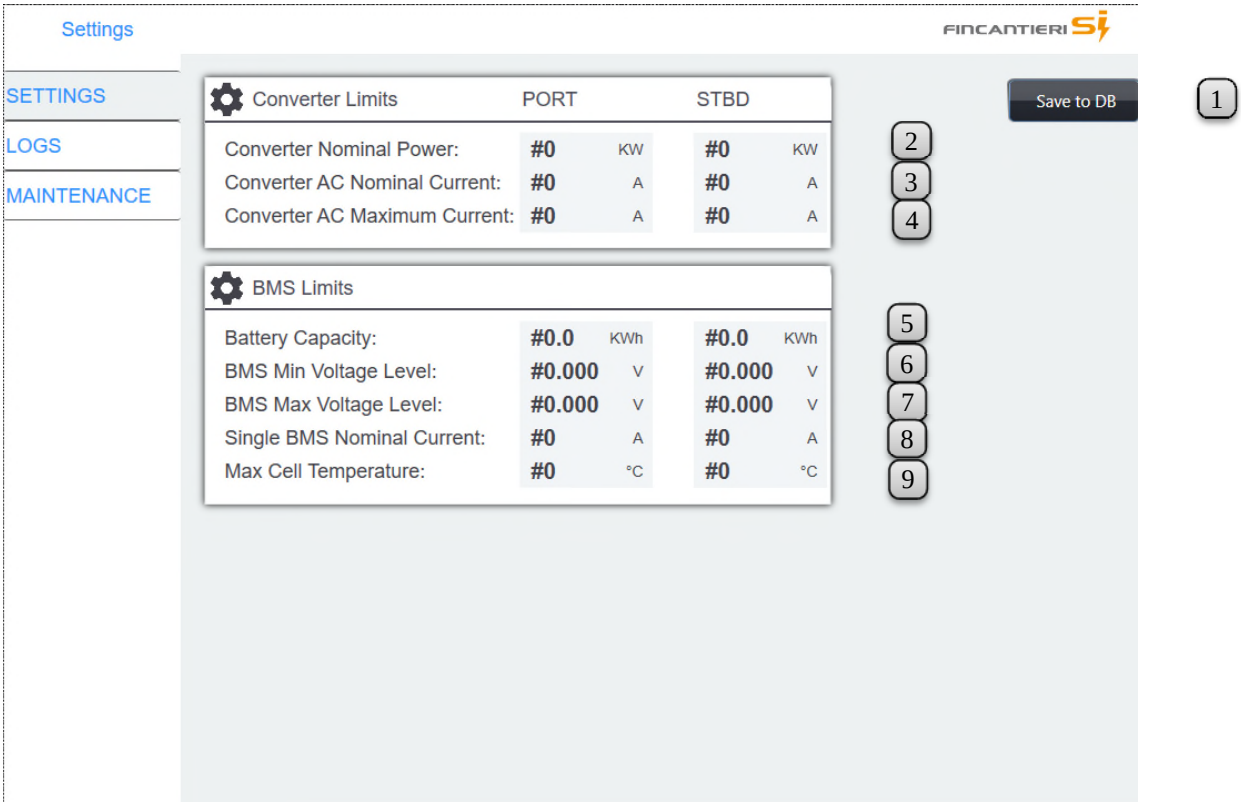


1	Alarms can be filtered by date and time.

Minuti	Display only acknowledged alarm in last minute.
Ora	Display only acknowledged alarm in last hour.
Giorno	Display only acknowledged alarm in last day.
Settimana	Display only acknowledged alarm in last week.
Mese	Display only acknowledged alarm in last month.
Anno	Display only acknowledged alarm in last year.
Tutto	Display all alarm history.
Ora di Inizio 01/01/2014 00:00:00 Ora di Fine 31/12/2099 00:00:00	Display selected date range

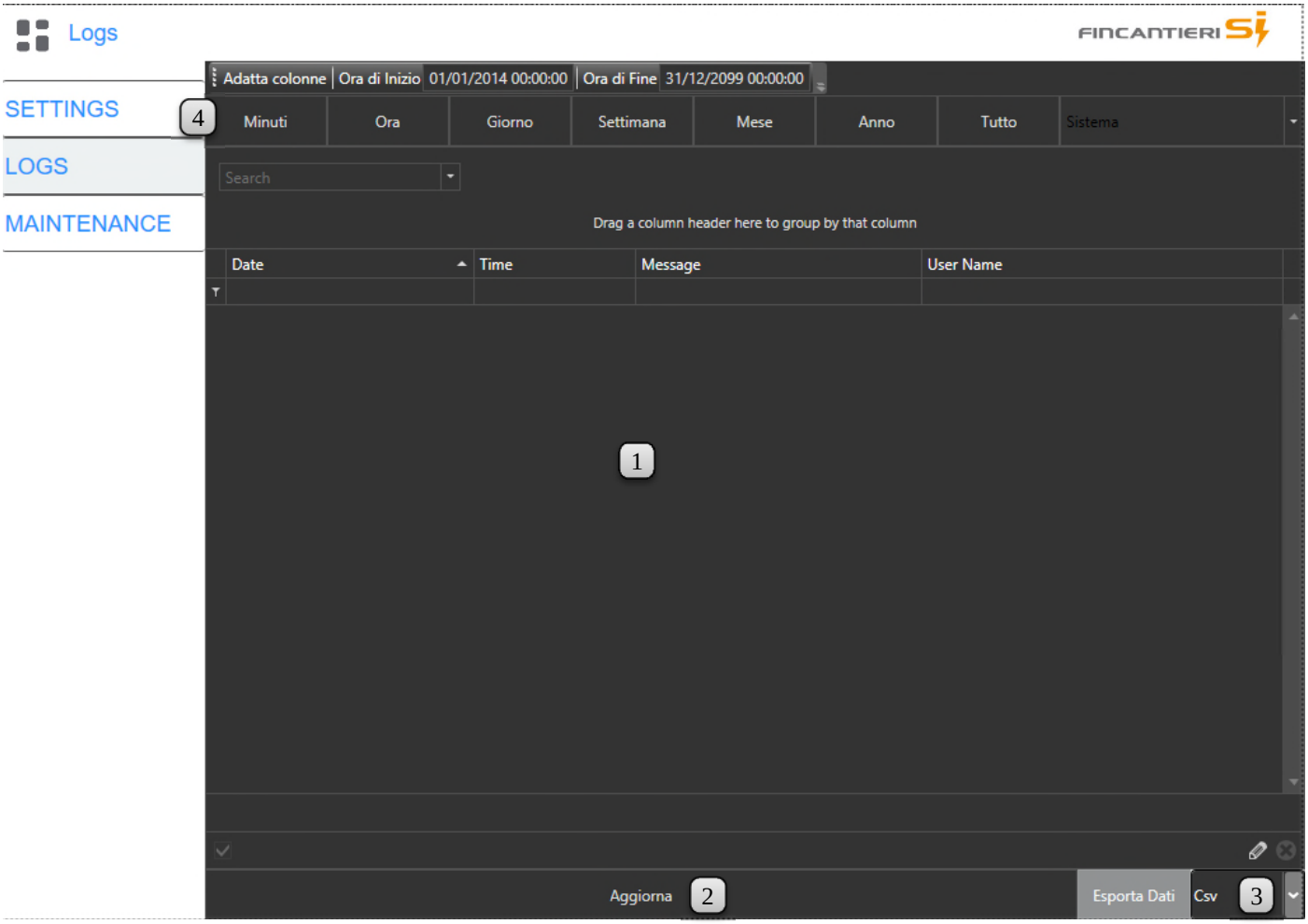
2	Refresh of alarm history display.
3	Alarm History can be exported in a “CSV” file.

6.5. SETTINGS PAGE



1	Store current active settings to database.
2	Converter nominal power, used to limit the maximum available power sent to PMS.
3	Converter nominal current, used to calculate current reference to converter.
4	Converter maximum current, not used, just as reference.
5	Nominal cell capacity used to calculate time to charge and discharge.
6	Cell minimum voltage used to calculate DC voltage limit to converters. To find the minimum DC voltage this value must be multiplied by 264 (number of battery cells in series).
7	Cell maximum voltage used to calculate DC voltage limit to converters. To find the maximum DC voltage this value must be multiplied by 264 (number of battery cells in series).
8	Single battery pack maximum current (charge and discharge), used to limit the maximum available power sent to PMS. This value is referred to the single battery pack, the limit of the available power is calculated based on how many battery packs are connected to the DC-bus.
9	Maximum cell temperature, if a battery pack has a cell that reaches this temperature for at least 10s a disconnect command will be sent to BMS master for that pack, and an alarm message will be displayed.

6.6. LOGS PAGE



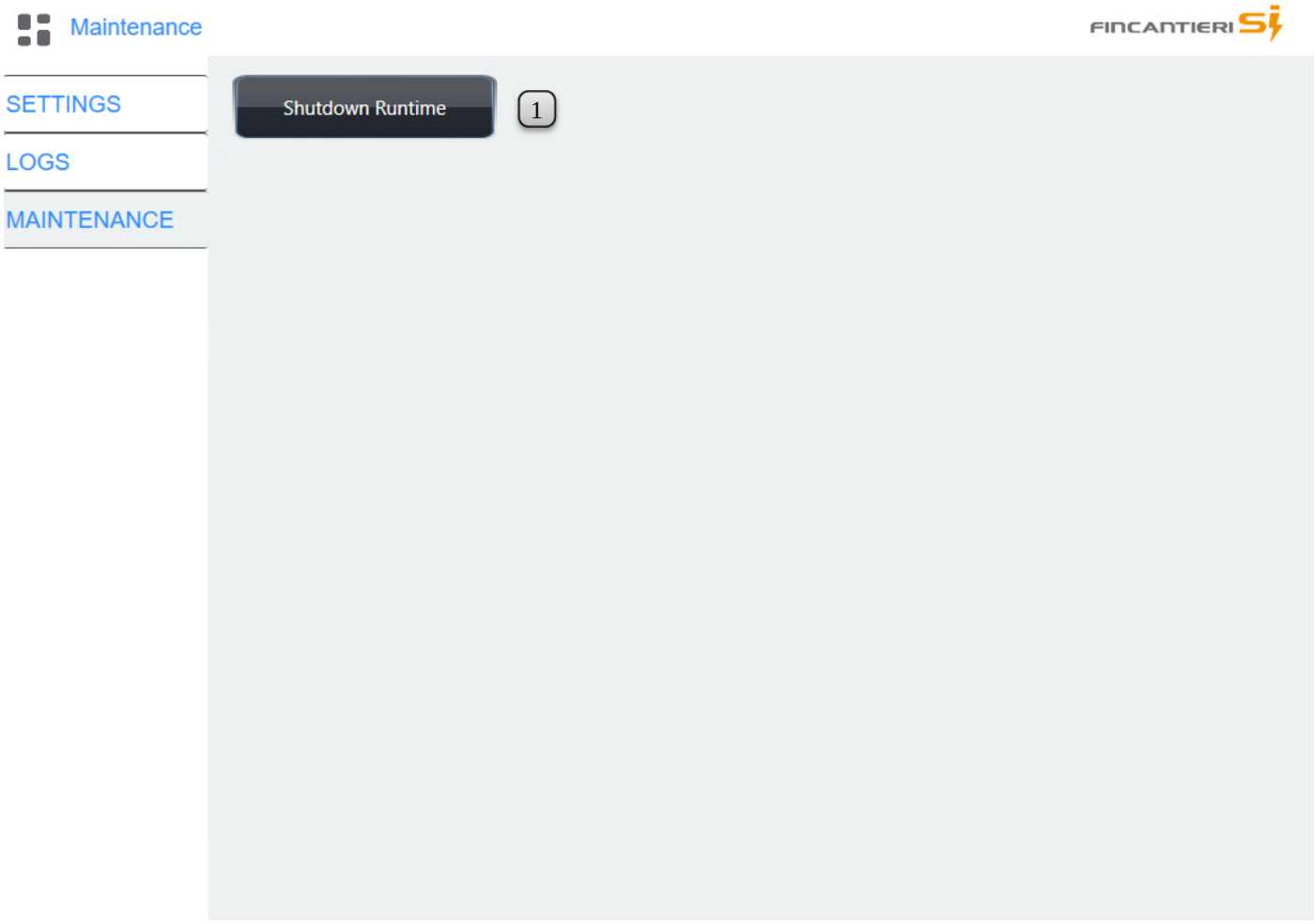
1	Log area. All log messages such as Login/Logout, system startup, settings change, alarms, selected variables variation are displayed here
2	Refresh current visualization
3	Export current data to an external file

4

Log messages can be filtered by date and time.

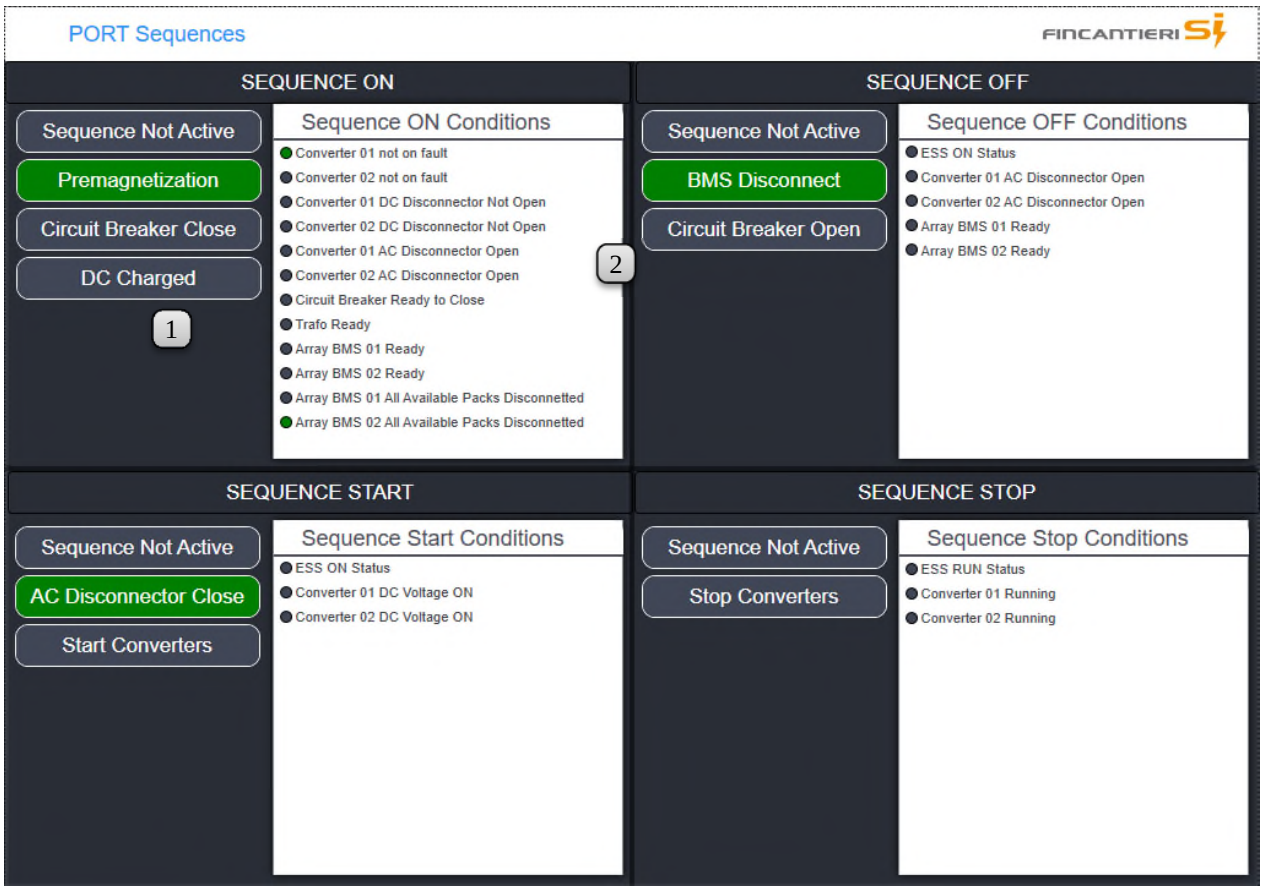
Minuti	Display only log messages in last minute.
Ora	Display only log messages in last hour.
Giorno	Display only log messages in last day.
Settimana	Display only log messages in last week.
Mese	Display only log messages in last month.
Anno	Display only log messages in last year.
Tutto	Display all log messages history.
Ora di Inizio 01/01/2014 00:00:00 Ora di Fine 31/12/2099 00:00:00	Display selected date range

6.7. MAINTENANCE PAGE



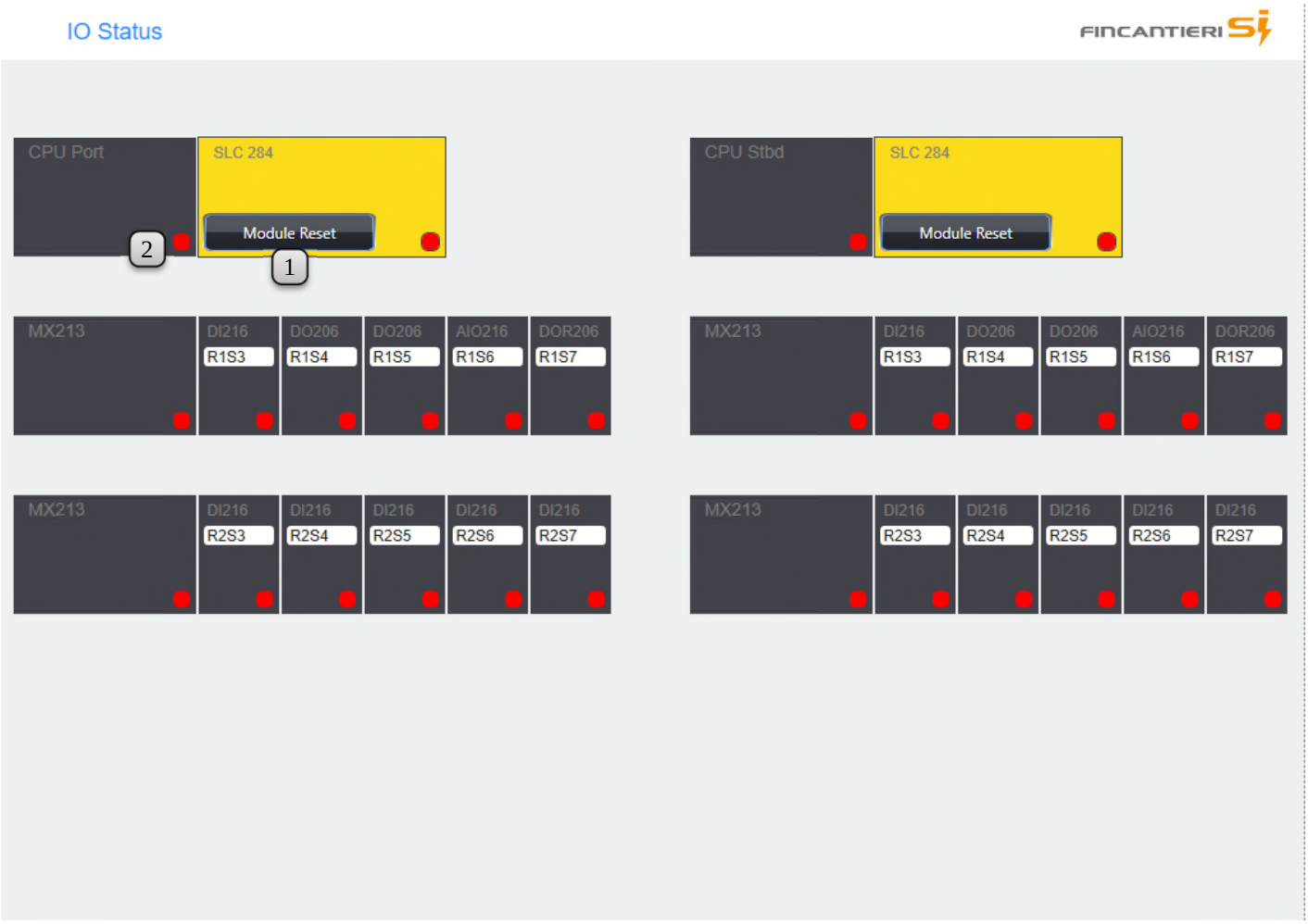
1	Shutdown HMI runtime. This function is reserved to the software developers.

6.8. SEQUENCES PAGE



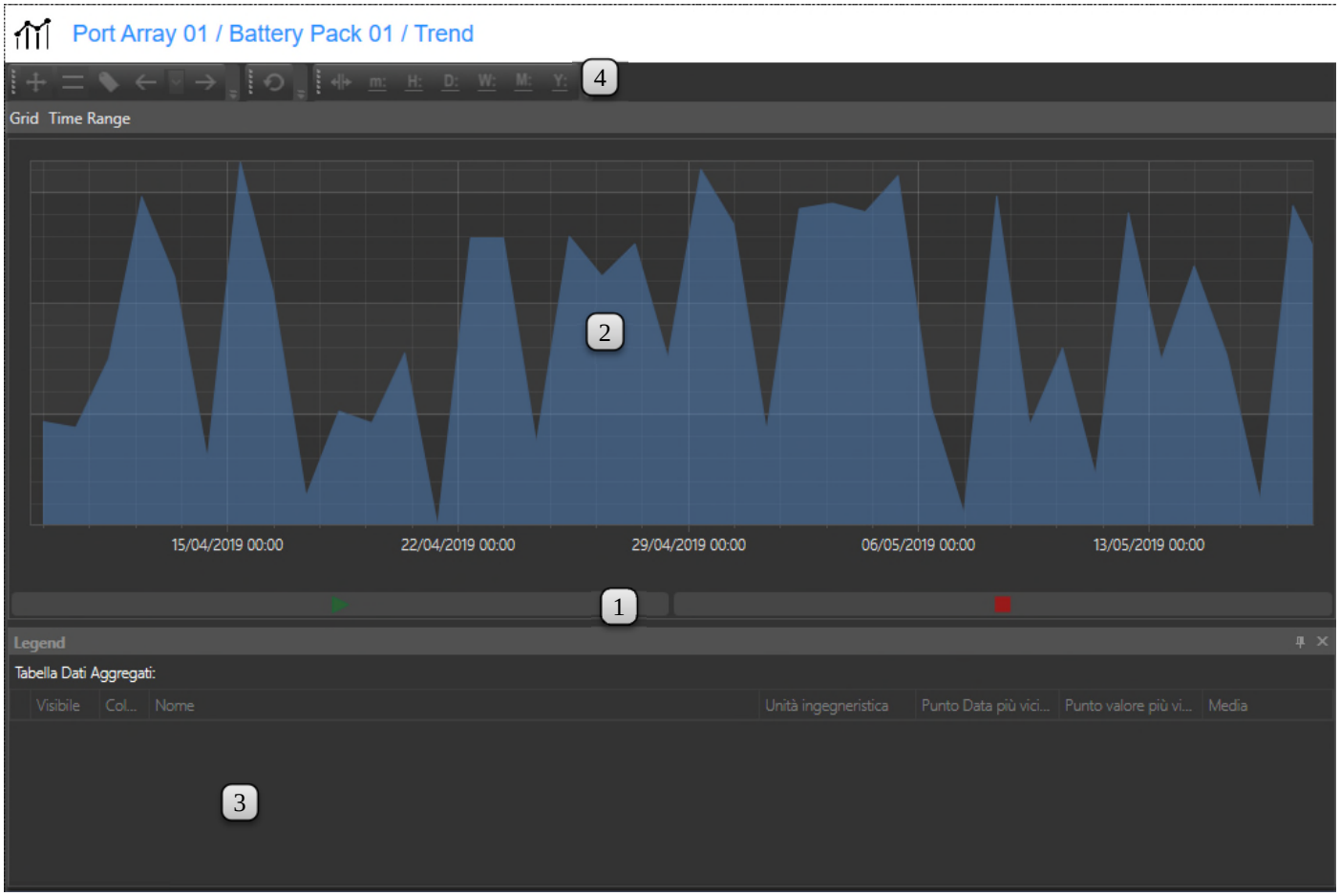
1	Step of the sequence that is in course.
2	SEQUENCE CONDITION: Condition satisfied; Condition not satisfied. Only if all conditions are green the sequence can be initiated.

6.9. I/O STATUS PAGE



1	Reset Safety module error status. The reset is necessary after a failure of the SLC284 module or of one of its power supplies.
2	MODULE STATUS: ● Module without errors ● Module on fault If a module is in failure, it should be replaced by means of a spare parts. If no spare parts are available contact Fincantieri SI to purchase it, referring to the codes that are found in above picture (for example R1S3/DI216). If the module in failure is a R1S6/AIO216 module, check if the module failure is due to a wire break detection.

6.10. TRENDS PAGE

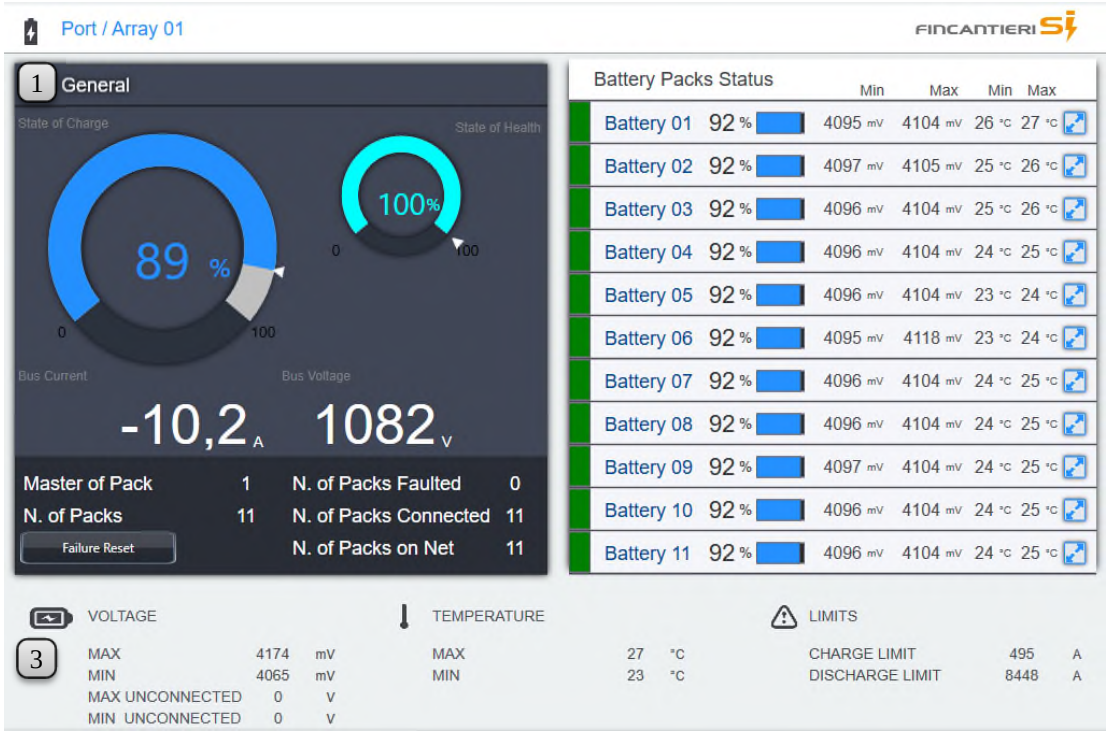


1	Chart working mode. ▶ Chart working as real time chart ■ Stop chart real time mode. When real time mode is not running it's possible to select points on the chart and see in legend area recorded values. While runtime is not running it's also possible to display historical data selecting from top bar the time range.
2	Chart display area.
3	Pens legend area. From this area it's possible to select which pen to show. By selecting a point on the chart, it's possible to display the relevant sample date, time and value.

4 Historical data filter area:

m:	Display last minute historical data
H:	Display last hour historical data
D:	Display last day historical data
W:	Display last week historical data
M:	Display last month historical data
Y:	Display last year historical data
	Once a time range is selected (minute, hour, day,…) is possible to navigate to previous or next time unit by means of the arrows

6.11. BATTERY ARRAY PAGE



1

ARRAY GENERAL STATUS:

Value	Description
State of charge [%]	Actual array state of charge, available only when at least 1 battery pack is connected
State of health [%]	Actual array state of health, available only when at least 1 battery pack is connected
Bus current [A]	Actual DC bus current, with minus sign from batteries to converters (discharging) , with plus sign from converters to batteries (charging)
Bus voltage [V]	Actual DC bus voltage read from BMS
Master of Packs	Array master selected by EMS
N. of Packs	Number of battery packs
N. of Packs Faulted	Number of battery packs faulted (only BMS internal faults)
N. of Packs Connected	Number of battery packs connected
N. of Packs on Net	Number of battery packs available on internal BMS network

2

BATTERY PACKS STATUS:

VALUE	DESCRIPTION
STATUS BAR	RED: Failure active; Yellow: Warning; Green: Connected; Gray: Ready
State of charge [%]	Numeric value and bar graph
Cell voltage [mv]	Battery pack minimum cell voltage and maximum cell voltage.
Cell temperature [°C]	Battery pack minimum cell temperature and maximum cell temperature.
	Icon to open battery pack details

3

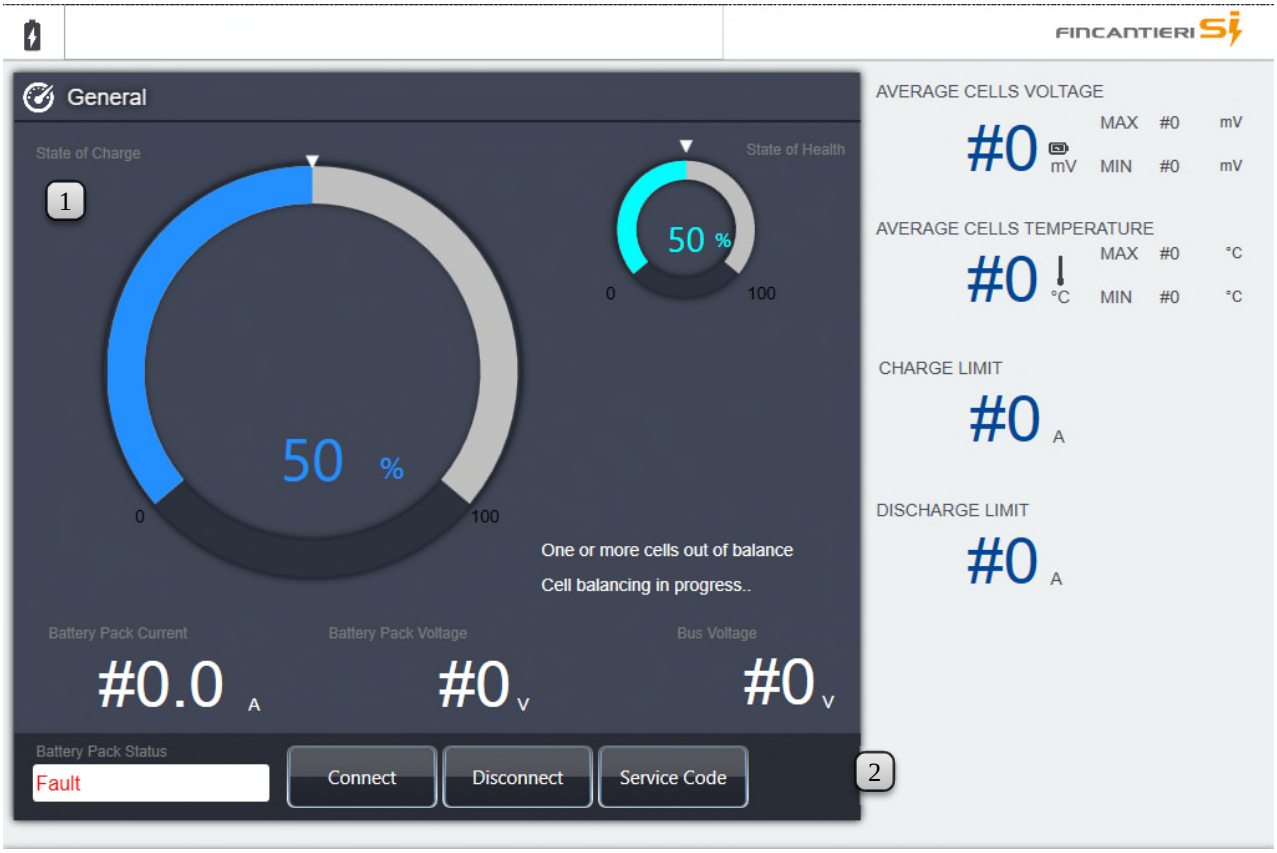
ARRAY INFORMATIONS:

VOLTAGE	DESCRIPTION
Max [mV]	Maximum cell voltage (only connected packs)
Min [mV]	Minimum cell voltage (only connected packs)
Max unconnected [V]	Disconnected battery packs maximum bus voltage
Min unconnected [V]	Disconnected battery packs minimum bus voltage

TEMPERATURE	DESCRIPTION
Max [°C]	Higher cell temperature inside the whole array
Min [°C]	Lowest cell temperature inside the whole array

LIMITS	DESCRIPTION
Charge limit [A]	Maximum current allowed by BMS for the battery charge
Discharge limit [A]	Maximum current allowed by BMS for the battery discharge

6.12. BATTERY PACK DETAILS PAGE



1 BATTERY PACK GENERAL STATUS:

Value	Description
State of charge [%]	Actual array state of charge of the single battery pack
State of health [%]	Actual array state of health of the single battery pack
Battery Pack Current [A]	Actual DC bus current, with minus sign from batteries to converters (discharging) , with plus sign from converters to batteries (charging)
Battery Pack Voltage [V]	Actual DC bus voltage
Bus Voltage [V]	Selected master from EMS side
One or more cells out of balance	This message appears if BMS find some cells out of balance inside a battery pack
Cell balancing in progress…	This message appears while BMS system is balancing cells inside a battery pack

2 BATTERY STATUS / COMMAND BAR:

Battery Pack Status	Fault: Failure active, battery pack has been disconnected by BMS; Ready: Battery pack ready (no fault and no warning active); Connected: Battery pack connected;
Connect	Send a connect command for single battery pack to BMS master. BMS master will execute the command as soon as possible. To cancel the connect command you'll need to press Disconnect button. If the battery pack is in failure, reset the power unit before providing a connect command to it.
Disconnect	Disconnect currently connected battery pack or cancel connect command.

	Service Code	Open a popup where you can find 4 registers with battery pack service code inside. You'll need to send this information to Corvus in case of service required message in alarm list.

3

BATTERY PACK INFO:

Value	Description
Average cell voltage [mV]	Display actual average cells voltage inside battery pack, together with the indication of minimum and maximum voltage.
Average cell temperature [°C]	Display actual average cells temperature inside battery pack, together with the indication minimum and maximum temperature.
Charge limit [A]	Maximum charge current allowed by BMS for the specific battery pack
Discharge limit [A]	Maximum discharge current allowed by BMS for the specific battery pack