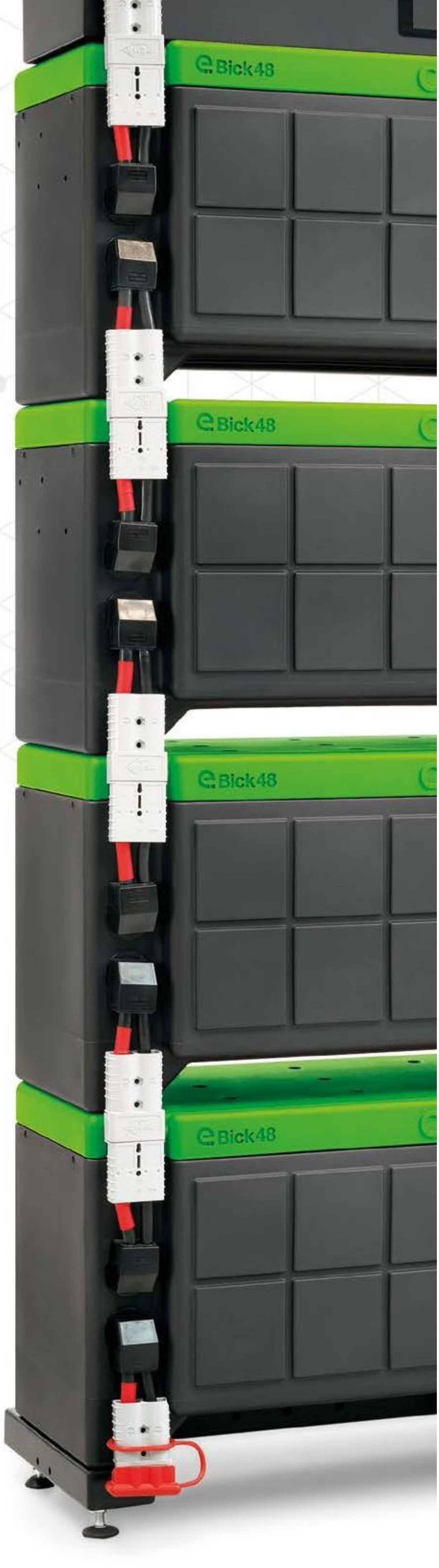

Bick 280 Pro Paralelo Technical manual

cegasa

Revision control

REV.	DATE	REASON / RESPONSIBLE
03	22/07/2021	First issue

Limitation of Warranty and Liability

The limitation of warranties and liabilities shall be described in the contractual agreements between CEGASA PORTABLE ENERGY and the buyer.

The information included in this manual has been written for the purpose of providing the user with more detail and clarity in terms of content. Nonetheless, CEGASA PORTABLE ENERGY reserves the right to modify the contents of this manual through future revisions at any time and without prior notice.

Confidentiality

All information provided by CEGASA PORTABLE ENERGY by virtue of this User Manual and any data or features that may be disclosed by such shall be completely confidential and may not be shared with third parties or used for purposes other than that for which is was intended without prior and express written authorization from CEGASA PORTABLE ENERGY.

Limitations on the use of this equipment

This equipment may not be used in applications for recharging electric vehicles. CEGASA PORTABLE ENERGY shall not be held liable for use with these types of application. The buyer shall be wholly responsible..

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Contents

1.1 Purpose

The following document represents the complete manual for the installation, use and maintenance of the eBick PRO energy storage system, comprising eBick PRO 280 PARALLEL modules and PCM 48V300A protection and control module or PCC protection and control cabinet.

1.2 Acronyms

FAT	Factory Acceptance Tests
BMS	Battery management system
eBick PRO	Battery pack de 48V 280Ah
EMS	Energy management system
PCM	Power Module Control
PCC	Power Control Cabinet
SoC	State of charge. Amount of energy in battery
SoF	State of function. Maximum admissible amount of charge or discharge current at any moment
STRING	Cabinet containing various modules and a PCM or PCC

2. Safety

WARNING: RISK OF FIRE OR EXPLOSION

Failure to comply with safety messages may cause serious injury, death or damage to property

DANGER!

Always use the eBick PRO 280 module with a PCM/PCC protection and control system. Never connect the module without the PCM/PCC.

To prevent high inrush currents, a bus pre-charge is required. A direct connection may result in damage to the system. This pre-charge is managed from the PCM/PCC.

DANGER!

Check that the voltage is within range before connecting the equipment to the inverter. NEVER connect the string if the voltage is out of range or NULL.

DANGER!

NEVER remove or bypass PCM/PCC switching and protection systems.

DANGER!

Do not short-circuit the current circuit terminals of the eBick PRO 280 module or the PCM/PCC. The short-circuit current may be several thousand amperes. Prolonged short-circuiting will destroy the battery module and electrolyte may leak out of the cells, causing a fire and/or explosion.

DANGER!

eBick installation and maintenance personnel shall wear protective apparel, special gloves and safety glasses. All personal metal objects such as wristwatches, rings, jewellery, etc., shall NOT be worn while working with the eBick PRO 280 modules.

DANGER!

To avoid short-circuits and electric shock, use safety tools (EN 60900) and protection devices when installing and servicing the equipment.

DANGER!

Do not connect or disconnect the load when the main contactor is closed. This may cause an electric arc and expose personnel to high DC voltage. The electric arc might also destroy connectors, due to a welding effect.

DANGER!

In case of fire, disconnect the circuit from the battery and use a CO_2 extinguisher to extinguish the fire. The batteries contain flammable materials. Always inform fire-fighters about the lithium batteries.

DANGER!

Do not open the covers on the eBick PRO 280 modules or the PCM/PCC. Do not place or drop conductive objects inside the battery module or between the module's terminals.

DANGER!

Do not expose to temperatures above 65ºC. The equipment will not be operational beyond these temperatures, however, even with non-operational equipment exposing the cells to high temperatures may cause fire and/or explosion.

DANGER!

Do not immerse the eBick PRO 280 module in water or any other liquid.

DANGER!

Never drop or knock the eBick PRO 280 modules.

DANGER!

If chargers/converters are used, use only those authorised by CEGASA. Misuse of the battery module during charging or discharging may cause the equipment to age prematurely leading to fire and/or explosion. Both units have complex communications and these need to be carried out by authorised specialists.

DANGER!

In the event of an emergency, read the MSDS (Material Safety Data Sheet) for the cells before proceeding.

2.1 General information

The eBick is a smart energy storage system with Li-ion cells.

The whole system contains a high energy capacity. To minimize the risk of electric shock, short-circuit, explosion and/or fire, follow the relevant procedures and local guidelines, as well as the instructions that are included with the system.

Only qualified personnel should perform the installation, in accordance with the applicable regulations. Systems with visible electrical connections have to be isolated from public access. For safety purposes, cover all direct connections and terminals.

Carefully read, understand and apply all requirements presented in this section.

2.2 Safety Instructions– Potential hazards

- **The area around the eBick PRO shall be kept clear and free** of combustible materials, gasoline and/or other flammable fumes, vapours and liquids.
- The area defined by safety margins for the necessary supply and venting of air shall be respected.
- In the event of an emergency, the eBick has electrical safety cut-off elements (fuses and contactors). It is advisable to install an element that protects against over-current and possible short-circuiting. It is also advisable that the cut-off element can be manually operated if necessary. Remember, because this is a battery, the STRING's internal DC bus will always be live.
- **Do not use the module if any of its parts have been immersed in water**. A water damaged cell is potentially dangerous. Any attempts to use the system could cause a fire or an explosion. In such cases, contact CEGASA PORTABLE ENERGY to have the battery pack inspected.
- The following instructions shall always be followed:
  - **Any air inlet or outlet within the room shall be kept clear and free of obstacles.**
  - **The floor shall be capable of bearing the weight of the STRING.**
  - **There shall be no obvious signs of wear on any STRING element.**
  - **As this is a battery, there is voltage on the +/- terminals whenever the PCM/PCC contactor is closed.**

2.3 Electrical safety

- Never remove safety guards or devices that protect against live parts.
- Do not reach inside the STRING or the modules, nor touch any internal component.
- Do not use or handle any eBick component when accidentally wet, or with wet hands or feet.
- In the event of a failure or incident, as a first step cut off the current. To rescue a person being electrocuted, do not touch them but immediately cut the current.

- If it is not possible or takes too long to cut the current, try to disengage them by means of an insulating element (wooden strip or board, rope, wooden chair ...).
- Whenever a module is not installed on the STRING, make sure that the power terminals at the front are protected against accidental contact.
- Make sure that the output and input connection cables are not short-circuited.
- Make sure there is no short circuit between positive and negative terminals at any point.
- Make sure there is always protective insulation on the output and input cables and a reliable connection.
- Never use cables that are visibly damaged or that may be suspected of being damaged.
- Minimise conductivity, avoiding surfaces in contact with water. Hands and clothes have to be dry.
- Do not use, install or store the system under wet or damp conditions.

2.4 Mechanical safety

- Due to the weight of the battery modules (>100 kg), mechanical means have to be employed to install them.
- Do not stack eBick PRO modules more than 4 high.

2.5 User requirements

In addition to personnel who work with the module, workplace users should also implement safety measure by applying the minimum provisions of RD 614/2001 on the protection of the health and safety of workers exposed to electrical risk in the workplace.

Hazards related to electrical risk are specifically identified during the work process with this equipment. This does not exclude the possible existence of other risks present during handling and use, such as overexertion, posture, or other measures against health risks. Operators shall receive the necessary training, sufficient to be able to prevent and avoid any risks arising from use of the equipment.

By design the equipment protects against these risks under normal operating conditions, however, it is with operations that differ from normal ones (installation, maintenance, ...) where special precautions have to be taken.

Particular care should be taken when handling modules, due to their weight. Respect guidelines according to current regulations regarding ergonomics in the workplace (Royal Decree 487/1997). Use appropriate handling equipment.

2.6 Lockout-tagout of machines and installations (L.O.T.O.)

To perform operations, absent of voltage (L.O.T.O.), the device shall be locked and tagged to non-hazardous voltage values. The following section is based on the lockout-tagout at several points according to RD 614/2001:

1. Restrict access to the work area to prevent entry of unauthorised personnel.
2. It shall be disconnected and isolated from the supply network or connection to the converter.
3. Once disconnected, the STRING shall be sectioned into parts with voltages below 75 VDC.
4. The terminals of these parts shall be protected by insulating caps designed for this purpose.
5. Given that the batteries are an energy storage system, it is impossible to make certain points of the system free of voltage. If there is any exposed point where the voltage cannot be eliminated, the terminals will have to be tagged, indicating the voltage value at that point.
6. Prior to conducting any work, the voltage shall be measured at the point where the work is to be done. Some points may be energised directly from the batteries.
    - Use only 75V insulated tools
    - If terminals are exposed during the sectioning process, use 75V rated insulating gloves.
    - Use a face shield during the work.
    - Should it be necessary to perform an operation on a battery pack, place the modules on insulating matting.
    - Use insulating footwear.
    - To avoid possible short-circuiting, do not carry any conductive device (e.g., pens, tape measures, etc.) during the work.
    - Do not wear any metal, conductive or sharp edged accessories.

2.7 Switching, measurements and checks

The regulation permits operations and interventions without lockout-tagout, provided that an equivalent level of safety is guaranteed.

These interventions are called switching, trials and checks. They have to be carried out by authorised personnel with protection devices and personal protective equipment appropriate for the voltages in question.

Special protection against short-circuits should be ensured. Instructions to follow:

- The operations shall only be carried by authorised, duly trained, personnel.
- Safety apparel that covers the whole body (long sleeves) shall be used. Fireproof or flame retardant, with protection against chemicals and arc flash.
- The work shall be done from a solid, stable support
- If a work table is used, it shall be insulated or covered with Insulating matting.
- No terminal with an electrical charge should be left uncovered. If, after removing the connections, the terminals are exposed, then they have to be protected with the terminal covers supplied.
- All tools shall be insulated and rated up to 75V
- Operators shall not wear or carry any metal elements or devices.
- The work area shall be free of obstacles.
- If necessary, when there are exposed terminals nylon slings shall be used instead of chains.
- The operator shall wear a face shield or safety glasses to protect against short-circuits

Occasionally, depending on the operation, there should be a preventive resource worker present.

This person should satisfy that stated in Annex IV of RD 614/2001

3. Introduction

3.1 General description

The CEGASA eBick PRO 280 PARALLEL is a lithium-ion battery, 48Vdc nominal and 280Ah capacity.

Each one of the modules or batteries comprises 15 x 3.2V cells in series welded using laser technology. The voltage of each of these cells and the temperature of the module is continuously monitored by its own local card (BMS), developed by CEGASA.

Each module is fitted with a 48Vdc 300A single-pole fuse, accessible via a cover on the side of the module, enabling a quick change in the event of electrical failure on the installation.

The eBick PRO 280 PARALLEL modules can be connected in parallel in towers up to 4 high, with a maximum of 24 modules (i.e., 6 towers, 4 high; 320kWh at 48Vdc)

The system requires a **PCM or PCC** protection and control body in order to operate, depending on the needs of the project. Both the PCM and the PCC contain the system's protection elements, as well as a card developed by CEGASA responsible for managing them (EMS).

This EMS card acts as the MASTER for the system, receiving all the information from the BMS found in the system's battery modules via ISO SPI communications. To complete the information needed, a reading of the current passing through the circuit is made, as well as several voltage readings at string level.

Via an independent communications channel, the EMS also manages the exchange of information with a higher order system; be it an inverter, PC or SCADA.

The EMS uses all of this information to operate the protection systems, collect statistical data and send critical information to external systems (measurements, states, alarms, ...).

4. Specifications

4.1 Dimensions, weight and interfaces

The dimensions of the **eBick PRO 280 PARALLEL** module are the following:

Model	eBick PRO 280 PARALLEL
Height	448 mm
Width	762 mm
Depth	405 mm
Weight	≈105 Kg

The following table lists the eBick PRO PARALLEL module interfaces, with a short description of each.

eBick PRO PARALLEL module interfaces	
Power	**Internal (1):** Two SB350 REMA GREY connectors on the left side
Communications	Two RJ45 connectors on right side (3)

The dimensions of the **PCM 48V 300A** are as follow:

Model	PCM cabinet 48V 300A
Height	165 mm
Width	762 mm
Depth	250 mm
Weight	≈15 Kg

The following table lists the interfaces for a PCM, with a short description of each.

PCM interfaces	
Power	**Internal (1):** SB350 REMA GREY connectors **External (2):** M12 screw termination. (POSITIVE & NEGATIVE) at rear; recommended cross-section **>120mm²**
ON/OFF	On/Off at rear
CAN Communications (4)	RJ45 Connector at rear of PCM
Modbus/TCP Communications (5)	RJ45 Connector at rear of PCM
HMI (6)	Touch screen on the PCM
User access (7)	USB port on the PCM
Error LED (8)	LED to see if the system has an error
ISO SPI Communications (9)	Connector for eBick PRO modules
Ground screw (10)	M5 screw for grounding

The dimensions and weights of the PCC (Electric Protection Cabinet) depend on the dimensioning of the project; nominal current, number of inputs, number of outputs…

4.2 Electrical / energy characteristics

4.2.1 eBick PRO PARALLEL Module

The following table gives the specifications of the **eBick PRO 280 PARALLEL module:**

Electrical specifications	eBick PRO 280 PARALLEL
Nominal voltage (Vdc)	48
Minimum static voltage, SOC 0% (Vdc)	42
Maximum static voltage, SOC 100% (Vdc)	52,2
Nominal current during charge/discharge: (A)*	<140
Maximum current during charge/discharge: (A)*	275
Rated energy (Kwh)	13,4 kWh
Rated capacity (Ah)	280Ah
Cell data: *Charge: CC-CV, 0.2 C, 3.65V, 0.01C cut-off @ 25±2ºC* *Discharge: CC, 0.2C, 2.7V cut-off @ 25±2ºC*	

4.2.2 PCM 48 300Module

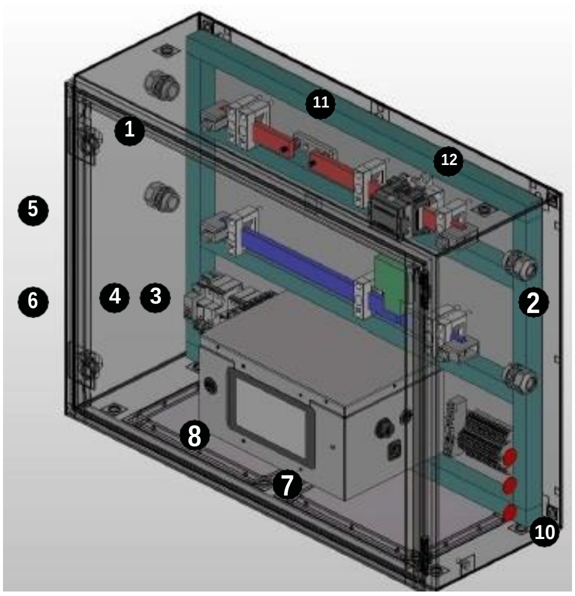
Electrical specifications	PCM 48 300
Nominal voltage (Vdc)	48Vdc
Maximum current during CHARGE/DISCHARGE	275A / 300A
Maximum peak current DISCHARGE	470A (1min)

4.2.3 Armarios eléctricos PCC (opcionales)

Electrical specifications	PCC 48 500
Nominal voltage (Vdc)	48Vdc
Maximum current during CHARGE/DISCHARGE	500A
Maximum peak current DISCHARGE	700A (1min)

Electrical specifications	PCC 48 1000
Nominal voltage (Vdc)	48Vdc
Maximum current during CHARGE/DISCHARGE	1.000A
Maximum peak current DISCHARGE	1.400A (1min)

For both PCC options, the measurements and weight of the PCC 500 and 1000 electrical cabinets will depend on the needs of the project. Likewise, the number of power inputs (or parallels) and outputs on the cabinet.



PCC 500 or 1000 interfaces	
Power	**OUTPUT (1) - Left side of cabinet:** Depending on the number of inputs (parallel) needed; Cable minimum 120mm^2 **INPUT (2) - Right side of cabinet:** Depending on the number of outputs needed; Cable minimum 120mm^2
ON/OFF switch (3)	Front panel for On/Off
Disyuntor ULTRALOW ULTRA-LOW MODE breaker (4)	Front panel for switching on after entering ULTRA LOW MODE
CAN communications (5)	RJ45 connector on left side of PCC; Non-crossover Cat5e SERIES cable
Modbus/TCP Communications (6)	RJ45 connector on left side of PCM; noncrossover Cat5e parallel cable
HMI (7)	Touch screen on the PCM
User access (8)	USB port on the PCM
On and Error LED (9)	RED to show the system has an error on the PCC's front door; GREEN system ON
ISO SPI Communications (10)	FEMALE RJ45 connector for eBick PRO modules on the right side
Fuse	On positive terminal 48Vdc 500 or 1,000A Continuous, depending on the project
Contactor	On positive terminal 500 or 1,000A, depending on the project

4.3 Hardware

4.3.1 Battery module

Each battery module consists of:

- **Cells** 3.2V – 280 Ah; forming a final array of 48V – 280 Ah.
- **BMS:** Card that takes the direct voltage reading for each one of the cells and temperature reading for the module.
- **Fuse:** Each module has a fuse interposed between the cell links. The acts in the event of an internal short-circuit or short-circuit on one of the modules' terminals, opening the string and preventing adjacent modules (depending on the position of the shorted module) from feeding the fault.

4.3.2 PCM or PCC

The protection module consists of the following elements:

- **EMS:** Card that acts as the string's CPU. It collects the data from all the BMS, manages this data, acts on protection elements and communicates with equipment at a higher level.
- **HMI** Touch screen, connected directly to the EMS. This shows data on the state of the system, allowing manual intervention if required.
- **Error LED:** This LED flashes when the EMS detects a fault on the system, whether it be an electrical or hardware fault.
- **Contactor:** Safety element that cuts the current in the event of a system alarm. Located just before the protection module's output terminals, it is used to isolate the cabinet before conditions that guarantee correct connection to the bus are established, as well as protecting the string against external faults.
- **Current transformer:** Transformer that reads the system's total input and output currents to calculate the charge remaining in the battery, as well as protection functions.
- **Power supply:** One a stationary battery's applications is to be used as an uninterruptible power supply. To be able to do this, the electronics that manage the batteries cannot stop receiving energy, so the only way to ensure this is to feed it off the batteries themselves.

  Feeding all the electronics off a single module in the string would cause imbalances between the different batteries in the set and an eventual decrease in available energy; therefore, this power supply is placed on the string terminals to take energy from all the batteries equally.
- **On/Off switch:** Used to start the PCM or PCC once the power connections have been made. Should the PCM or PCC have to be put out of operation, this button is also used to switch it off and isolate the electronics from the power supply.
- **Power terminals:** Access for the customer's power cables is located at the rear of the PCM or on the right side of the PCC electric cabinet.
- **Communications connector:** Both Communications connectors are located at the rear of the PCM or on the right side of the PCC, identified as "CANbus" and "Modbus"

  The Modbus/TCP connector uses a standard parallel TCP cable.

  The pinout for the CAN Communications cable can be checked in chapter 9.2 CAN protocol. If a different pinout is required, please contact Cegasa for assistance.

  This state appears when a software reset is performed on the EMS, either due to a settings change or a firmware update. During this state, the EMS saves the system's state to memory, to continue under the same conditions once the restart has finished.

5. Operating modes and processes

5.1 State machine

The string is controlled by a sequential state machine. This state machine is managed by the EMS located inside the PCM or PCC. The user can check the state of the string both from the HMI and by communications at address 0x3000 - 1 via CAN or at address 3001 via Modbus.

The EMS state machine has the following states:

- **Start-up:**

  This starts the card, communications, and each of the BMS located inside the battery packs. System settings and error-free check.
- **Ready / Disconnected:**

  Value at memory location = 2

  Once the start-up sequence has finished, the system remains in this state until the connection sequence starts, whether due to a command, if the battery works together with a master or after a standby period, if the battery works independently.
- **Eq Balancing:**

  Value at memory location = 3

  If the EMS detects that the charge difference between cells is too high, and that system conditions are suitable for the string to enter equalization, the EMS automatically orders the equipment to this state.

In this state any excess energy in cells with the most charge will be dissipated until all the cells have approximately the same stored energy.

- **Connecting**:

  Value at memory location = 4

  Transition state. the state machine changes to this state once the connection command has been received and the pre-charge has been performed (pre-charge is optional, described in its own chapter). If the bus voltage reading is correct, it orders the contactor to close and then changes to the connected state.

  If the voltage reading is not correct, the sequence is aborted, and it changes to the disconnecting state.

- **Connected:**

  Value at memory location = 5

  Transition state. After receiving the close command and running the connection sequence, the string will have the contactor closed. If no errors occur within a specific time, it changes to the idle state.

- **Idle:**

  Value at memory location = 15

  Once the string is connected, it remains in this state until a through-current is detected. If the current value read has a positive sign, it changes to the charging state, but if it is a negative sign, then it changes to the discharging state.

- **Charging:**

  Value at memory location = 25

  In this state the current is being fed to the string, so the SoC value will grow proportionally to the current read and the protection functions with the “charge” suffix will be enabled.

- **Discharging:**

  Value at memory location = 35

  In this state the current is being drawn from the string. The SoC value will decrease proportionally to the current read and the protection functions with the “discharge” suffix will be enabled.

- **Disconnecting:**

  Value at memory location = 35

  In this state the current is being drawn from the string. The SoC value will decrease proportionally to the current read and the protection functions with the “discharge” suffix will be enabled.

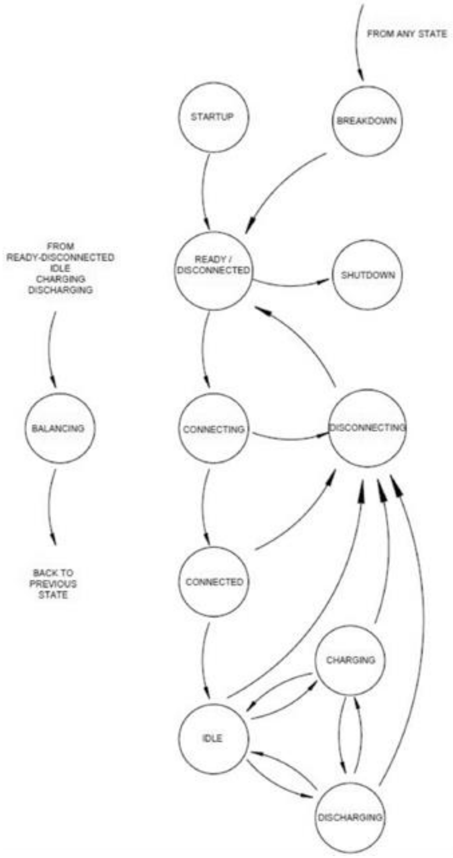
  Breakdown:

  Value at memory location = 1

  If the system experiences a critical fault (any error that prevents safe use of the batteries), the EMS will change to the Breakdown state, in which the contactor opens. It will remain in this state until the errors are cleared, either via the local HMI or by receiving a communications command to reset errors.

- **Shutdown:**

  This state appears when a software reset is performed on the EMS, either due to a settings change or a firmware update. During this state, the EMS saves the system’s state to memory, to continue under the same conditions once the restart has finished.



5.2 Start-up and shut-down processes

All points included in the “installation” section should have been followed prior to starting the system. Once this has been done, the system can be started by pressing the ON/OFF switch.

Pressing the switch powers up the control electronics in the PCM or PCC. The EMS then checks hardware integrity (own hardware and that of the BMS distributed by communications) and that the cabinet distribution set-up corresponds with that read. If no error is detected, the EMS allows work with batteries to commence. The time required for start-up is less than 1 minute.

To stop the system, the same switch has to be pressed. The string should never be switched off while current is flowing through the system. The contactor has to be opened from the screen (connect button) prior to switching off the PCM or PCC.

DANGER:
ELECTRONICS SELF-CONSUMPTION
The electronics inside the cabinet are powered by the batteries. If the batteries are not going to be used for a prolonged period, the PCM has to be switched off.

5.3 Connection process

eBick PRO systems can operate in 2 different ways: Slave mode and Stand-alone mode

In **slave mode** control depends on a higher level system, be it SCADA, an inverter or operation personnel. In this mode, after the system is started it remains in the ready/disconnected state until it receives an external close command.

In **stand-alone mode** the system automates various operations, including direct connection. Once the eBick is started in this mode, if no critical errors occur, the contactor will close independently. This mode is used together with inverters that do not have communications, or whose communications system is not suitable for controlling lithium battery pack switches.

The latter (stand-alone) is the default connection mode.

5.4 Ultra-low consumption mode

Should the batteries be left unattended for a prolonged period, the cabinet has an ultra-low consumption system to protect them. If the equipment were to be left on without supervision or use, the electronics in the batteries would consume their energy, so if the EMS detects a battery voltage value lower than a desirable level, it follows a series of steps as the voltage decreases, until it switches the string off completely.

Input conditions for this mode:

Current less than 2A AND minimum cell value <2975mV for 2h

The actions that occur are as follows:

1. Contactor opening due to undervoltage
2. BMS switched off on each of the batteries
3. Screen and EMS switched off.

If the battery does reach any of these points it may still be recovered, however, it requires a specific charging method.

DANGER:

ULTRA-LOW CONSUMPTION MODE

If the user detects that the string has disconnected itself and that the screen is off, charging battery should be avoided.

If the battery tries to charge normally in this state; in the best of cases, it would lead to a severe loss of capacity for the equipment; in the worst case it would cause a short circuit.

Under these conditions the battery has to be recharged in a specific way.

Please contact CEGASA's technical support department so that it can analyse the situation and provide additional instructions.

5.5 Pre-charge process

The pre-charge process is designed to be used with commercial 48V inverters. This application requires specific custom-built hardware.

Power inverters, MPPT controllers and most of the power electronics equipment work with a set of capacitors, coils and transistors to modify the input signal to achieve the desired output signal for the application.

To solve this problem, a DC bus soft-start is used.

In this instance, instead of initially closing the circuit with the main contactor; an auxiliary contactor is used, which is connected in series with a resistor that limits the current. This resistor decreases the capacitors' energisation current and once the DC bus is energized, the main contactor closes while this auxiliary contactor is disconnected, as long as the bus pre-charge has been done safely by reaching the desired bus voltage level.

5.6 Passive equalisation

As the string charges and discharges, slight differences in the chemistry of the cells produce different resistive values, leading to differing

losses during use of the battery and different amounts of energy stored in each cell.

The end of the charging process is determined by the cell that has the highest amount of stored energy in the whole string (when a cell reaches 100% charge, the process stops regardless of the charge stored in the rest of the string's cells), while the end of the discharge process is determined by the cell with the least amount of charge.

The differences in stored energy increase as the number of cycles in the string increases; making the system increasingly less efficient. To solve this problem, the EMS monitors the difference between cells, initiating the equalisation process whenever necessary.

Cell imbalance is due to different factors, the most common being:

- **Depth of Discharge** (DoD): Higher DoD, greater imbalance.
- **Charge and discharge cycles:** More cycles, greater imbalance.
- **Operating temperature:** Working at temperatures other than the optimum one produces greater imbalance for the same charge/discharge cycle.
- **Charge/discharge current:** Higher currents, greater imbalance.

The charge in a cell is partially related to the voltage in that cell. eBick constantly controls the voltage in each of its cells. If a high imbalance between cells is detected at any point, then the EMS enters passive equalisation mode, assuming the string is not being used.

During this process, any excess energy in cells with the largest amount of charge is dissipated. By doing this, the charge value of each cell begins to decrease slowly until each cell reaches the charge value of the least charged cell.

There are two passive equalisation modes: **Normal mode and extreme mode**

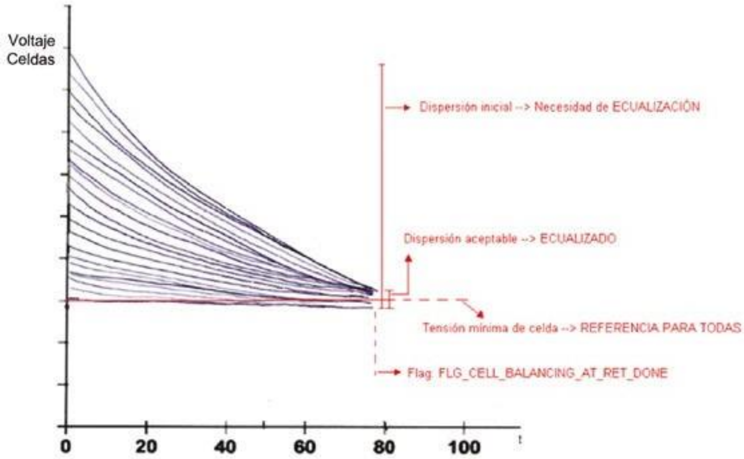
The system's input conditions in the normal passive equalisation mode:

- Charging
- When the spread is greater than internal normalised values depending on the load current; CEGASA's own tables
- As long as Vmin > 3300mV
- Only the series outside the admissible level of spread is equalised
- Vmin is going to be dynamic, checked in real time

The System's input conditions in the extreme passive equalisation mode:

- Standby (no current)
- When the spread between Vmax and Vmin is greater than 10mV
- Vmin is going to be dynamic, checked in real time
- SOC=>10%

The graph below shows an example of the equalisation process, where a set of lithium-ion cells with initially spread voltages can be seen. This spread is reduced over time as the process is executed.



System monitoring

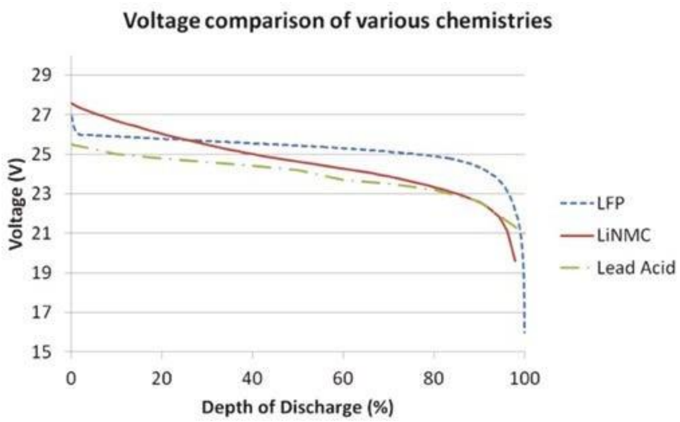
6.1 State of Charge (SoC) calculation

One of the most important aspects in a battery is to know how much stored energy remains in it, in order to determine how the battery can be used.

This is quite simple with lead acid batteries, given that the system voltage is practically proportional to the charge remaining in the batteries.

However, LFP-type batteries have a characteristic discharge curve in which the voltage is flat for most of its utilization range, and where a variation of 1-2 mV could represent a 10-20% error when estimating the charge. Only the voltage extremes vary enough to be able to relate directly to the charge remaining in the battery.

This, coupled with the fact that the shape of the characteristic varies with different factors (discharge current, temperature ...), makes direct measurement of the voltage to represent the charge remaining in the battery infeasible.



To solve this problem and attain a faithful representation of the system's state of charge, a mixed solution has been applied.

During most of the utilisation range the EMS continuously calculates the batteries' SoC using a coulometric based algorithm. A reading is taken of the output current during discharge and input current during charge, and the SoC is then updated by adding or subtracting this energy.

An update of the estimated charge is performed at the ends of the curve (0-20% and 95-100% charge), where the voltage can be more precisely related to the remaining charge; updating the SoC to this voltage under certain physical conditions.

- **100% update;** given the SW defined voltage and current conditions to interpret that the battery is fully charged. Similarly, if one of the series reaches a value of 3575mV for 10 seconds.
- **Idle update;** The EMS electronics use their own algorithms to update the SOC when idle (ZERO current after a period of inactivity) depending on the voltage of cells only within the range from 0 to 20%.
- **0-20% update based on discharge current;** The EMS electronics use their own algorithms to update the SOC based on the discharge current of each module connected in parallel and minimum cell voltage; this SOC value is only updated with current within the range from 0 to 20%.

6.2 Ideal charging conditions

The EMS system constantly controls the SOC conditions, temperature, voltages of the entire system and uses communications to send the inverters/chargers the optimum charge voltage and charge current values in order to ensure correct control of the charging process.

- **Charge voltage** based on cell temperature:

- Between 0 and 5ºC 51.5V
- Between 6 and 10ºC 52V
- Between 11 and 40ºC 52.2V
- Between 41 and 45ºC 51.8V
- Above 46ºC 51.5V

- **Charge current** based on cell temperature:

Charge current		Temperature					
		0 - 5ºC	6 - 10ºC	11 - 25ºC	26 - 40ºC	41 - 45ºC	>46ºC
SOC	0 - 20%	0,2C	1C			0,5C	0,2C
	21 - 50%	0,3C	1C			0,5C	0,3C
	51 - 60%	0,3C	1C			0,5C	0,3C
	61 -70%	0,3C	0,5C	1C		0,5C	0,3C
	71 - 80%	0,3C	0,5C	1C		0,5C	0,2C
	81 - 95%	0,3C	0,3C	0,5C			0,2C
	96 – 100%	0,1C					

Table 8. Charge currents based on SOC & Temperature

(*) The Parallel PCM will always have a maximum of 275A, determined by the PCM itself; In the case of several parallels and if the resulting value of the previous table exceeds 275A (e.g., 550A), then the charge current value sent to the inverter will be limited to 275A.

6.3 State of Function (SoF) and final battery use

State of function (SoF) is an algorithm that shows the largest amount of current that a battery can absorb or supply depending on the charge stored in the string, and adjusted with reference to various physical, chemical and electrical characteristics.

6.4 Calculation of battery integrity (SoH)

The battery ages over time due to several reasons: Number of charge and discharge cycles performed, over-currents, humidity, chemical changes due to time or extreme temperatures, ...

All of these factors mean that the battery is not able to store as much energy as it did when new. As a way to indicate how much the battery has aged, and consequently how much energy it is able to supply, an SoH algorithm has been developed.

This algorithm uses various equations to compare the present discharge cycle with a standard discharge cycle, and then internally update how much stored energy represents 100% SoC, showing the user the quotient of maximum storable capacity with respect to the theoretical maximum capacity as a % (SoH).

To do this, several charge-discharge cycles are stored under different physical conditions. These cycles are used for comparison. In day-to-day operations, the EMS controls several key variables and if these coincide with those stored in a standard cycle, it then compares the energy exchanged during that cycle with the energy of the standard cycle.

Included among these control variables are:

- SoC start and end value
- Average temperature during the cycle
- Average current during the cycle
- Percentage of imbalance between cells

6.5 Extending the life and end use of the batteries

Due to various factors, the battery loses some of the useful capacity it can supply.

The factors that affect the life of a lithium battery are the following:

- Using the battery outside the recommended temperature range.
- Subjecting the battery to deep discharges, below 5% of SoC
- Heavy charging and discharging (high currents)

Depending on the application, there will be conditions that can be met and others that cannot. E.g., in an application for an uninterrupted power supply, the priority is to guarantee that the demanded current is supplied with respect to the number of cycles that the battery can provide. Lost capacity generated by possible current peaks is offset by the number of cycles demanded from the battery, since in this type of application the battery is not working continuously.

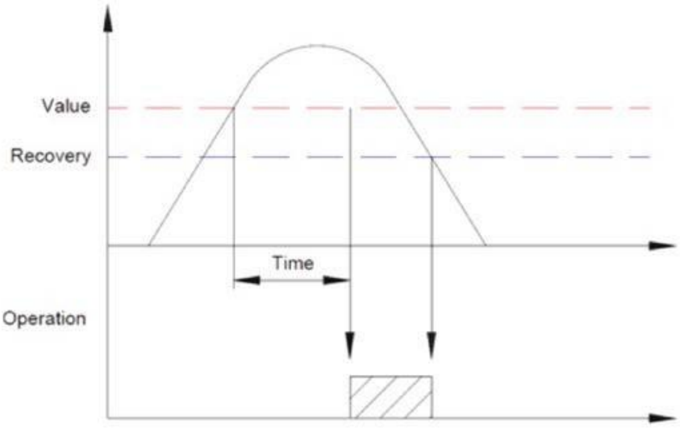
In those cases where battery use is continuous, as in renewable energy installations, the priority is to maximize battery life. In these cases where moderate charges and discharges are performed with reduced values of current, other values such as DoD will be controlled in order to maximize battery life.

The EMS system continuously monitors the current, voltage and temperature values at different points on each of the modules. Likewise, it continuously checks the state of the contactor and the state of the string within the state machine. If the EMS detects that there is a problem with the process, it operates the contactor to isolate the battery and clear the fault.

7.1 Parameters involved in the protection functions

Each protection function is factory set, based on the composition of the battery pack and the chemistry that it uses. Functions that have been operated are displayed on the HMI and communicated through any of the communication options.

The nomenclature and meaning are as follow:



XXX_XXX_value: Value from which, if we stay at, we will end up operating.

XXX_XXX_time: Time required for the protection to operate, once the battery is in an unsafe situation.

XXX_XXX_recovery: After having operated, dropping below this value will reset the operation variable.

Depending on the severity of the fault, there are 2 operation levels:

XXX_XXX_warning: This variable indicates that the system is heading towards a dangerous situation. If this variable is detected, the system control should act to correct the situation.

XXX_XXX_alarm: This variable indicates that the system is in a dangerous state. The EMS will operate the cut-off elements to isolate the string.

7.2 Reclose

The EMS monitors the electrical and temperature values before, during and after a fault. If it detects that the system has recovered after a fault, and that it is safe to continue with the operation, it will close the contactor again. Should an SOTF (switch on to fault) situation occur, this reclose is limited to a maximum of 3 times over a period of 5 minutes.

There are, however, several safeguards where the reclose does not operate as it would be harmful to the string, meaning that the battery can only be brought back into service once an authorised person verifies that the cause of the fault has been corrected, that the equipment is not damaged, and that the battery can be reconnected to the bus.

7.3 Undertemperature

The EMS controls the temperature at which each module is both a charging and discharging. If there is a temperature below an admissible range, the string will trigger an alarm. If this temperature drops even further, it opens the safeguard to protect the batteries.

There is a group of safeguards for undertemperature during charge and another group for undertemperature during discharge.

Name of variable	Operating value	Operating time
Undertemperature in charge warning	0ºC	30 seconds
Undertemperature in charge alarm	-20ºC	30 seconds
Undertemperature in charge recovery	2ºC	30 seconds
Undertemperature in charge warning	-15ºC	30 seconds
Undertemperature in charge alarm	-20ºC	30 seconds
Undertemperature in charge recovery	-13ºC	30 seconds

7.4 Over-temperature

The EMS controls the temperature at which each module is both a charging and discharging. If there is a temperature below an admissible range, the string will trigger an alarm. If this temperature drops even further, it opens the safeguard to protect the batteries.

There is a group of safeguards for undertemperature during charge and another group for undertemperature during discharge.

Name of variable	Operating value	Operating time
Overtemperature in charge warning	48ºC	30 seconds
Overtemperature in charge alarm	51ºC	30 seconds
Overtemperature in charge recovery	46ºC	30 seconds
Overtemperature in charge warning	48ºC	30 seconds
Overtemperature in charge alarm	51ºC	30 seconds
Overtemperature in charge recovery	46ºC	30 seconds

7.5 Undervoltage

Causes the voltage drop in a battery for long periods to progressively deteriorate the electrode materials. The first problem that occurs is that the anode's copper current collector dissolves in the electrolyte. This not only increases the cell's self-discharge rate, but if an attempt were made to recover the cell by recharging it, those copper metal ions dispersed by the electrolyte would not necessarily reintegrate on the current collector but would remain as copper metal wherever they were. This situation could eventually cause a short-circuit between the electrodes.

Keeping the cells at low voltage for prolonged periods also has an effect on the cathodes. A low voltage causes the gradual breakdown of the cathode, due to the gradual release of oxygen from the lithium iron phosphate cathode, and with it a permanent loss of capacity.

Name of variable	Operating value	Operating time
Undervoltage warning	2900 mV	5 seconds
Undervoltage warning recovery	3200 mV	5 seconds
Undervoltage alarm	2700 mV	5 seconds
Undervoltage alarm recovery	2950 mV	30 seconds

**Note: This protection function is calculated at the cell level*

7.6 Overvoltage

If the charge voltage increases above the level recommended for the cells, this produces an increase in the amount of current flowing through it. Excessive current means that lithium ions cannot settle fast enough in the carbon anode's lattice and end up depositing themselves on the surface of the anode as lithium metal.

As is the case during operations at low temperatures, at best this effect will produce a loss of capacity, and in the worst case a short-circuit, due to this lithium being deposited as dendrites that can perforate the insulation.

Name of variable	Operating value	Operating time
Overvoltage warning	3650 mV	5 seconds
Overvoltage warning recovery	3400 mV	5 seconds
Overvoltage alarm	3800 mV	5 seconds
Overvoltage alarm recovery	3600 mV	30 seconds

**Note: This protection function is calculated at the cell level*

7.7 Temperature difference

The EMS monitors the temperature at several points on each battery module. If a temperature difference occurs between the maximum measured temperature and the minimum measured temperature, this would indicate that the system that reads these data has failed (NTC, connection cable, BMS, ...).

Under such conditions, the operation of all modules within a correct temperature range cannot be guaranteed, so the string will be isolated.

This function is not included in the reclose process

Name of variable	Operating value	Operating time
Temperature difference alarm	10ºC	10 seconds

7.8 Voltage difference

The EMS monitors the voltages of each and every one of its cells. If a voltage difference occurs above a certain value between the maximum measured voltage and the minimum measured voltage, this would indicate that the system that reads these data has failed (connection cable, BMS, ...) or that there is a cell with a problem.

Given that the integrity of the whole system cannot be guaranteed, the EMS will activate the protections to isolate it.

This function is not included in the reclose process

Name of variable	Operating value	Operating time
Voltage difference alarm	1000 mV	10 seconds

7.9 PCM 48 300 charge and discharge currents

A large increase in the current supplied by the battery might indicate that a short-circuit has occurred at the cabinet output. To prevent feeding the fault and/or damaging internal or external components with the circulating current, should an abrupt, sustained increase in current be detected, the EMS will activate the protection elements to isolate the system.

This function is not included in the reclose process. The defined values to be controlled in order to avoid triggering the current alarms are those indicated in this table:

Name of variable	Operating value	Operating time
Continuous overcurrent in charge (A)	SOF_CH + tolerancia (*)	120 seconds
Continuous overcurrent in discharge (A)	SOF_DCH +tolerancia (**)	120 seconds
Peak overcurrent in discharge (A)	475	60 seconds
Shortcircuit in charge (A)	550	100 ms
Shortcircuit in discharge (A)	500	100 ms

(*) The SOF_ CH is detailed in point 6.2 Ideal charging conditions, based on the system's temperature and SOC.

(**) The SOF_ DCH is always at 275A, except when an alarm or warning is triggered.

7.10 PCC500 / 1000A charge and discharge currents

In the case of PCCs, consult with CEGASA about the protections, as they may be conditioned by each one of the projects.

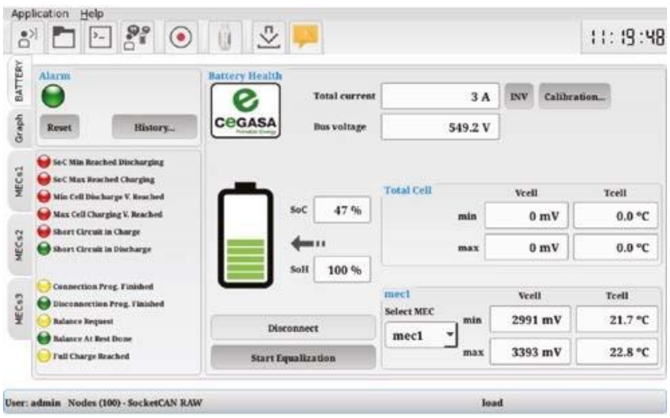
8. Data display

8.1 HMI display

The protection module has a built-in touch screen. This is used to display existing EMS data.

The HMI includes the following screens:

Main screen:



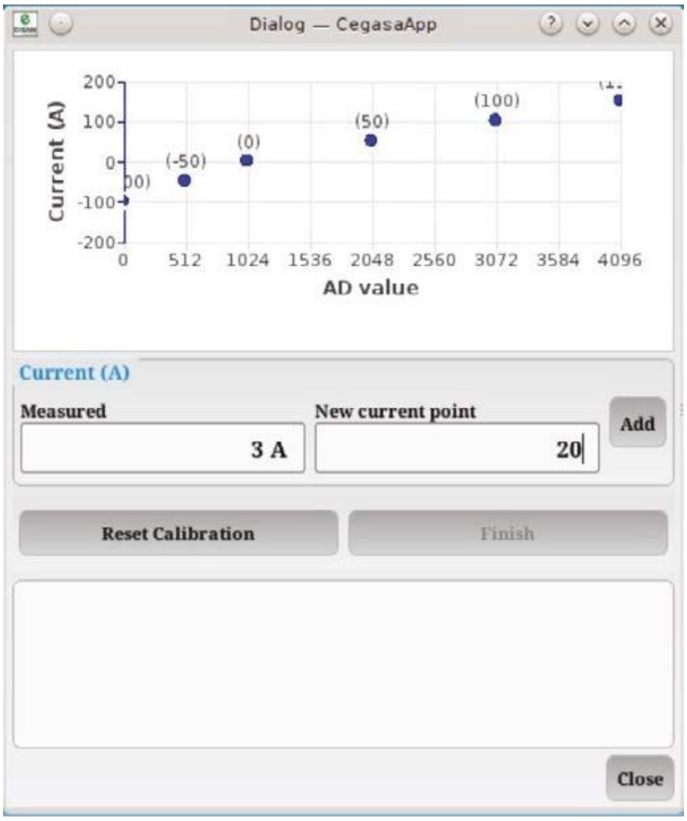
This is the screen displayed when the system is started. It provides a summary of the most significant battery data:

- State of Charge
- State of Health
- Current value in the system
- Cabinet's Voltage
- Minimum and maximum voltages and temperatures in the cabinet and per module
- Battery status (charging, discharging, balancing, on idle...)
- Alarms and flags

Likewise, this screen can be used to issue commands to connect and disconnect the contactor, equalise the battery or reverse the direction of the current if the current transformer has been connected the wrong way.

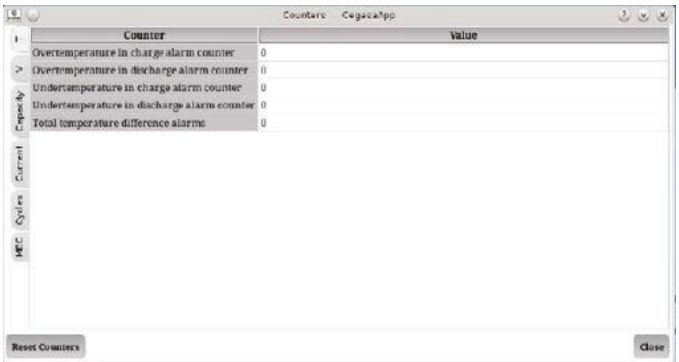
It is also possible to access log and calibration sub-screens from this screen.

Calibration sub-menu:



Due to the fact that the current transformer has a tolerance, the software-controlled option to correct its measurement errors has been implemented. The calibration screen shows the system's latest calibration, as well as options to delete or change it. Consult CEGASA if necessary.

Log screen

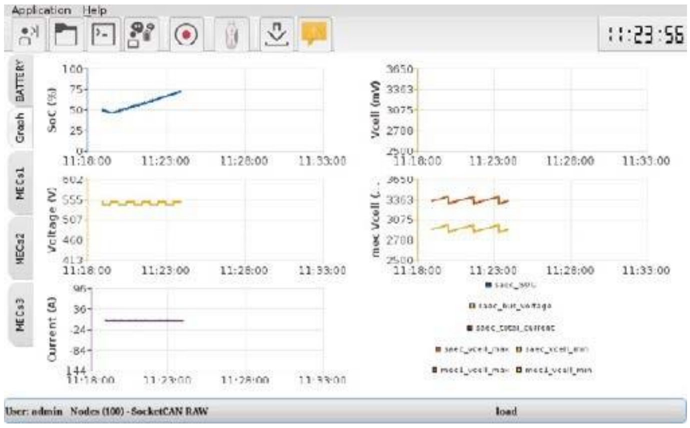


The counters included in the string can be consulted on these screens.

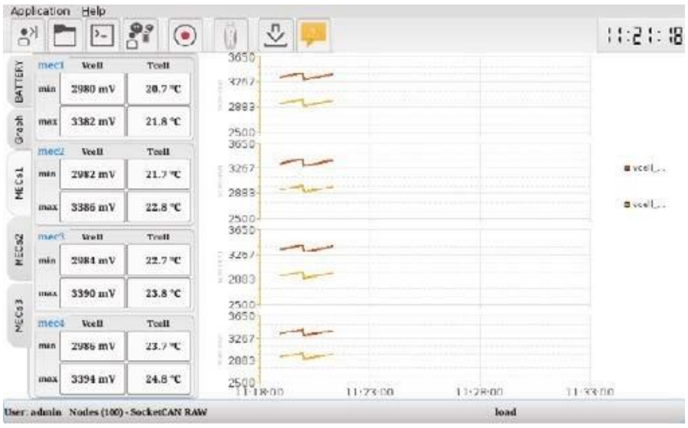
Among these are counters for alarms, trips, energy and cycles.

Graph screen

This screen displays the battery's most significant data in graph form, with values for the last 15 minutes.



MEC screen



These screens make it possible to view maximum/minimum serial voltage and maximum/minimum temperature data separated by battery module.

Each screen stores the data for 4 battery modules and MEC tabs appear on the left side of the screen, based on the modules in the string.

Alarms and events screen

This screen is accessible from any of the previous screens.

To open it, click the alarm icon on the top ribbon menu.

This screen makes it is possible to view all the events generated within the string chronologically, for subsequent use or failure analysis.

It shows the type of event that has occurred (alarm, trip, command ...), if it has been activated/deactivated, the time it occurred, and the value at which this change occurred, whether a relevant value associated with the event exists.

8.2 Remote display

There is an option for remote reading of the EMS data.

To access these data, a PC can be connected through the CAN communications connector, found on the PCC protection module. An isCAN adapter is used on the connector's output to provide a USB input for the PC.

This software shows the same screens that are available on the raspberry display. If required, CEGASA provides this software

Direct access to the CAN adapter drivers

Note: In CAN communication there can only be one master, consequently, if the external output is used to display data on a PC, then the EMS will not be able to communicate with the converter via CAN.

9 Communications

9.1 Introduction

The PCC is capable of external communications for data exchange and system control.

This is available for both CAN and Modbus TCP protocols

9.2 CAN protocol

This protocol, designed for the automotive industry, has as a characteristic immunity to noise and the capacity to detect errors and faults in the communications channel.

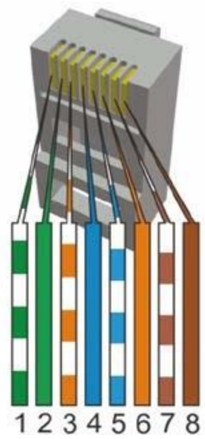
This network is physically connected to the EMS, consequently making all the data generated in the EMS available, as well as the data received by the EMS from each of the BMS. This EMS network acts as a slave, so it never sends data through the communications channel unless they are externally demanded by a master on this network.

In order for a SCADA or converter to communicate with the string, both the data transmission speed and the unique identifier of the equipment are required. The ID for the SMB is fixed, namely node 2. The established communication speed is 500 kBd. The EMS has certain IDs reserved for communication and other restricted ones. The master that wants to communicate with the cabinet has to have its ID set to one of the values between 101 and 106, inclusive.

Between these two extremes, communication is made by means of SDOs (service data objects), i.e., each time the SCADA or converter requests information, it will ask the EMS for the specific data, pointing to the address of its object dictionary, according to a SYNC request.

An RJ45 connector is available for external communication.

The standard pinout for the connection cable is shown below. If needed, this pinout can be altered. Please consult CEGASA



PIN	Signal
7	CAN_H
8	CAN_L
3	CAN_GND

If necessary, ask CEGASA for the CAN BUS output communications protocol

9.3 Modbus protocol

The Modbus protocol is an open protocol developed for industrial use. The eBick uses its TCP version. This type of communication is client server, with the EMS being the data server.

To start communication in this mode, the IP address, netmask and gateway parameters have to be configured, which will have to be done by the network administrator to adapt them to the system where it is going to be integrated. To facilitate integration, all data will be sent as a Holding Register, regardless of its format. The Modbus map (ask CEGASA if needed) indicates how each of the addresses should be interpreted, as well as the information they contain.

There is an RJ45 connector at the back of the PCM or the side of the PCC for communication via Modbus. Use of a CAT5e cable, or superior, is recommended for the connection, with a maximum theoretical length of 100m.

9.4 Type of data

The data to be shared between the string and the external control are divided into four categories:

- **Commands:** Inverter commands that make changes to the state of the string
- **Configuration values:** Variables that describe the installed system
- **Present values:** Analogue or digital variables that describe the present state of the system. These include the SoC, current readings or alarm notifications
- **Counters and logs:** Variables that record what happened in the string during its operation.
- **Contadores e históricos: V**ariables que registran lo ocurrido en el string durante su funcionamiento.

10. Installation requirements and recommendations

10.1 Applicable regulations

Given below are the standards applied to this type of system.

10.1.1 Requirements for Electrical installation

If the equipment is going to be connected to a converter, then the set consisting of the string and converter will be connected to the electrical installation as receiver and generator. This set shall comply with the requirements related to both these functions.

The requirements for the material are those of the applicable directives, specifically to LVD 2006/95/EC.

If used in a network, it shall be considered as a network generator, with no voltage limits.

The electrical installation set shall comply with the requirements of the REBT (Spanish Low Voltage Regulation) and specifically ITC BT 40 as generator and ITC BT 19 as receiver.

For legalization of the installation, the requirements of ITC 03 for projects concerning generating installations of> 10kW shall be met.

DOCUMENT	TITLE
ITC-BT-01	Terminology
ITC-BT-02	Reference Standards for Low Voltage Electro-technical Regulations
ITC-BT-03	Authorised Installers
ITC-BT-019	Indoor installations or low voltage receivers. General Prescriptions
ITC-BT-040	Low-voltage generating installations

The purpose of the REBT (Low Voltage Regulation) is to establish the technical conditions and safeguards that have to be met by electrical installations connected to a supply source within low voltage limits, in order to:

- Protect the safety of people and property.
- Ensure the normal operation of said installations and prevent disturbance occurring in other installations and/or services.
- Contribute to the technical reliability and economic efficiency of the installations.

It shall apply to installations that distribute electrical energy, generators of electricity for self-consumption and receivers, when the voltage is less than 1500VDC.

10.1.2 Requirements for Battery Installations

UNE-EN 50272-2 standard Safety requirements for secondary batteries and battery installations. Part 2 Stationary batteries, containing requirements for safety aspects associated with assembly, use, inspection, maintenance and disposal.

The standard deals with lead and nickel-cadmium batteries. No reference is made to lithium ion, however, in the new revision (still being drafted) stationary lithium ion accumulators are mentioned. Nonetheless, this standard has been used as a basis because they share similar features. Below is a summary of the most important considerations of the said standard

This standard applies to stationary accumulators and battery installations with a maximum rated voltage of 1,500V in direct current. It describes key measures to protect against hazards arising from:

- Electricity
- Gas emissions
- Electrolyte, in cells used in this String
- Protection against electric shock
- Protection against direct contact

Batteries with a rated voltage greater than 120V in direct current shall be located in closed places with restricted access. Doors on battery rooms are considered obstacles and shall therefore be marked with signs according to section 12.1 ("Dangerous voltage", "Fire, naked flames, smoking prohibited" and "Accumulator battery room").

If protection is applied by means of barriers or enclosure, the degree of protection shall be at least EN 60529 IP2X (Protection against solid objects > 12 mm, water untested). This shall ensure protection against indirect contact.

Protection shall also be available through automatic disconnection of the supply, disconnection and isolation. Likewise, the battery installation shall have devices for disconnecting all lines for input and output circuits and earth connection potential.

Short-circuit prevention and protection against other effects of electric current

Apart from electric shock, current in battery systems may cause other hazards. This is due to the possible existence of a high current flow due to a fault, but it is not possible to remove the voltage from the battery terminals. Points to consider in this section: short-circuits, protection measures during maintenance, leakage currents.

Provisions against explosion hazards

The standard's instructions regarding this point refer to lead acid and nickel cadmium batteries. The values it mentions cannot be used to calculate the necessary ventilation flow or the minimum safety distance-volume wit regard to a possible source of ignition.

It should be noted that in order to classify zones, not only normal operation (situation in which the material works within its design parameters) but also abnormal conditions that might produce secondary leaks which, if large enough, could lead to dangerous zones should be assessed. In our case, the eBick does not generate a surrounding ATEX, consequently Directive 94/9 does not apply.

On the other hand, it should also be noted that the classification of zones does not apply to events referred to as "catastrophic failures" such as the rupture of a vessel, pipeline or unpredictable events.

Provisions against electrolyte hazards

This type of cell does not contain electrolyte that can be spilled, it is absorbed by the separator paper. Should it be suspected that it may be possible to come into contact with it, then the following safeguards should be used:

- Protective glasses or masks for the eyes and face.
- Protective gloves

In case of contact with eyes, rinse immediately with plenty of water for at least 15 minutes and seek immediate medical attention.

In case of contact with skin, the affected area should be washed with plenty of water or neutralising aqueous solutions such as soapy water. If skin irritation persists, medical attention should be sought.

The cells shall only be handled by CEGASA personnel.

Housing – Cover

The batteries should be covered and in protected places. If necessary, electrical protection and even restricted access should be implemented.

The following types of housing may be used:

- Special rooms for batteries.
- Specifically separated areas with electrical protection.
- Strings or enclosures inside or outside the buildings.
- Battery compartments inside the devices.

The following factors should be taken into account when selecting the housing:

- Protection against external hazards (fire, water, shock, vibration ...)
- Protection against battery-related hazards (high voltage, explosion hazards, electrolyte hazards ...)
- Protection against unauthorized access.
- Protection against extreme environmental influences (temperature, humidity, air pollution ...)

Working on or near batteries

To accommodate inspection, maintenance and loading of elements, an adequate work space is required. A free passage at least 600mm wide shall be maintained at all times to allow emergency evacuation.

Any work on the batteries or within the safety distance for welding, drilling or similar tools shall only be performed by personnel who have been advised about the possible hazards. Before beginning work, disconnect the battery and any flammable fumes or gases from the batteries should be removed.

FIRE REGULATIONS

These shall comply with Royal Decree 2267/2004; Regulation of fire safety in industrial establishments.

The purpose of this regulation is to establish and define the requirements and conditions that establishments and installations for industrial use shall meet in order to ensure safety in the event of a fire, prevent this from occurring, respond appropriately should it occur, limit its spread and enable its suppression in order to cancel or reduce the damage or loss that the fire may cause to people or property.

Fire prevention activities shall seek to limit the presence of fire hazards and the circumstances that may cause a fire. Fire response activities shall seek to control or fight the fire in order to extinguish it and minimise any damage or loss that may occur.

This regulation shall be applied as a complementary measure to the fire protection measures established in current regulations that regulate industrial, sectoral and/or specific activities, for aspects not foreseen in the latter, which shall be fully implemented.

To this effect, the provisions contained in the Complementary Technical Instructions MIE APQ-1 on the Regulation for the storage and handling of chemical products, approved by Royal Decree 379/2001, 6th April, and those stated in the technical instructions for the Regulation of Petroleum facilities, approved by Royal Decree 2085/1994, 20th October, shall be fully applicable in order to comply with fire safety requirements.

The conditions stated in this regulation shall have the minimum required as indicated in article 12.5 of Law 21/1992, 16th July 16, for industry.

EMERGENCY PROTECTION REGULATIONS

In the event of an emergency, the regulations impose certain obligations on the user to allow this type of emergency to be managed.

The following should be consulted, among others:

Royal Decree 393/2007, 23rd March, which approves the Basic Standard of Self-Protection of centres, establishments and premises dedicated to activities that may give rise to emergency situations

Royal Decree 277/2010, 2nd November, which regulates the obligations of self-protection required for certain activities, cen

REGULATIONS FOR USE AND MAINTENANCE

In addition to the regulations stated above, those regulations concerning proper use and maintenance are general rules. However, the following should be noted: ROYAL DECREE 614/2001, 8th June, establishing minimum safety requirements for the protection of health and safety of workers against electrical hazards.

10.2 Environmental requirements

Parameters	Technical specification	Comments
Operating Temperature Range during CHARGE (ºC)	0ºC ~ + 45ºC	
Operating Temperature Range during DISCHARGE (ºC)	-20ºC ~ + 45ºC	
Humidity (RH%)	5%≤RH≤85%	

10.3 Maintenance and storage procedure

The customer is responsible for complying with this procedure:

- Each month, check the voltage (within the range of the battery) and the visual state of the casing (no bumps, swelling or discolouration) and the positive and negative terminals of the power connector (free of oxidation).
- If the battery is to be left off, then it has to be charged every 3 months up to 40 - 60% SoC.
- A full charge is recommended every 10-15 days to update the SoC due to measurement errors.

Storage recommendations

- Do not expose to direct sunlight or rainfall

Parameters	Technical specification	Comments
RECOMMENDED STORAGE SOC (%))	40-60%	
STORAGE TEMPERATURE RANGE (ºC)	-20ºC ~ + 45ºC	
RECOMMENDED STORAGE TEMPERATURE RANGE (ºC)	15ºC ~ + 25ºC	
Humidity (RH%)	5% ≤RH≤85%	

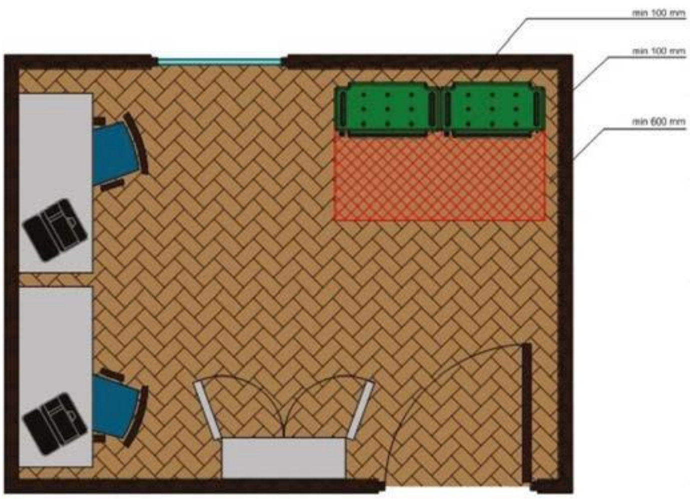
10.4 Layout

Place the equipment in a flat area that can support the specified weight.

With regard to accessing the equipment:

- **Front access** 600 mm
- **Side and rear access** At least 100mm for air circulation
- Each battery module weighs approximately 105 kg. It should not be moved without tools or machinery that guarantee safe transportation.

  When installing, the pallet containing the battery modules shall be positioned as close as possible to the final installation point. From this point up to the installation area, the path shall be level, without steep slopes, steps or any other situation that makes it impossible to transport the equipment safely.



Caution: ***Given that the modules are supplied with electrical charge levels necessary to maintain the chemical properties of the batteries, the entire installation process shall performed with the recommended protection equipment.***

11.1 Electrical and component verification

With the aid of a multimeter, check the integrity of the power circuit, continuity/absence of continuity (AC) and short circuits according to the attached diagram.

Prior to the checks, make sure that no connection has been made between modules or between a module and the PCM.

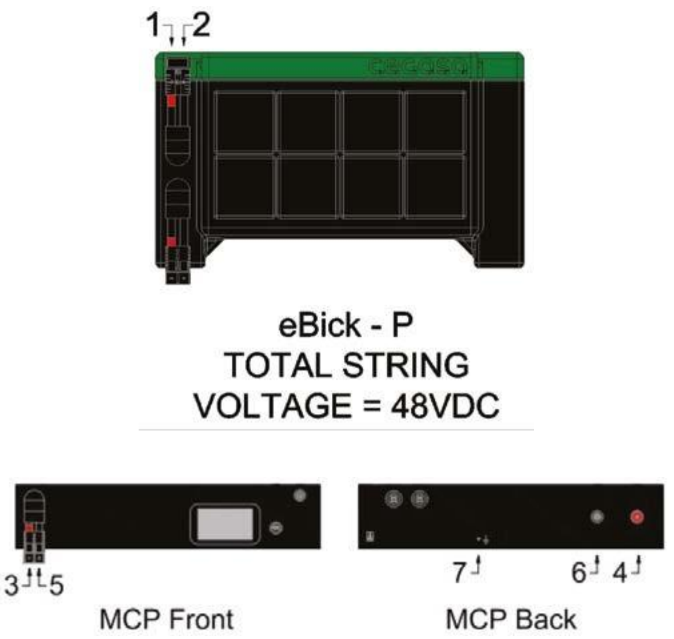
a. **eBick PRO PARALLEL module;** Measure DC voltage between the positive and negative terminals on each battery module (points 1 & 2). Check that polarity is correct and that the voltage is within range (≈ 48VDC)

   A red label indicates positive polarity, whereas the absence of a label indicates negative polarity.

b. **PCM;** Check continuity of the PCM's positive branch (points 3 and 4)

c. **PCM;** Check that the contactor is not welded (NO CONTINUITY in points 5 and 6)

d. **PCM;** Check ground insulation of terminals (On PCM ground screw with points 3, 5 and 6)



11.2 Steps to follow

Each battery module and PCM are pre-wired, pre-set and factory tested.

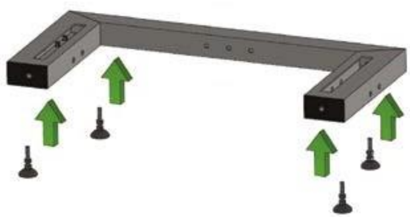
After receiving and unpacking the system, the installer should find that each string contains:

- 1 PCM
- Various eBick PRO PARALLEL battery modules
- One or several base frames
- A set of fastening plates
- A set of communication extenders (*)

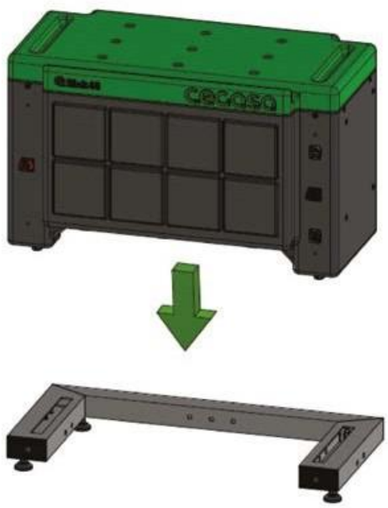
(*) Should the project have more than 4 modules, these have to be distributed in several columns. The wiring between columns will be done using these extension cables.

11.2.1 Fitting the modules

1. First place the base frame on the floor and use the feet to level it. If required, secure the string to the floor, the base frame has a space where brackets can be fitted. The eBick system is designed to be stationary, with no possibility of movement and with its weight distributed evenly.

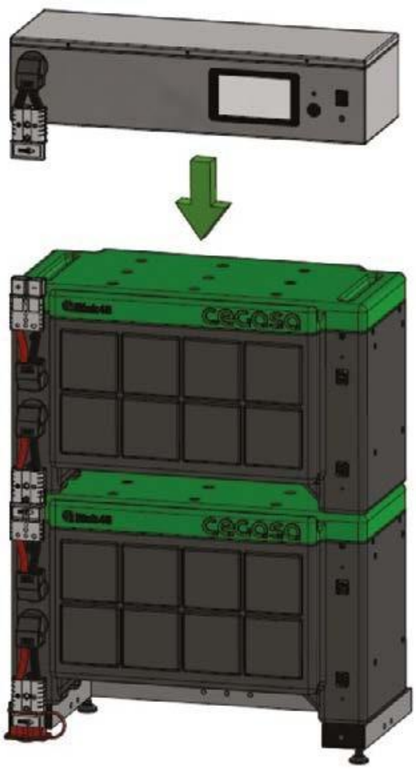


2. Stand the first eBick module on the base frame that is already level and fixed to the floor. Any module can be inserted in any order in the string, without affecting power or communications.

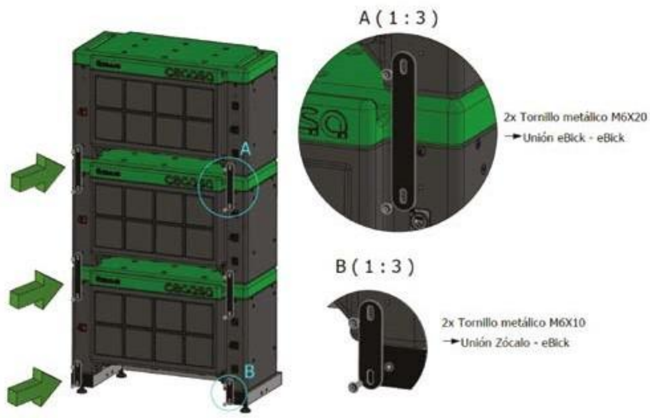


3. Stack the rest of eBick modules up to a maximum of 4 high. Without connecting the power or communications.

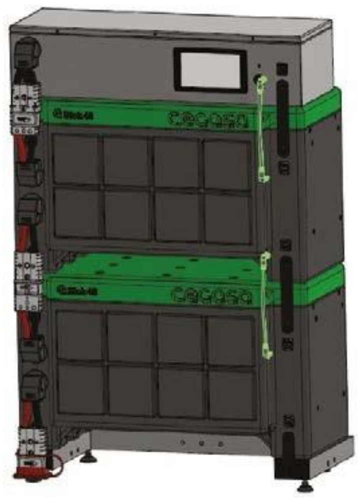
4. check that the ON/OFF switch at the back is in the OFF position and place the PCM above the last module. Without connecting the power or communications.



5. Use the fastening plates to fasten all the eBick modules to each other, to the base frame and to the front of the PCM. Note: Screw length is different when fastening the PCM (see picture below)



6. **Communication connection between modules;** starting with the PCM, make the communication connections between modules using the RJ45 MALE communication connectors on the right.



7. Power connection between modules; Be sure to use PPE (protective gloves and safety glasses)
   - Without connecting to the PCM (leave that till last), connect all the power connectors between the columns.
   - Use the supplied protective cap to protect the power connector left uncovered on the last eBick module.

- Check polarity and voltage (close to 48Vdc) on the power connector below the PCM
- Use the multimeter to check that there is no continuity between positive and negative on the PCM power connector (no beep)
- If everything is OK, proceed to connect the PCM connector to the already connected DC BUS connector.

IMPORTANT; If connecting several TOWERS IN PARALLEL to the same PCM or PCC, take the following into account:

- **1. Each TOWER has to be connected separately to a power busbar (positive and negative).**
- **2. It is advisable to place a 48Vdc 300A fuse on the busbar positive.**
- **3. The power output of this busbar will be connected to the powered PCM (REMA 350 GREY connector)**
- **4. The RJ45 communication cables are ALWAYS connected between towers from the bottom connector (bottom module in the tower) to the top connector (top module in the tower); NEVER BETWEEN BOTTOM MODULES**

Grounding

Because the system may be used to power a UPS, continuity of service is one of the product requirements. Owing to this, the battery is distributed as an IT system; i.e., none of the power terminals are ground referenced.

To ensure the safety of people, the equipment casing is made of non-conductive material and none of the power terminals are accessible.

However, there is a ground screw on the PCC. This screw is used to eliminate any electrical noise that may affect the electronics. A cable with a cross-section of between 1 mm2 and 2.5 mm2 has to be connected this M5 screw.

External wiring

Power supply. The system is self-powered and does not require connection to an external supply.

Power output. Access for connecting the output power cables is located at the back of the PCM. 2 cable glands are provided for connecting the power cable, terminated with an M12 screw, the red one being the positive battery terminal and the black one the negative terminal.

.

To ensure correct power transfer, a cable with a minimum cross-section of 120mm2 with an M12 terminal and a tightening torque of 12Nm is recommended. Over time, this torque decreases, ultimately causing small sparks to degrade the metal material and increasing contact resistance.

The maintenance plan should include a visual inspection of the interconnection and the tightening torque should be checked on an annual basis.

**Note: The length (resistance) of the interconnecting cables affects the final voltage detected by the application. It is advisable to install the battery as close as possible to the element that is going to use it (inverter, DC bus, ...) and avoid sharp curves or bends in the cables.*

For recommended cable lengths, wire sizes and characteristics, please contact CEGASA.

**Note 2: If the battery is to be connected to a de-energised network, then it is advisable to make this connection before connecting the battery modules to the PCM. The PCM output cable glands have bare terminals that may be potentially hazardous if any interconnection work is done after the batteries have been connected.*

External communications

There are 2 RJ45 connectors at the back of the PCM.

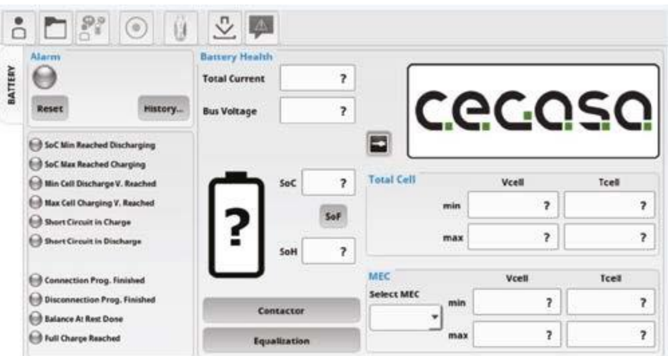
The Modbus/TCP connection is made using a standard CAT5e cable (maximum length < 100m).

The CAN connection is made using a parallel Ethernet cable. The pinout for this is described in section 9.2. To ensure correct communication, the cable should be less than 10m long.

ID configuration

Once the batteries have been installed and the power and communication cables have been connected, the PCM can be turned on using the ON/OFF switch. During the initial start-up, the layout of the modules' serial numbers has to be configured.

Once the PCM has started, it displays all read values as "?" until distribution is configured.



The first step in this process is to log in to the system as an administrator.

The default user is ***admin*** and the default password is ***cegasa***.

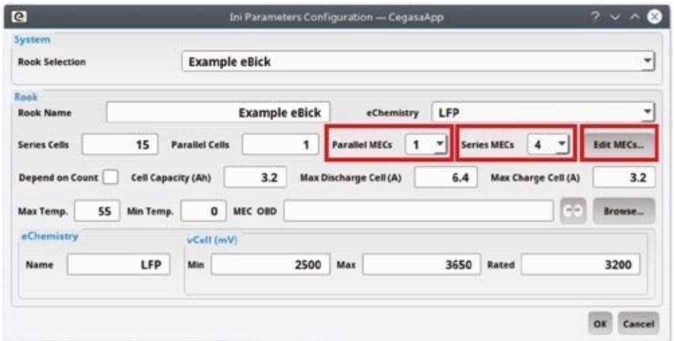
Please contact your administrator if the access data has been changed.

Having accessed the system, the ini file has to be changed.

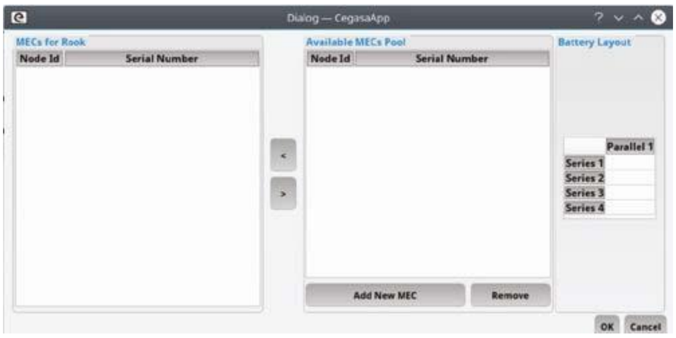
In the dialogue box enter the number of modules in series and parallel

In this example there are 4 modules to connect in series (final bus voltage of 200Vdc) and only one string to connect on the system (1 parallel)

Once the number of modules has been configured, the IDs have to be configured on the "Edit MECs" screen.



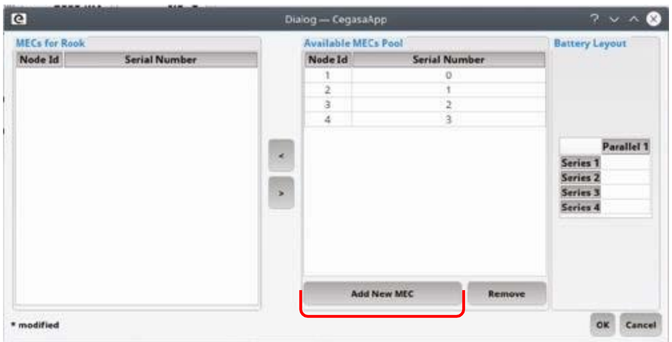
The following screen displays what is seen during the initial start-up.



The battery layout table on the right shows the series and parallel configuration that has been defined in the previous screen.

The software does not show any of the modules during the first start-up. They have to be configured manually.

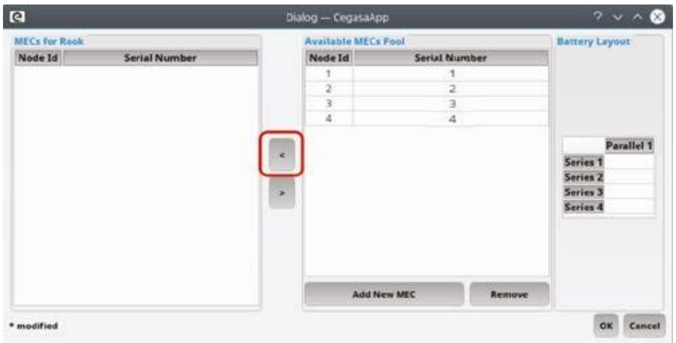
To do this, click on the "Add New MEC" button as many times as there are battery modules. In this particular example, 4 times.



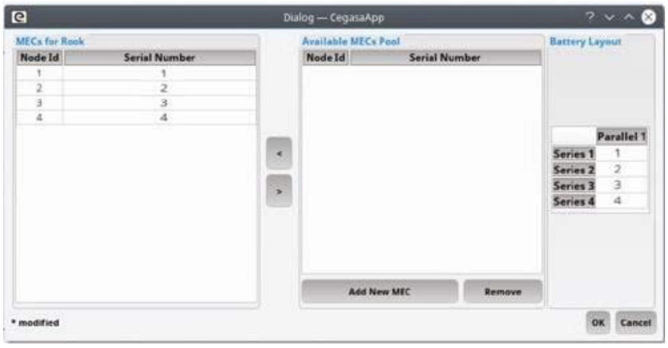
After clicking the button, the software generates battery modules that can then be configured, and these appear inside the "Available MECs Pool" table. As they have not yet been configured, they appear with the default values.

To change the serial and/or ID number, just click on the one that needs changing and an on-screen keyboard will appear so that the new number can be entered. It is a matter of calling the modules the same as their ID, serial number = ID

Once the serial numbers have been changed to reflect the ones that had been written down, select the first one and click on the "<" arrow to pass it over to the "MECs for Rook" table. Do the same with the rest of the modules, following the ID numbers.

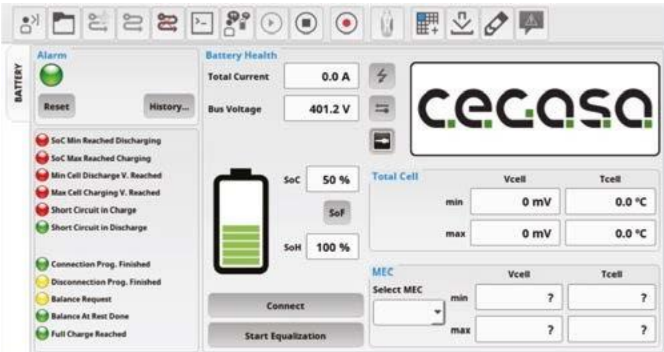


The screen now shows a layout that matches its physical counterpart.



After accepting the changes on both pop-up screens, a warning appears, stating that changes have occurred and requesting permission to restart.

After restarting, the display shows the battery values. The installation is now completed.



Inverter Setting	Recommended Value
Charge Voltage	52 V
Floating Voltage	51.8 V
Low Voltage Warning	46 V
Low Voltage Alarm	45 V
Max. Charge / Discharge	175 A / module

12. Transportation requirements and recommendations

The battery modules contain hazardous substances classified as class 9 in the ADR 2013 document, identified by the number UN3481.

-Their shipment requires:

- Modules tobe sent in packing group 1, withapproved boxes.

It is advisable to keep the original shipping boxes.

- Transportation with ADR authorisation to move this type of substances.

13. Maintenance plan

There are three types of maintenance within the maintenance plan, depending on the personnel and the type of incident that may occur.

The tasks mentioned in this plan are the minimum considered essential for maintaining the equipment during the proposed warranty period. All of these have to be included in the final maintenance programme.

Listed below is the maintenance schedule necessary for installing the storage system

13.1 Predictive maintenance

Proposed Level I maintenance to be performed by the customer's own personnel. The training required to carry out all the actions mentioned below shall be provided.

The proposed incidents that can be addressed at Level I all focus on analysis and simple resolution, they do not include scheduled maintenance, analysis, or complex fault-finding tasks. These last two types of intervention shall be detailed further below.

The proposed Level I maintenance includes the following types of work:

13.1.1 Verifying voltages, warnings and alarms

IMPORTANT: It is necessary to perform this section on installations where the string is not operational for prolonged periods.

Objective: Every three months, use a PC, external CAN or HMI to monitor the voltage values (Vcellmin - Vcellmax) of each module, if the value of Vcell min is equal to or less than 3200 mV charge the string up to the desired energy value.

Check the rest of values, events and alarms to make sure that the equipment is operating correctly.

13.2 Preventive maintenanceo

To guarantee the useful life of the storage system, it is necessary to carry out preventive maintenance tasks on a regular basis. Preventive maintenance makes it possible to detect repeated faults, reduce dead spots due to stops, increase the equipment's useful life, reduce repair costs and detect weak points in the installation, among a long list of other advantages.

This work may be carried out by the customer's personnel or CEGASA, depending on the maintenance schedule and the corresponding training plan. If performed by the customer's personnel, these shall have to be trained and authorized by CEGASA.

To maximise the life of the system, **annual intervention** including the tasks listed below is proposed, however, the preventive maintenance plan may be coordinated based on the customer's needs.

To guarantee the operation of the storage system, it is necessary to comply with the proposed preventive maintenance, frequency and interventions.

13.2.1 Preventative maintenance schedule

This section lists the main maintenance tasks that should be carried out on each of the main components, however, they are merely indicative. The maintenance ranges (personnel necessary, personnel profile, tools needed and description of the maintenance to be done) are detailed further below.

DESCRIPTION OF THE TASK (monthly)	
01.	Charge the battery at least once a month (SoC> 80%) This point is necessary to comply with warranty requirements

DESCRIPTION OF THE TASK (yearly)	
01.	Check the general state of the modules (appearance, leaks, etc.)
02.	Check the electrical resistance of each of the battery modules
03.	Check for rust and/or blackening due to arc flash on the PCC's output terminals. If present, clean with a wire brush.
04.	Check the tightening torque of the PCC's output terminals
05.	Visually inspect the condition of the communication cables
06.	Use HMI to check that all modules are communicating with the EMS
07.	Test mechanical elements (contactors, repeating relays)
08.	Check EMS and BMS inputs and outputs
09.	Check the calibration and reading of voltage and current sensors. Collect data for events and alarms and analyse them.
10.	Register of internal counters to detect one-off and recurrent faults. Correction of these faults.
11.	Controlled and recorded charge and discharge. Charge and discharge the battery to points defined for correcting the SoC, according to point 13.2.2, measure string ageing (SoH) and assess the battery's remaining useful life.
12.	Check the string for hot spots using a thermographic camera.

13.3 Corrective maintenance

Should planned replacement of any component be required, a joint action plan can be agreed between CEGASA and the customer. Planning sufficiently in advance to organise the availability of the installation as well as the necessary CEGASA personnel and equipment would be required

> **Prior to conducting any preventive and/or corrective maintenance, Lockout-tagout of machines and installations (L.O.T.O) shall be observed. – SECTION 2.7**

Should the module's single-pole fuse need to be changed, then proceed as follows:

1. Reference of single-pole fuse to be changed:
   Code: 576-155.0892.6301

   https://www.littelfuse.com/products/fuses/automotive-passenger-car/high-current-fuses/cf8/155_0892_6171.aspx
2. Use a flat-blade screwdriver to help release the module's left-hand side cover.
3. Check that there is NO continuity between positive and negative on the fuse to verify that it has blown.
4. Use an insulated spanner to remove the fuse, putting the fasteners to one side.
5. Insert the new fuse, refit the fasteners and tighten to a torque of 12Nm

13.4 Maintenance requirements

The following table shows a summary of the needs for the different maintenance work, such as the tools, operator profile and time required:

PREDICTIVE MAINTENANCE (Customer personnel)		
TOOLS NEEDED	OPERATOR PROFILE	FREQUENCY
01. Multimeter	2 operators from the CEGASA commissioning department with knowledge of the installation and CAN communications. Assistance from a customer operator with knowledge of SCADA	Annual (8 hour workday)
02. Current clamp		
03. Torque wrench		
04. Thermographic camera		
05. Equipment's HMI or PC with CAN adapter to display and modify the battery status		

CORRECTIVE MAINTENANCE (CEGASA personnel)		
TOOLS NEEDED	OPERATOR PROFILE	FREQUENCY
Depending on the procedure	Depending on the procedure	Depending on the procedure

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