Energy Management System

Installation and User Manual

EMS & EMS config application

Revision A.01

TAO Performance limited

www.tao-perf.com

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1. ABOUT THIS MANUAL

This manual has been written with a number of public in mind:

- prospective buyer to understand the capabilities of the TAO Performance Battery Management System (TAO EMS)
- installation architect to design the integration of the TAO EMS in an off-grid electrical installation
- qualified installer to understand specific procedures and safety guidelines
- end user to learn how to best use the TAO EMS and program it to meet specific needs

Pictograms

Throughout this document, the pictograms below are used to underline points or important notions

(i)	Important information
(bulb)	Good to know / trick
(warning)	Risk
(prohibited)	Action to be avoided
(!)	Mandatory action
(X)	Sensitive or difficult procedure requiring special care

Manual revisions

Revision	Date	Description
A.01	01/01/2024	First released version

2. OVERVIEW

2.1 What is the TAO Performance Energy Management System (EMS)?

It is a complete Energy Management System for off-grid installations.

It is composed of:

TAO EMS

The heart of the Battery Management System: it protects a 12-volt battery and the electrical installation, it also performs continuous dynamic cell balancing and commands the different components of the installation to keep the battery in a state that reduces ageing (extend battery life).

Its main functions are to:

- measure each cell's voltage and temperature with high precision
- measure current in and out of the battery (with TAO Shunt)
- protect the battery when voltage, temperature or state of charge are out of bound / fault
- maximise battery capacity and lifespan by keeping all the cell voltages tightly balanced
- manage battery State of Charge and command chargers for optimum battery lifespan (Charge cycle Management) (with TAO Shunt)
- inform the user on battery status, warnings and faults (led panel)
- activate of up to six independent outputs / relays to command external equipment based on actual measures and user defined triggers
- disconnect the battery when the "shutdown" button is pressed

BMSconfig

Desktop application (Windows & Mac OS) used to configure and monitor TAO EMS. It also has an option to run self diagnostics and validation tests for the whole installation.

TAO Shunt

Optional high accuracy current measuring shunt to enable current measure and computation of battery Sate of Charge and State of Health.

TAO Monitor

Optional display to visualise battery actual and historical data. It has advanced functionalities like full events log and lifetime historical measures for battery warranty purpose. It provides CAN bus functionality, wireless access to the EMS as well as connectivity to the Cloud for remote monitoring.

EMS Extension

EMS extension module to protect and optimise batteries with a voltage of 24, 36, or 48 volts (one EMS extension is required for each additional 12 volt)

2.2 Package content

The standard TAO EMS package includes:

- EMS main unit

- colour coded and fused wire harness to connect the EMS to the battery

- cables with the 6 EMS outputs

- LED panel with 10 metres cable

- cable with USB connector to link to a computer

note: the TAO EMS config application can be downloaded from the TAO Performance website (BMSconfig download)

What must be purchased separately to suit specific installation needs

- a way to attach the battery harness to the cells (5 wires with 6 mm lugs)

- a mini-USB cable to update the EMS firmware

2.3 Principle of TAO EMS

TAO EMS measures voltage and temperature for each cell (or group of cells in parallel) in the battery. It also measures the current flowing in or out of the battery when the TAO Shunt is installed.

Based on these measures TAO EMS generates events to protect or optimise the battery. These events can be a combination of the following:

- activate one or more led and audible signal on the led panel

- activate / deactivate one or more relay outputs

- send CANbus commands (with TAO Monitor)

Each event is defined by what we call a "TRIGGER".

TAO EMS comes with factory default triggers that are set to be conservative and suitable for most situations when LiFePo4 lithium cells are used. Each trigger settings can be adjusted by the user with the BMSconfig application running on a personal computer.

Up to 20 triggers can be defined.

A trigger can be based on either a cell voltage, a cell temperature or the battery state of charge (SOC) if the TAO Shunt is connected. There are three possibilities to trigger an event:

- HIGH: measure is above a set value or;

- LOW: measure is below a set value or;

- DIFFERENTIAL: difference between highest and lowest cell measure is above a set value.

For each trigger a reset value can be specified to clear the event. If one or more triggers are active they can also be reset by pressing the "Reset" button on the led panel.

2.4 Specifications

TAO EMS

Description	Value
General	
Individual cell voltage	2.1 V to 4.9 V
Number of cells	4 (up to 16 with EMS extensions)
Operating temperature range	-20 °C to +75 °C
Battery capacity	10 Ah to 10 000 Ah
Cell voltage resolution	0.0001 V
Cell temperature accuracy	0.5 °C
Cell balancing current (bidirectional)	2 A + 2 A
Power consumption (no alarms)	0.39 W
Computer connection port	USB
Enclosure size (L x W x H)	160 x 114 x 46 mm

Isolated relay outputs*

Output type	Dry contact (volt free)
Default output state	NO or NC (user defined)
Number of outputs	6
Maximum continuous current	2 A
Maximum pulse current	7 A for 100 ms
Output protection	Internal resettable fuse

* The 6 TAO EMS relay outputs are ranked from 1 to 6. If a trigger commands more than one output, the lowest ranked output will be activated first then the other outputs will be activated sequentially with a user defined delay between each of them.

* Relay output 1 can be used for pre-charge

Cell balancing	
Balancing principle	Dynamic energy transfer between cells
Balancing trigger	Voltage differential between cells
Adjustable minimum voltage to initiate balance	Yes
Compensation for internal resistance	Yes
Balance current (charge + discharge)	4 A
Energy transfer efficiency (charge / discharge)	>90 %

Features available when connected to TAO Shunt	
Current range with standard shunt *	-250 A to +250 A
Minimum current	25 mA
Current measure error	<1 %
Battery state of charge	Yes
Battery cycle counting	Yes
Cell internal resistance	Yes
Battery state of health	Yes
Actual battery capacity calculation	Yes

Factory *settings*

The EMS is delivered with conservative factory settings for LiFePo4 cells with a nominal voltage of 3.2V. All these default settings can be modified with the BMSconfig application.

The factory settings can be downloaded from the TAO Performance website:

Parameters (PDF):   https://tao-perf.com/wp-content/uploads/2023/11/ems_parameters_v200-1.pdf

Triggers (PDF):   https://tao-perf.com/wp-content/uploads/2023/11/triggers_worksheet_default_v201-1.pdf

Configuration file (CFG):   https://tao-perf.com/wp-content/uploads/2023/12/EMS_config_v2.00.zip

BMSconfig application

This application can be downloaded from the TAO Performance website.

Windows 10 and above: https://tao-perf.com/wp-
content/uploads/2023/12/BMSconfig_v109_setup.zip

Mac OS v10.15 and
above: https://tao-perf.com/wp-
content/uploads/2023/12/BMSconfig_v109.zip

Features:

- view battery voltage and temperature (plus current, SOC, SOH and number of charge cycles with TAO Shunt)
- view each cell voltage, temperature (plus cell internal resistance with TAO Shunt)
- edit all parameters
- edit the 20 triggers parameters with corresponding relay output(s) and led status
- run the EMS self-diagnostics
- start manual balancing (charge one cell and/or discharge one cell)
- simulation mode to validate the entire installation settings and wiring

3. SAFETY INSTRUCTIONS

Please read the safety and installation instructions before installing and using the product. The equipment should be used for the designated application only and should be installed by a qualified electrician.

WARNING: DANGER OF ELECTRICAL SHOCK

Always disconnect the battery by removing the 4 fuses before performing maintenance.

The product is used in combination with a permanent energy source (battery). Even if the equipment is switched off, an electrical voltage can occur at the input and/or output terminals.

Do not open the enclosure if the product is connected to a source of electrical power and the fuses are in place.

NO INTERNAL USER-SERVICEABLE PARTS

All maintenance should be performed by qualified personnel.

Do not put the product into operation unless the enclosure lid is fitted.

BATTERY HAZARD

Refer to the specifications and instructions provided by the manufacturer of the battery to ensure that the battery is suitable for use with this product.

Be careful when using metal tools in vicinity of batteries. Dropping a metal tool onto a battery might cause a short-circuit, damages to electronic circuits, explosion...

Use isolated tools, remove personal metal items such as rings, bracelets, necklaces, and watches when working with a battery.

INSTALLATION

Read the installation instructions before commencing installation activities.

Installation must be in accordance with the local applicable regulations.

Ensure that the connection cables are provided with fuses.

Never replace a protective device by a component of a different type (refer to the manual for the correct part).

Before switching the device on check that the battery cell voltage conforms to the configuration settings of the product as described in the manual.

Ensure that the equipment is used under the correct operating conditions. Never operate it in a wet or dusty environment.

4. INSTALLATION PLANNING

Based on your required level of integration within your electrical system, different installations can be considered.

It is important to plan and document your installation in accordance with the product features you wish to use.

This section covers 6 types of installation:

1.   No relay (no relay or other switching devices are commanded by the EMS)

2.   Two relays (to disconnect charge and load buses)

3.   Remote controlled chargers

4.   Combined charger / converter

5.   Solar charge controllers

6.   Alternator that cannot be remotely controlled

> DO NOT CONNECT ANY CABLE DIRECTLY TO THE BATTERY
>
> A properly sized main fuse must be installed as close as possible to the battery in accordance with local regulation.
>
> A general isolation switch should be installed just after the main fuse
>
> When in this document it is said to connect an equipment or a cable to the battery it must be connected to the general isolation switch – and in no case between the battery and the fuse.

4.1 No relay

This is the minimum installation needed to use TAO EMS. Use this installation if your system is not fitted with any power relays or equipment that can be commanded by the EMS.
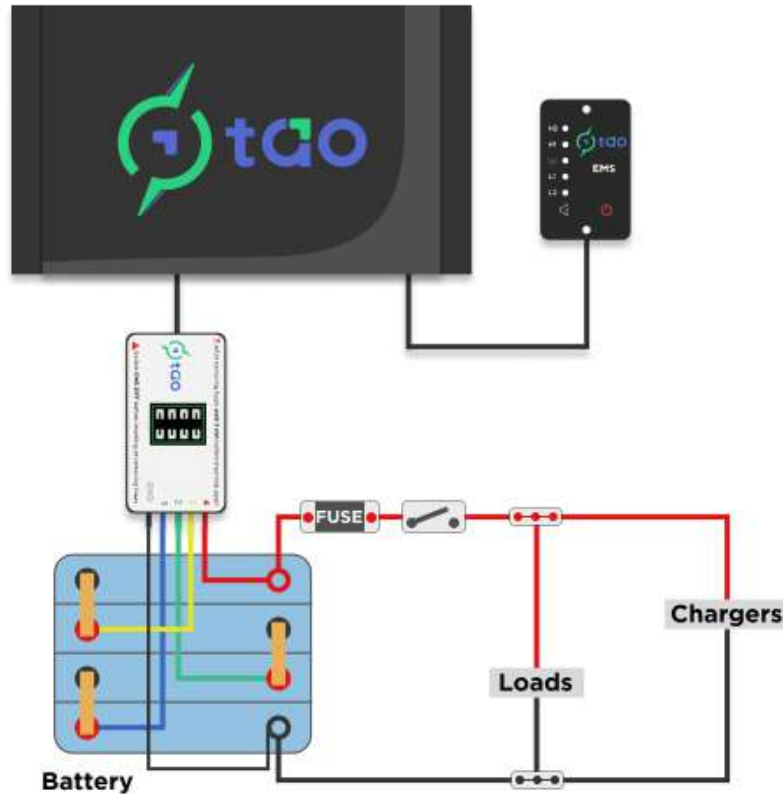
> ℹ️ **NO COMMAND OF EXTERNAL DEVICES**
>
> Safety measures are taken manually. The TAO EMS / led panel will give visual and audible warnings / fault alarms. It is the responsibility of the user to take the necessary actions to protect the battery and/or the electrical circuit.
>
> This type of installation should be used only for non-critical applications where there is constant user supervision.

4.2   Relays for charge and load buses

Although this type of installation is typical of many EMS on the market, TAO Performance does not recommend it as it could damage the chargers and lead to unsafe situations.

This type of installation is used when chargers and loads are connected to different busbars. This setup allows to:

- protect the battery against overcharge while loads are still powered

- protect the battery against too deep discharge while allowing charging of the battery

- isolate the battery by disconnecting both chargers and loads
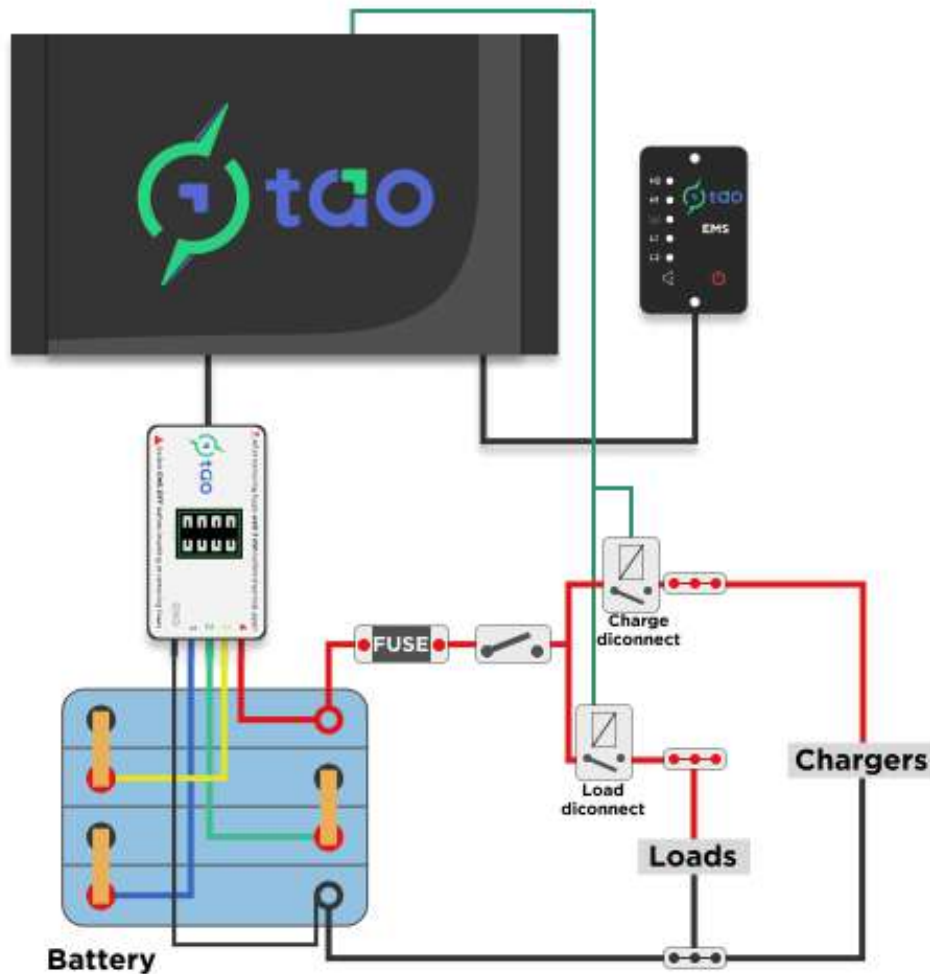
> ℹ **PROTECTION ON CRITICAL FAULTS ONLY**
> EMS triggers must be set so that load and charge disconnection happens only in critical fault situations. It is the user's responsibility to act on non critical warnings.

> ⚠ **CHECK CHARGERS COMPATIBILITY**
>
> Many types of chargers and regulators cannot be disconnected from the battery while they are in operation. If the charge disconnection relay is opened when the charger is in operation the charger could be damaged.

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4.3   Remote controlled chargers

This type of installation is an improvement on the previous one when chargers on/off sate can be controlled with a remote switch.

This setup allows to:

- switch the chargers OFF before opening the "charge disconnect" relay
- use the EMS charge cycle management functionality to safely stop the charge based on set criteria
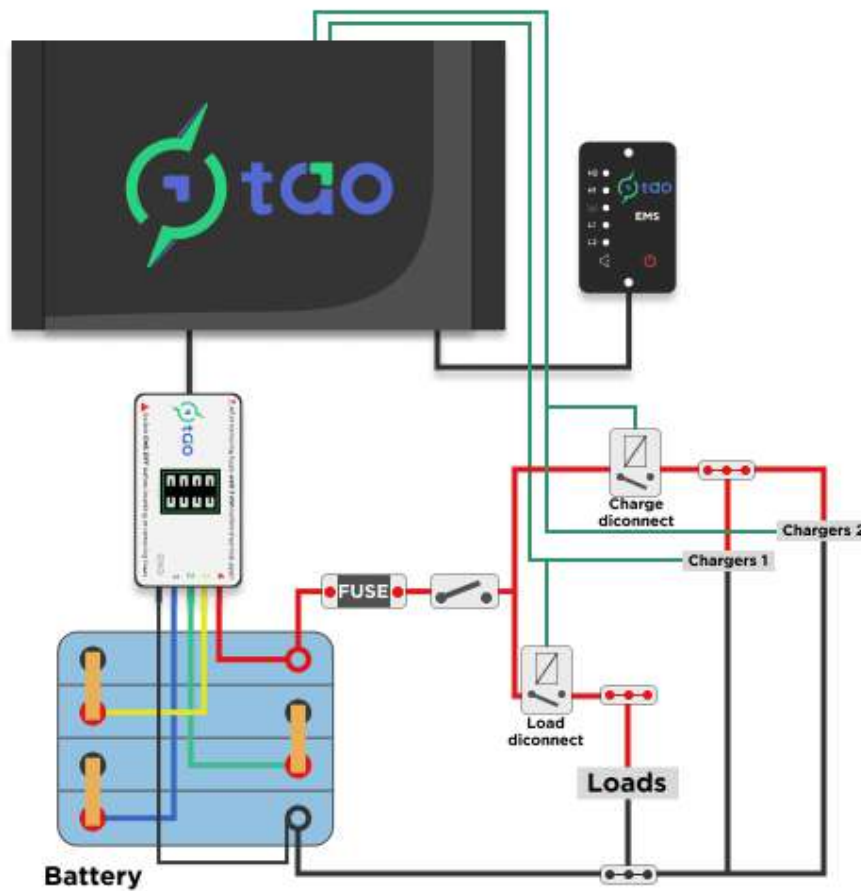
4.4 Combined charger / converter

Some equipments combine charge and load functionality (like a charger / converter) with a single cable to connect to the battery. In that situation it is not possible to have completely independent busbars for chargers and loads.

You need to decide on which bus to connect the charger/converter.
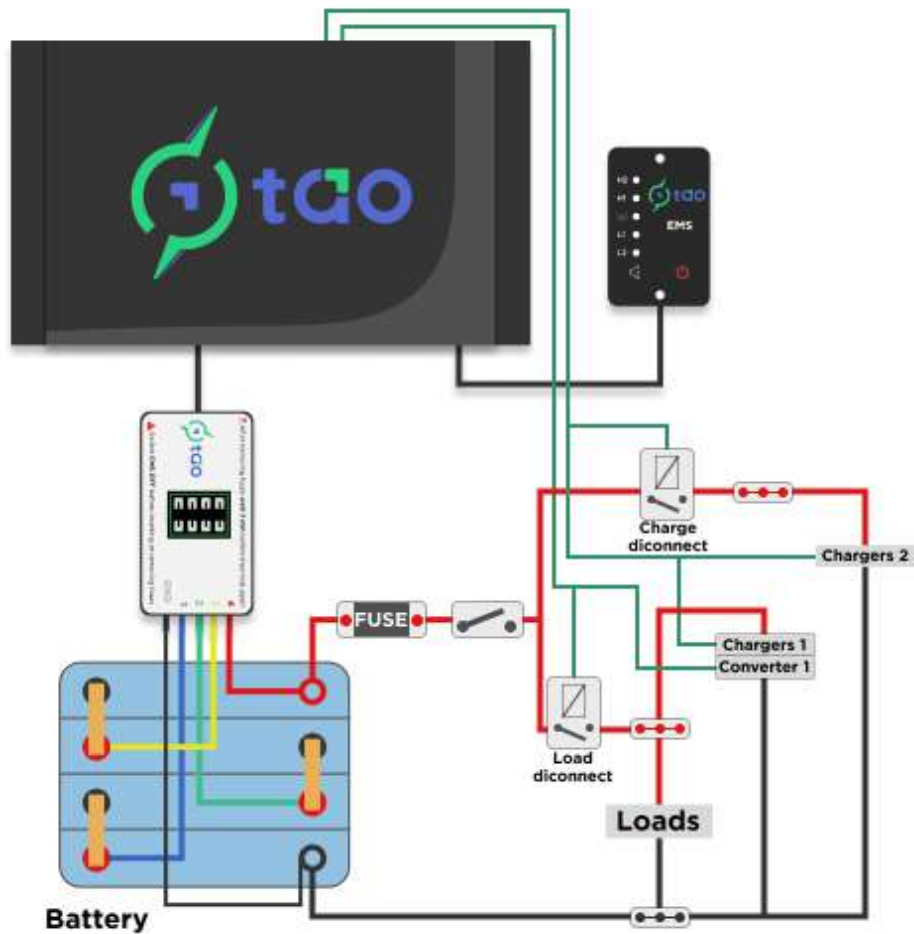

> ⓘ **CHECK CHARGER / CONVERTER COMPATIBILITY**
>
> Your equipment must have the capability to remotely turn on and off the charger and the converter independently.

- command wires for the charger and the converter are each connected to a EMS (relay) output (two outputs are used)

4.5   Solar charge controller

If the solar charge controller cannot be turned on and off remotely, you can install a relay between the solar panel(s) and the solar charge controller.
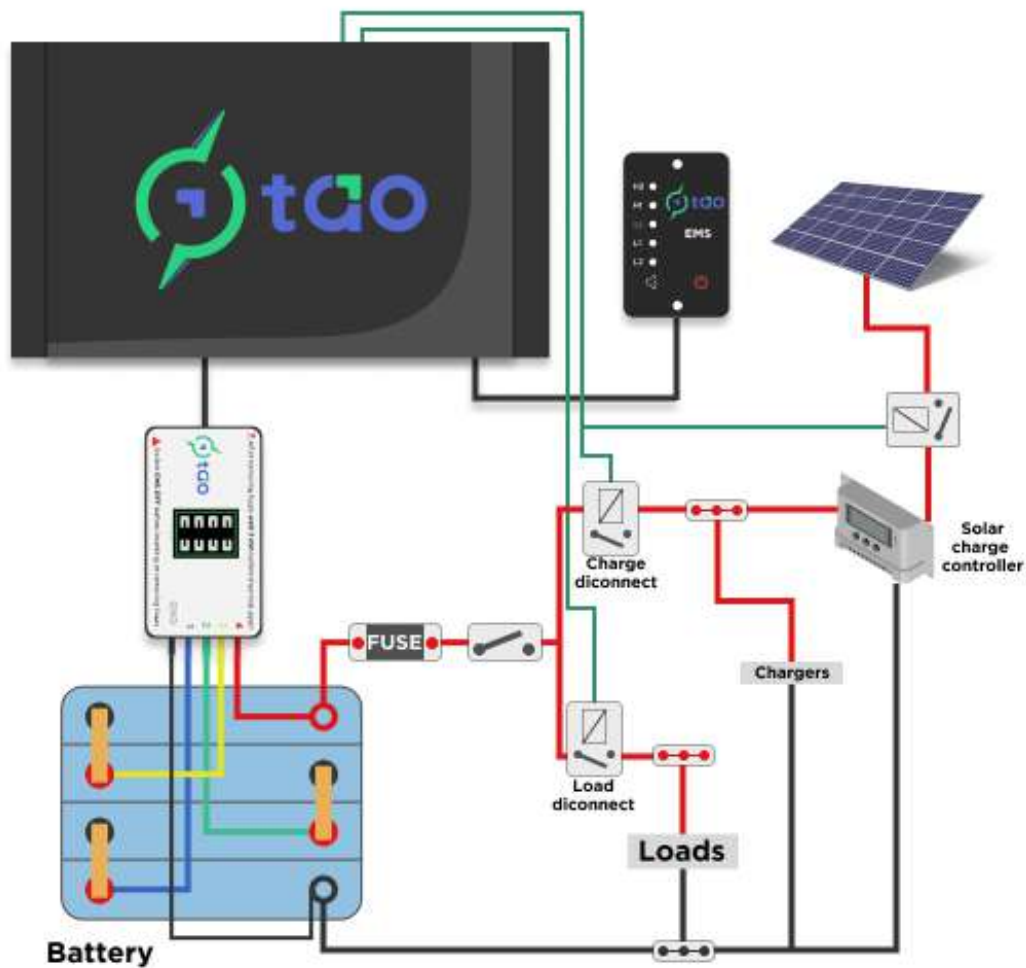
💡 **REDUCE RELAY SIZE**
If you have two or more solar panels, connect them in series to increase output voltage (within the limits of the solar charge controller) in order to reduce the current output and therefore the size of the relay.


⚠️ **RELAY PLACEMENT**
The relay must be between the solar panels and the charge controller.
It should not be placed between the charge controller and the battery.

4.6 Alternator that cannot be remotely controlled

Most alternators that are not fitted with an external regulator cannot be remote controlled and their output voltage cannot be regulated. This means that when the battery is full the voltage will increase above what is safe for the battery. When the battery is full or the voltage is too high the EMS must disconnect of the alternator - which may damage the alternator!
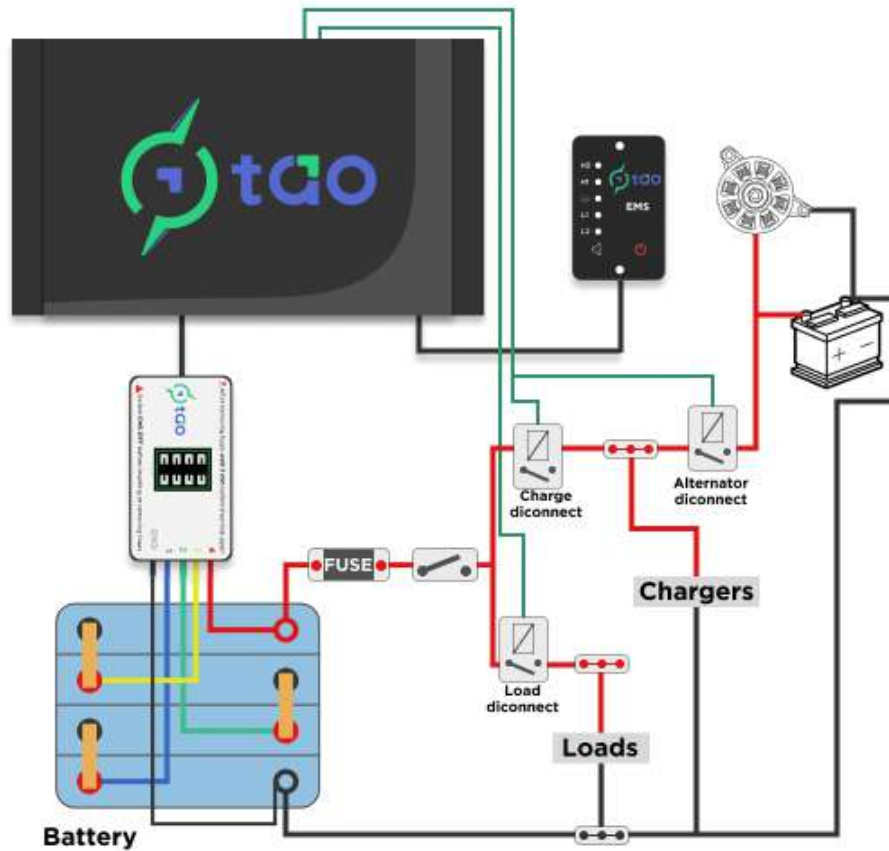
> 🚫 DO NOT DISCONNECT AN ALTERNATOR'S OUTPUT WHILE IT IS RUNNING

When the alternator is disconnected it is imperative to still have a load on the output of the alternator. The easiest way to achieve that is to connect a lead-acid battery (usually the starter battery) directly to the alternator. A relay is installed between the alternator and the lithium battery. The EMS commands that relay when the battery is full.

Most of the time the lead-acid battery is connected to the lithium battery. The lithium battery will therefore always trickle charge the lead-acid battery and keep it full. But if the voltage of the lithium battery gets too low there is a risk to discharge the lead-acid battery. If that battery is also the starter battery, you not be able to start the engine.

For suggestions to avoid such situation follow this link on the TAO Performance website:

How to charge lithium and lead-acid batteries with an alternator

5. TAO EMS INSTALLATION

5.1 Main unit (EMS)

The main unit comes with the battery wire harness and two cables for the relay outputs.

You need to attach the case to a bulkhead close to the battery bank. Use four screws diameter 4mm that are suited to the material of the bulkhead. Place a washer between the head of the screw and the fixing tabs of the EMS case.

Make sure the case is close enough to the battery so that the fuse box can reach the centre of the battery bank without stretching the cable.
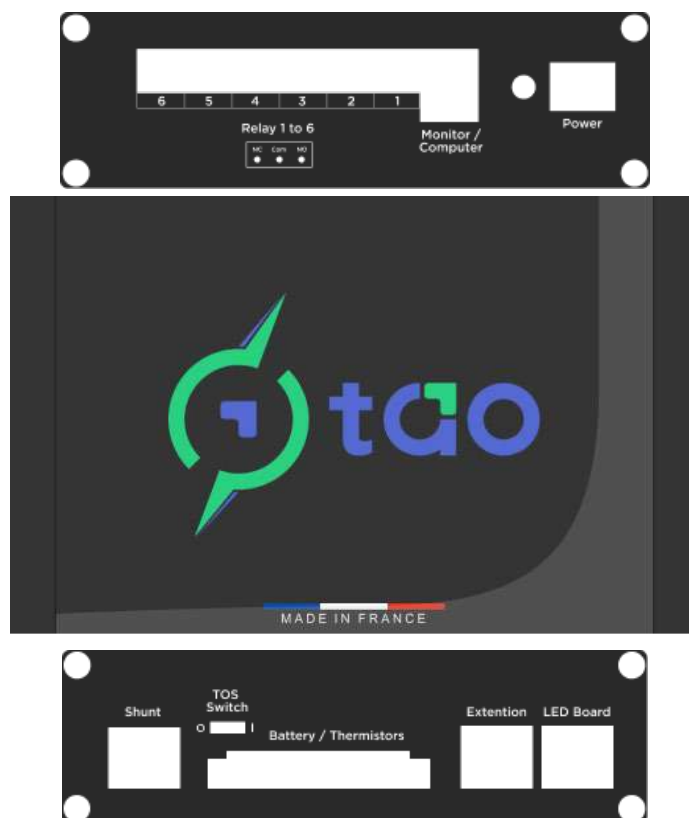
Hardware configuration when using EMS extensions:

5.2 Led panel

The led panel should be placed in a central location. Users of the installation must be able to see and hear it without any obstruction. It is designed to be placed on a vertical panel. Drill a rectangular opening in the panel per the attached drawing. The part to drill out is the hatched area.
Download the drill template from the website: Downloads
Position the led panel in the opening and use the provided wood screws to attach it.

Use the supplied 10 metres cable with RJ45 connectors to connect the LED panel to the EMS. Refer to picture in section 5.1 to identify the correct connector socket on the EMS.

Created by:	Title:	Size:	Sheet:	Scale:
TAO Performance Limited	Led panel cut out template	A4	1/1	1:1

Supplementary information:	Part number:
led panel outline seen from the front	PN
cut out hte hatched area (body of the led panel)	Drawing no.: DN

Date: 20/10/2021

Revision: REV A

5.3   EMS (relay) outputs

Top view
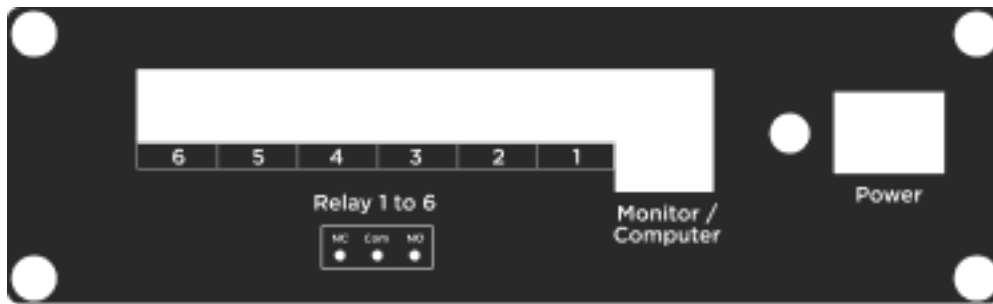
## Bottom view
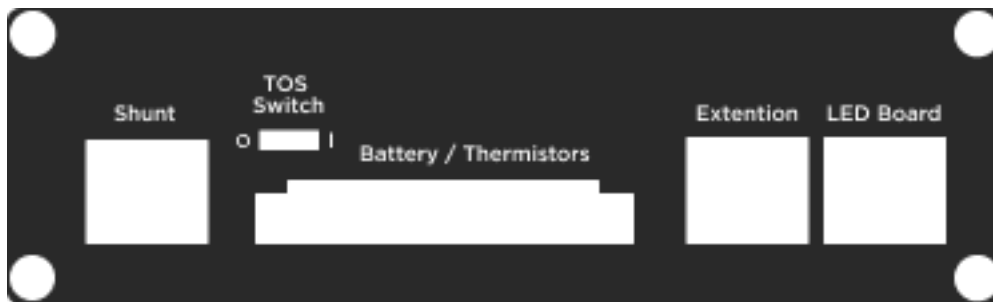
The EMS (relay) outputs are dry contacts (no voltage), just like a switch. The continuous maximum current for these outputs is 2 A, but they can accept up to 7 A for up to 100 ms. Outputs are protected by an internal resettable fuse.

These outputs can be used to:

- directly command equipments that are capable of being switched on and off remotely
- command an external power relay

Through hardware setting, each (relay) output can be either:
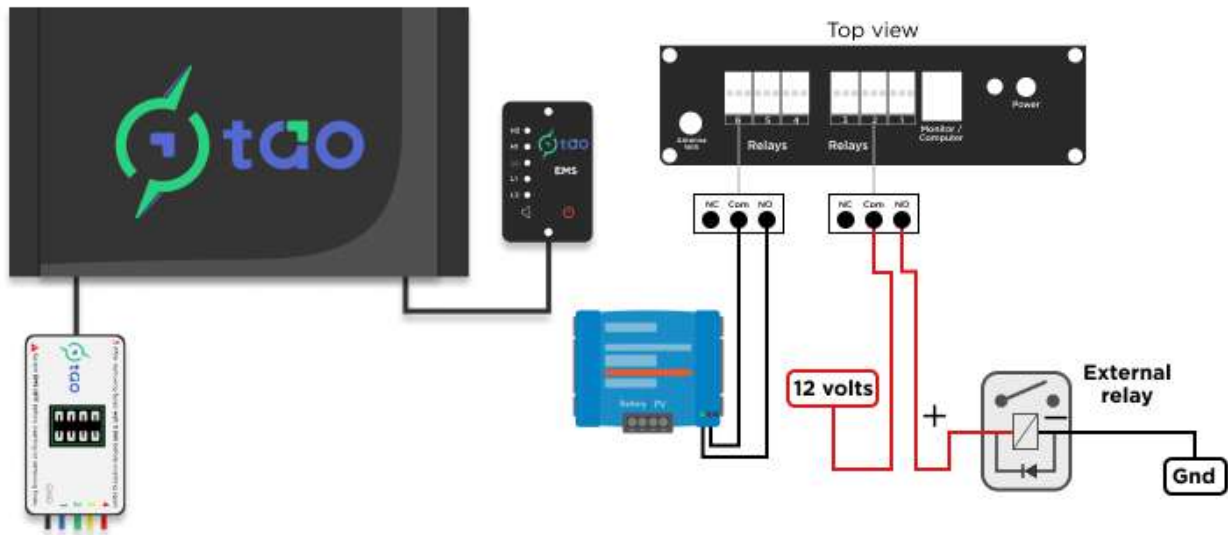
- Normally Open (NO) – contact is open when output is not activated or EMS is switched OFF / contact is closed when output is activated

- Normally Closed (NC) – contact is closed when output is not activated or EMS is switched OFF / contact is open when output is activated

In addition to the hardware (relay) output setting as NO or NC, the BMSconfig application can be used to set EMS (relay) outputs to be activated by default. This means that the output is activated as soon as the EMS is switched ON, and the output is deactivated by triggers.

EMS (relay) output state in different situations	Hardware setting Normally Open (NO) (Factory Default)		Hardware setting Normally Closed (NC)	
	Not activated by default	Activated by default	Not activated by default	Activated by default
EMS OFF	Open	Open	Closed	Closed
EMS ON	Open	Closed	Closed	Open
Fault: output commanded by trigger event	Closed	Open	Open	Closed

After any change in the EMS connections, parameters or triggers you should run a SIMULATION in the BMSconfig application to validate that triggers and outputs work as expected

EMS (relay) output configuration strategy:

A EMS (relay) output configuration must be defined to match the requirements of the equipment it commands and on your choice to privilege either battery protection or energy availability.

Example: the output commands a load disconnect solenoid that needs to be powered to be closed and connect the loads to the battery.

Option 1 - hardware EMS (relay) output set to Normally Closed (NC) / output Not Activated by default:
The only situation where the solenoid is not powered (load disconnected) is when a fault is triggered by the EMS. When the EMS is ON, OFF or out of service the solenoid remains powered (load connected).

This option could present a risk for the battery (it may also void your battery warranty). If the EMS is switched OFF or is defective, the loads are connected to the battery and battery could be drained below the minimum specified by the manufacturer. On the other hand it allows to perform maintenance on the EMS without interrupting power availability. This option could be considered in a situation where loss of power without any backup system could result in a dangerous situation (like on a boat when navigation lights, chart plotter, radio, radar and autopilot are no longer powered).

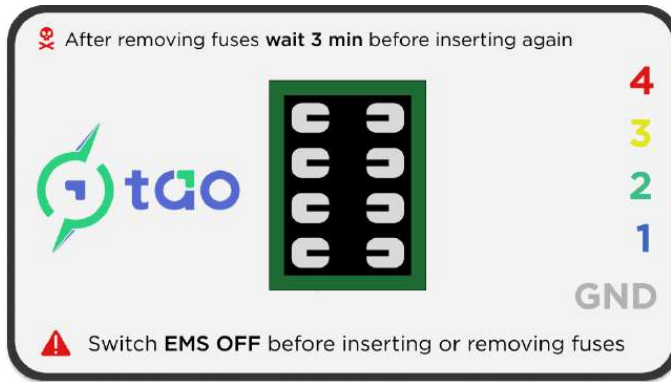Option 2 with a backup battery is a better approach to avoid loss of energy.

Option 2 - hardware relay output set to Normally Open (NO) / output Activated by default:
In that case the solenoid is powered (load connected) only when the EMS is ON and there is no fault triggered by the EMS. In all other situations (EMS is OFF, out of service, or there is a fault triggered by the EMS) the solenoid is not powered (load disconnected).

This is the safest mode of operation for the battery protection. But the energy will not be available during EMS maintenance or in case of a defective EMS. You may consider a backup battery to mitigate that situation (the connection of the backup battery can be commanded by the EMS just before disconnecting the loads).

This example is to stress the importance to carefully think through the balance between energy availability, battery protection and safety strategies. You need to anticipate the possible events in different situations and define the desired actions you want the EMS to command. You should seek advice from a professional if you are unsure about your needs.

5.4   Connection to the battery

☠ After removing fuses **wait 3 min** before inserting again

4
3
2
1
GND

⚠ Switch **EMS OFF** before inserting or removing fuses

The battery wire harness has five colour coded wires. You need to connect one wire to the battery negative terminal and one on each cell's positive terminal.

⚠ Do not trust the colour on the battery terminals
We came across battery cells where the positive terminal is black
the customer thinking it was the negative did all his wiring with reverse polarity...
the EMS did not survive!

⚠ Do not tamper with the wires or the connectors

The four colour coded wires and their connectors are designed to measure both the voltage and the temperature of each cell.
They include a temperature sensor and should be handled with care.

⊖ Remove the four fuses before connecting the wire harness to the battery

⊖ BEFORE INSERTING THE FUSES
with a voltmeter check the voltage on each fuse socket
by placing the common (black) probe on the negative terminal of the battery and the positive (red) probe on each fuse socket

readings should be positive and increasing by ~3.25v from cell 1 to cell 4

Cells are numbered sequentially from 1 to 4 starting from the cell connected to ground.
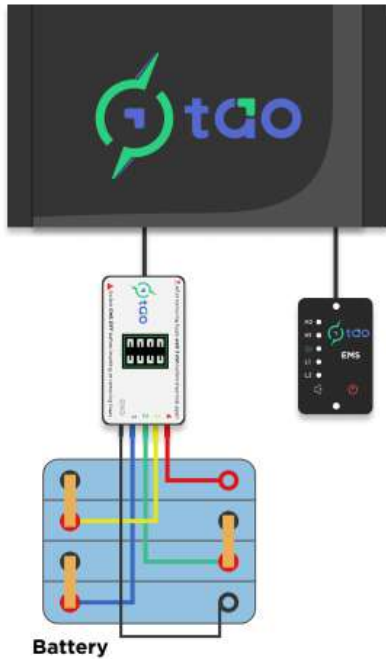
The positive wires are colour coded in the order of the rainbow colours from cell 1 to 4.

Wire / connector colour	Cell #	Cell post
Black	1	Negative
Blue	1	Positive
Green	2	Positive
Yellow	3	Positive
Red	4	Positive

The cell wires are fitted with lugs for 6 mm screws. They are designed so that they can be connected and disconnected without interfering with your installation power circuit. If your battery screws are larger than 6mm you need to use an adapter. Here are examples:
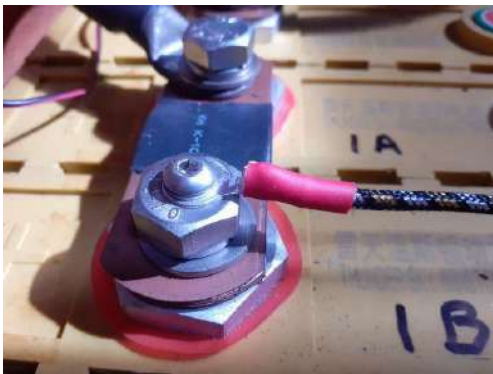
The fuse box:

Each fuse corresponds to one cell wire.
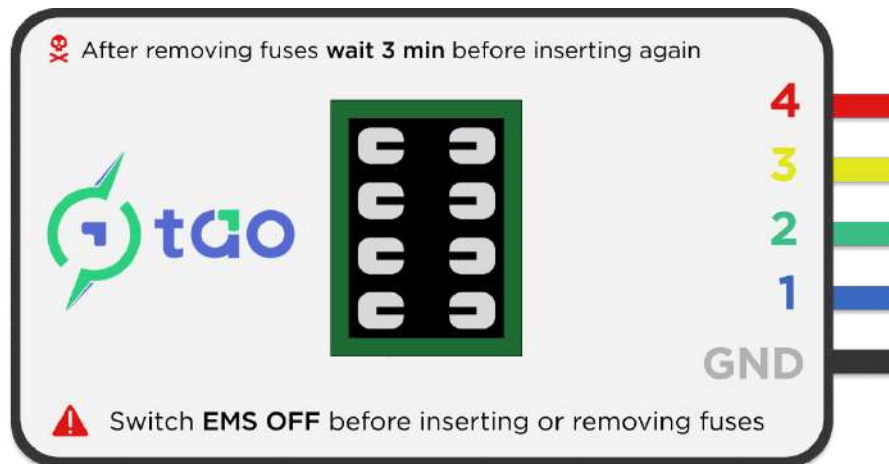
To avoid current spikes in the TAO EMS, it is imperative that all cell connection/disconnection operations are carried out with the TAO EMS switched off and the 4 fuses removed.

Connection:

1. Remove the four fuses

2. Connect and secure the negative wire and the four cell wires as described above

3. Using a multimeter, check the voltage between the negative pole of the battery and each fuse holder (battery side) - from cell 1 to 4, the voltages measured should be in the range 3.25 - 6.50 - 9.75 - 13.00

4. Insert the four fuses sequentially
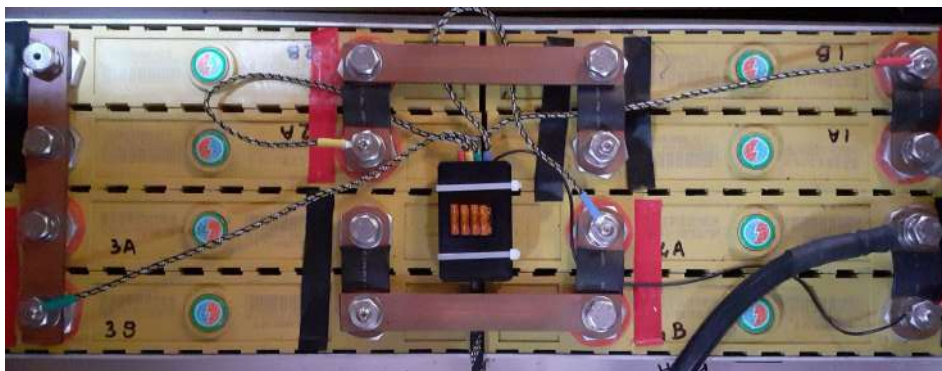
6. EMS OPERATION

6.1 Main unit

Once the EMS is properly connected and all connections have been verified, flip the switch to ON (position I).

The green heartbeat led on the led panel starts blinking.

Voltage, temperature and current (if the shunt is installed) are monitored and events are triggered using the default factory parameters. These parameters are listed in 2.4 Factory settings.

Cells are automatically balanced if enabled.

See the BMSconfig application (8.BMSconfig application) for instructions to change the parameters and triggers definition.

(i)	EMS self diagnostics The EMS runs self diagnostics at startup and at regular intervals. Any defect is indicated on the led panel (see troubleshoot section). The results of the self diagnostics can be consulted with the BMSconfig application

6.2 Led panel

When TAO EMS is turned ON and operates in normal conditions, the "ON" led flashes slowly (green – period 3 seconds).

If an error or dysfunctionality is identified during self diagnostics, led H1, H2, L1 and L2 are lit and the buzzer sounds. Use the diagnostics option of the BMSconfig application to identify the problem.

When an event has been triggered and the trigger is set to turn on one or more led on the led panel, then the corresponding led are turned on and the buzzer sounds.

(i)	Cell balancing indication If TAO EMS is balancing the cells the heartbeat led flashes rapidly (every second)

Mute:

When the buzzer sounds, press the button for up to three seconds to turn off the buzzer.

Output reset:

When events have been triggered and some EMS (relay) outputs have been activated, you can reset the outputs to their default state by pressing the button for a short time (<2 seconds). This action is confirmed by a single flash of all the leds.

All the EMS (relay) outputs are reset to their default state and the EMS continues its normal operation by triggering events based on measured conditions vs. trigger settings.

Shutdown:

When the button is pressed for more than 2 seconds and then released, all the led flash twice and the EMS (relay) outputs that are set as "Shutdown" relays in the parameters are activated. See section 8.5.1. Parameters for instructions.

6.3   EMS usage

Initial setup

After any change in the EMS connections, parameters or triggers you should run SIMULATION in the BMSconfig application to validate that triggers and outputs work as expected

Shunt not connected (no current measure)

No parameters or triggers setup required if factory defaults match your requirements.

It is a good idea to use the BMSconfig application to validate the parameters in the "General" and "Balance" sections (the other parameter sections are not applicable).

Shunt connected (current measure active)

Using the BMSconfig application (screen and option selections are indicated in green):

- Configuration / Parameters / Current:

  ◦ set the "Current shunt connected?" field to "Yes" and click "Upload to EMS" button

- Configuration / Adjustments:

  ◦ disconnect all loads from the battery

  ◦ click on the "Calculate zero current offset" button

  ◦ new offset value is displayed

  ◦ repeat the operation until the displayed offset value is stable within 5mA

- Configuration / Parameters / SOC:

  ◦ set the "Nominal battery capacity" field to the battery capacity in Ah and click the "Upload to EMS" button

- Configuration / Adjustments:

  ◦ click on the "Reset actual capacity to nominal" button and confirm

  ◦ set the "Set SOC to" field to your estimated battery state of charge, then click on the "Set SOC %" button

  ◦ if your battery is not new, set the "Set cycle count to" field to the estimated number of cycles already done by the battery, then click the "Set cycle count" button

- Configuration / Parameters / Internal resistance:

  ◦ set the "Cell nominal internal resistance" field to the internal resistance value provided by the manufacturer for a single cell

  ◦ set the "Number of cells in parallel" field based on the configuration of your battery then click the "Upload to EMS" button

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Balancing

You may need to adjust the balancing parameters depending on the size, quality, homogeneity and stability of your battery cells.

	Cell balancing indication
(i)	When the EMS is balancing the battery cells, the heartbeat led flashes rapidly (every second)
	If the EMS frequently balances the cells, this is a sign that there could be a problem with the cells initial balance, cell quality or cell connections
	You should investigate the cause for frequent balancing activity

- In the balance parameters you can set the differential cell voltage to start balance:
  - the value can be reduced if:
    - the cells are already balanced
    - <u>AND</u> if balancing activity is not frequent
  - This value needs to be increased if you observe frequent balancing activity

- The EMS balances the cells with a succession of cycles with a rest time between cycles. the duration of each cycle and the rest time are defined in the parameters. At the end of each cycle and after the rest time the EMS re-evaluate the need for further balancing.

Frequent balancing activity:
If you cannot adjust the balancing parameters so that balancing does not happen too often, it might be an indication that:

- There is an important imbalance between cells – in that case you should balance the cells manually by charging them to 100% while all the cells are in parallel (seek professional advice)

- One or more cells have less capacity than the other ones and may need to be replaced

- One or more cells have an internal resistance much higher than the other ones and may need to be replaced

⚠	A cell cannot be balanced if its voltage is less than 2 volt

SOC

When the TAO Shunt is connected, TAO EMS keeps track of the battery State of Charge (SOC)

When the EMS is switched OFF then ON, the SOC is reset to the value stored in the field Configuration / Adjustments / Set SOC to.

	Before switching OFF the EMS, you should record the current SOC value so that it can be reset once the EMS is turned ON again

	The EMS automatically resets the SOC to 100% (full charge) when the "100% SOC" parameters in Configuration / Parameters / SOC are met

- The Configuration / Parameters / SOC / Max current for 100% SOC needs to be adjusted in relation to the capacity of the battery bank. Set it to about 2.5% of the battery capacity (i.e. for a 600 Ah battery set it at 15A).

- The factory defaults for the other two SOC reset parameters (Mini battery voltage for 100% SOC / Mini time for 100% SOC) are for LiFePo4 lithium cells and are conservative. You should not change them unless you know what you are doing.

- Until the SOC has been automatically reset to 100% by the EMS, the SOC value displayed on the Measures / Battery screen should not be trusted.

	100% SOC reset indication
	If the EMS has not yet reset the SOC to 100% since the EMS has been switched ON or if the last reset to 100% is more than 35 days old, then the SOC value displayed on the Measures / Battery screen is framed in a red
	The displayed SOC value is framed in orange if the last 100% SOC reset is more than 28 days old
	The displayed SOC value is framed in yellow if the last 100% SOC reset is more than 21 days old

- After an initial full charge:

  ◦ any subsequent full charge recalibrates the SOC calculation parameters and adjusts the battery efficiency IF the battery has been discharged at least under 80% SOC between full charges

  ◦ the battery efficiency % should not be adjusted manually

> ⚠️ **The SOC value should not be trusted blindly**
>
> Many parameters are involved in the calculation of SOC. Any error in setting those parameters will give inaccurate SOC % reading.
>
> After TAO EMS has been switched ON, the SOC value is unreliable until two full charges and one full discharge have been completed.
>
> This is why triggers should not use SOC for critical events (faults)

If after two full charges and a full discharge the SOC value is far from 100 % when the battery is nearly full:

- check that there is no wire connected directly between the current shunt and the battery

- set the zero current offset (Configuration / Adjustments) making sure that the battery is disconnected from all loads and chargers (general switch open)

> 💡 You should fully charge the battery once a month to recalibrate the SOC measure
>
> See the 8.5.1. Parameters (Charge Cycle Management) feature to do that automatically

Capacity

When the TAO Shunt is connected, and after an initial full charge, the EMS calculates the battery's effective capacity every time the battery is fully discharged. The BMSconfig application displays this value on the Measures / Battery screen, below the SOH value.

	The battery is considered as fully discharged when one cell's voltage is less than the "Cell voltage when empty" parameter (Configuration / Parameters / SOC)

The battery effective capacity is used in the calculation of:

- State of Charge (SOC)
- State of Health (SOH)

	Capacity baseline for 100% SOH When the battery is new you should perform a full charge followed by a full discharge to let the EMS calculate the battery's effective capacity (note: depending on the SOC parameters this calculated capacity may be different from the nominal capacity announced by the battery manufacturer) In Configuration / Parameters / SOC set the "Nominal battery capacity" to the value that has just been calculated. This is the baseline for a new battery corresponding to a 100% state of health (SOH) After this initial setup the "Nominal battery capacity" should not be changed

	You should fully discharge the battery every few months so that the EMS can recalculate the effective capacity and have meaningful SOC and SOH indications

Cycle counting

When the TAO Shunt is connected, the EMS keeps track of the number of charge cycles for the battery.

(i)	Definition of "charge cycle" One charge cycle corresponds to an accumulated charge equal to the battery effective capacity This can happen over a number of charge episodes

Example with a 100 Ah battery:

Activity	Power (Ah)	SOC	Cycles
Initial	-	50 %	4.00
Charge	+ 40 Ah	90 %	4.40
Discharge	- 70 Ah	20 %	4.40
Charge	+ 60 Ah	80 %	5.00

Charge Cycle Management

The TAO EMS has an option to turn ON or OFF the chargers so that the battery is charged only when needed and is cycled for optimum life expectancy.

> A Lithium battery will age rapidly
> if its state of charge is above 70% most of the time

For this feature to work, the EMS must have a reliable estimate of the SOC. It will not be activated if the battery did not have a full charge in the last 30 days.

|	The best way to use a lithium battery and keep it healthy:
ℹ	1. charge it
	2. stop charging when it is full
	3. do not start charging again until the battery is close to empty.
	In addition a lithium battery does not need a full charge (100% SOC) every time

To set it up :

With the BMSconfig application set the following parameters:

- the "Relays to disable charge" – default = relay 2

- the "high SOC" value when to stop charging – default = 80%

- the "low SOC" value when to enable charge again – default = 35%

- the "Time between full charges" – default = 30 days

How it works:

1. for the first charge cycle the EMS lets the chargers do their job until the battery is fully charged, then the EMS disables the chargers

2. the chargers stay disabled until the battery's state of charge goes down to the set "Low SOC" value, then the EMS enables the chargers

3. the chargers stay enabled until the battery's state of charge goes up to the set "High SOC" value, then the EMS disables the chargers… go to step 2…

4. when the number of days since the last full charge reaches the set "Time between full charges" value, the EMS wait until the battery is fully charged before disabling the chargers
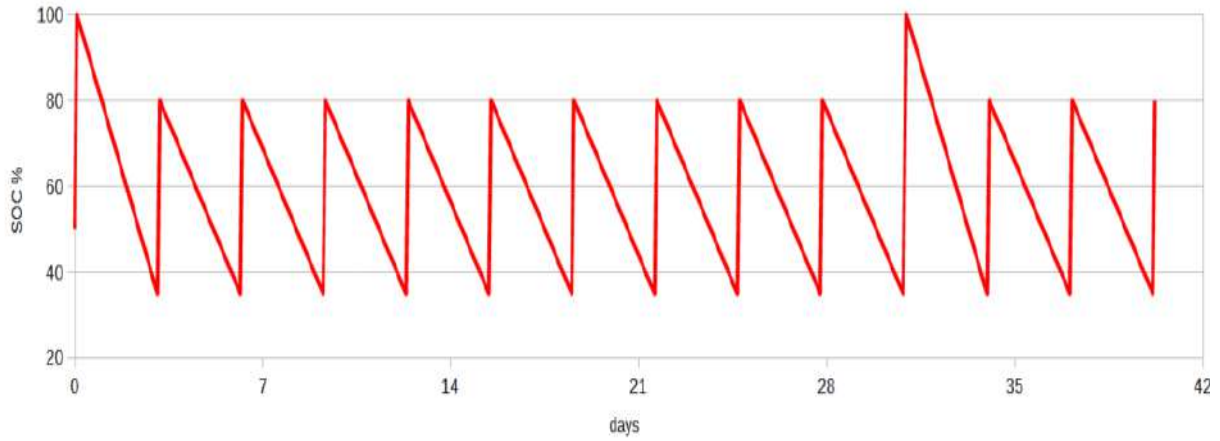
	The chargers can be enabled at any time with a short press of the "Reset" button on the led panel This is useful if you want to re-enable the charge when you anticipate high power requirements or low energy production

|	This feature can be very useful to keep the battery's state of charge around 50% when the installation is unattended for a long time

Pre-charge

TAO EMS has an integrated pre-charge feature. The relay output 1 can be set to charge the inverters input capacitors before closing the load relay.

The pre-charge is done through an external power resistor suited to your installation and for a maximum pre-charge current of 2A.

The pre-charge time can be adjusted to suit your installation.

Detailed explanation on how it works, sample schematics and configuration of the EMS can be found on the TAO Performance website: What is pre-charge and how it works...
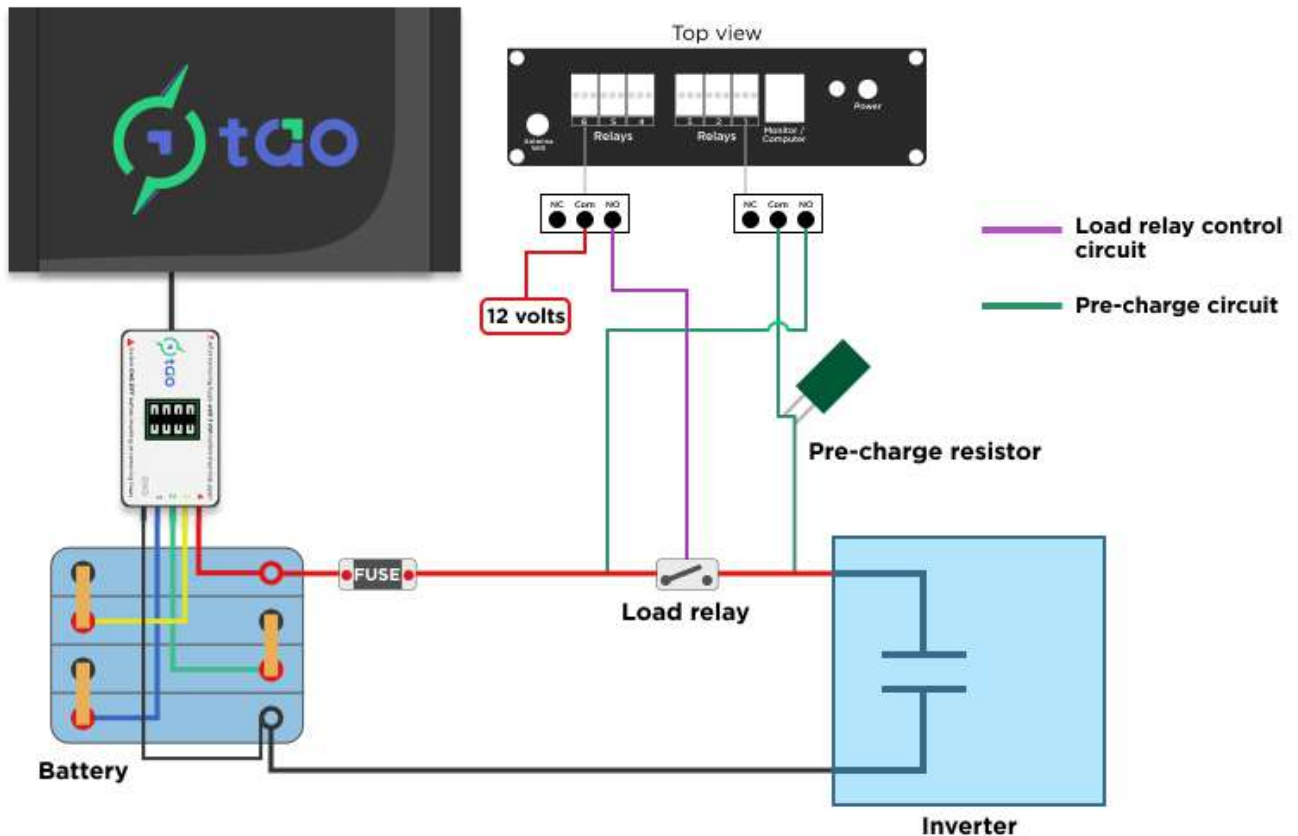
Basic configuration:

1. output 1 and the output for the load relay are both set to be Normally Open (hardware)

2. output 1 and the output for the load relay are both set to be "Activated by default" (Configuration - Parameters - General)

3. output 1 pre-charge delay is set to suit your installation - usually between 5 and 10 seconds (Configuration - Parameters - General)

4. the triggers that activate the load relay must also activate output 1 (Configuration - Triggers)

Internal resistance

When the TAO Shunt is connected, the EMS can measure each cell's internal resistance.

	Importance of a cell internal resistance
(i)	The "internal resistance" is one of the most important parameters to estimate battery ageing and State of Health (SOH)

A lithium cell's internal resistance is a complex notion as it is composed of a number of resistive and capacitive components. Special equipment (injecting current bursts in the battery) is required to measure those different components.

The TAO EMS implements algorithms to estimate each cell's internal resistance. This estimation is slightly different from the nominal internal resistance specified by the manufacturer of the cells.

Internal resistance varies with a cell's State of Charge and is most stable around 50 %SOC

	Cell internal resistance is not calculated if
⚠	battery SOC is less than 35% or more than 70%

To calculate the cells' internal resistance the EMS makes two sets of voltage and current measures when the battery is being discharged:

- 1st measure when the current is low: LESS THAN "maximum current 1st measure"

- 2nd measure when the current is high: MORE THAN "current 1st measure" + "minimum current differential"

- in any case the current must be LESS THAN "maximum current 2nd measure"

The three parameters "maximum current 1st measure", "minimum current differential" and "maximum current 2nd measure" can be adjusted with the BMSconfig application.

	When installing a new battery…
💡	Let the EMS calculate the cells internal resistance over a few discharge cycles
	Set the "Cell nominal internal resistance" to the lowest calculated cell resistance

In normal condition when the battery is regularly cycled between 20 %SOC and 80 %SOC with varying levels of load, the EMS will take every opportunity it gets to measure the internal resistance. But if the above conditions are never met the EMS will not calculate the cells internal resistance.

> (i) If internal resistance is not calculated you can force it
>
> 1. when the SOC value is between 35% and 70%
>
> 2. turn off the loads so that the discharge current is less that "maximum current 1st measure" and cell voltage is stable
>
> 3. turn on some high power loads consuming more than the "minimum current differential" and let the cell voltage stabilise
>
> 4. repeat steps 2 and 3 more than 10 times making sure the SOC remains in the range 35% - 70%

Example with "maximum current 1st measure" = 10 A and "minimum current differential" = 20 A :

- 1st measure: turn off the loads until current drops under 10 A and keep it stable

- 2nd measure: turn on some loads so that current increase by at least 20 A

State of Health (SOH)

When TAO Shunt is connected, the EMS computes a State of Health index that is based on the effective battery capacity and the highest cell internal resistance. The SOH index is expressed as a percentage of the condition of a new battery (as defined by the nominal battery capacity and the nominal cell internal resistance).

SOH = 100% (new battery) when:

- the effective battery capacity is equal to the nominal battery capacity

- <u>AND</u> the highest cell internal resistance is equal or less than the cell nominal internal resistance

SOH = 0% (battery at end of life) when:

- the effective battery capacity is less than half the nominal battery capacity

- <u>OR</u> the highest cell internal resistance is more than four times the cell nominal internal resistance

Between those two extremes, an algorithm estimates the SOH based on effective capacity and cell internal resistance.

7. TROUBLESHOOTING

When an abnormal situation occurs, the first thing to do is to use the Diagnostics / Self-tests option of the BMSconfig application. The EMS runs self-tests every 30 minutes and the last diagnostic data is displayed on that screen. Take a screenshot (Windows Snipping tool or MAC screenshot app) and save it on your computer.

After taking a screenshot, you can click the button to "Run self tests" again and display the new test results.

In addition to the self-tests, the EMS detects any abnormal situation and reports it with a flashing code on the LED panel. When that happens all the LEDs flash 5 times rapidly, then after a short pause one LED flashes from one to eight times - this flashing sequence repeats 10 times. Take note of the flashing LED (H2, H1, L1, L2) and the number of flashes. Look in the following table for its meaning.

In many situations the EMS attempts to recover from an abnormal situation. Press the button on the LED panel to check if the error is cleared. If the error is still present, turn the EMS OFF then ON again. If the error is still present the flashing sequence will be triggered again.

Symptom	Meaning / Possible causes	Suggested actions
Green heartbeat led does not flash when EMS is turned ON	Battery harness not or improperly connected Fuses not inserted or blown Defective led panel / cable Defective EMS unit	Check battery polarity and proper connection of the cables Remove and check each fuse – re-insert the fuses in the correct order Open the EMS and check that the connectors for the battery wire harness are properly inserted Run the diagnostics from the TAO BMSconfig application
LED H2 / 1 flash (0)	Internal error when reading cell voltage	Switch EMS OFF, wait 20 seconds, then ON again
LED H2 / 2 flashes (1)	Internal error when reading cell temperature	Switch EMS OFF, wait 20 seconds, then ON again
LED H2 / 3 flashes (2)	Internal error when reading the current	Switch EMS OFF, wait 20 seconds, then ON again

Symptom	Meaning / Possible causes	Suggested actions
LED H2 / 4 flashes (3)	Cell voltage less than 2V: • discharged battery and large difference in cell capacity • defective cell • defective battery wire harness	Measure cell voltages with multimeter to confirm Check the fuses Open the EMS and check that the connectors for the battery wire harness are properly inserted Switch EMS OFF, wait 20 seconds, then ON again Charge the battery Replace the defective cell
LED H2 / 5 flashes (4)	Cell voltage differential > 2V: • abnormal cell unbalance • defective cell	Measure cell voltages with multimeter to confirm Balance the cells manually Replace the defective cell
LED H1 / 1 flash (8)	Internal error reading the balance secondary voltage	Switch EMS OFF, wait 20 seconds, then ON again
LED H1 / 2 flashes (9)	Balance secondary voltage out of range	Check all cell connections to the battery are tight Switch EMS OFF, wait 20 seconds, then ON again Check that the "TOS" switch and jumpers inside the EMS are properly positioned for the battery configuration (voir section xxx)
LED H1 / 3 flashes (10)	Internal CRC error reading data from the balancer	Press "Reset" Switch EMS OFF, wait 20 seconds, then ON again
LED H1 / 4 flashes (11)	The balancer did not register a balance command	Press on the LED panel Switch EMS OFF, wait 20 seconds, then ON again

Symptom	Meaning / Possible causes	Suggested actions
LED L1 / 1 flash (16)	Cell voltage out of range (1.0 V to 4.5 V): • blown fuse • disconnected or loose cell wire • defective cell	Measure cell voltages with multimeter to confirm Check the fuses Check all cell connections to the battery are in place and tight Switch EMS OFF, wait 20 seconds, then ON again Open the EMS and check that the connectors for the battery wire harness are properly inserted Replace defective cell
LED L1 / 2 flashes (17)	Cell temperature out of range (-20°C to 100°C): • defective battery wire harness • defective thermistor	Check all cell connections to the battery are in place and tight Open the EMS and check that the connectors for the battery wire harness are properly inserted Switch EMS OFF, wait 20 seconds, then ON again
LED L1 / 3 flashes (18)	Current measure out of range: • poor shunt connection • defective shunt	Check the shunt cable is not damaged and is properly connected to the shunt Check shunt connector is not damaged Open the EMS and check that the shunt cable is properly inserted Switch EMS OFF, wait 20 seconds, then ON again
LED L2 / 1 flash (24)	Self-test: multiplexer error	Switch EMS OFF, wait 20 seconds, then ON again
LED L2 / 2 flashes (25)	Self-test: cell ADC conversion error	Switch EMS OFF, wait 20 seconds, then ON again
LED L2 / 3 flashes (26)	Self-test: auxiliary ADC conversion error	Switch EMS OFF, wait 20 seconds, then ON again

Symptom	Meaning / Possible causes	Suggested actions
LED L2 / 4 flashes (27)	Self-test: status ADC conversion error	Switch EMS OFF, wait 20 seconds, then ON again
LED L2 / 5 flashes (28)	Self-test: error reading status registers	Switch EMS OFF, wait 20 seconds, then ON again
LED L2 / 6 flashes (29)	Self-test: error reading voltage reference registers	Switch EMS OFF, wait 20 seconds, then ON again
LED L2 / 7 flashes (30)	Self-test: thermistor reference voltage out of range	Switch EMS OFF, wait 20 seconds, then ON again
LED L2 / 8 flashes (31)	Self-test: shunt reference voltage out of range • shunt is not installed properly	Check that the shunt is properly connected If the shunt is not installed, check the EMS parameters "Current shunt connected?" option is set to "No" Switch EMS OFF, wait 20 seconds, then ON again

Contact TAO Performance if the suggested actions do not solve the problem or if the same problem keeps happening.

8.   BMSCONFIG APPLICATION

PC based application to configure the parameters of the *TAO EMS*, to monitor the battery and cells measures, and to run the diagnostics / simulation processes.

The application runs on a personal computer with the Windows or Mac OS operating systems:

- Windows version 10 or above

- Mac OS version 10.15 or above

8.1   Application download and installation

Download:

The application installation file can be downloaded from the "Download" menu option on the TAO Performance web site:

Windows 10 and above: https://tao-perf.com/wp-content/uploads/2023/12/BMSconfig_v109_setup.zip

Mac OS v10.15 and above: https://tao-perf.com/wp-content/uploads/2023/12/BMSconfig_v109.zip

Save the downloaded file on your computer

Windows Installation:

1. Locate the installation file you downloaded from the web site and double-click on it. (the file name should in the format: BMSconfig_vxxx_setup.exe)

   Confirm that you allow this file to make changes to your computer.

2. The following window is displayed:
   Click the "Install" button and wait for the installation to complete

   The application is installed in the
   C:/Program Files(x86)/BMSconfig

3. The following window is displayed Click the "Finish" button and the BMSconfig application is launched

4. A shortcut has been created on your computer's desktop. Double click that shortcut to start the BMSconfig application
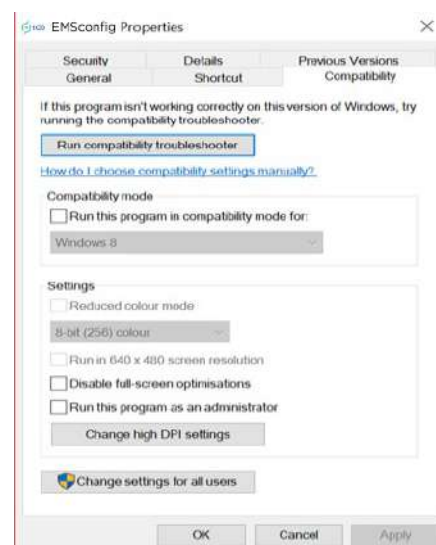
Note 1: with some high-definition screens the resolution may not set itself correctly and the writing on the screen may appear blurred and/or the window is too big for the screen.

To fix that follow the instructions:

1. From the desktop, right click on the BMSconfig shortcut and select the "*properties*" option
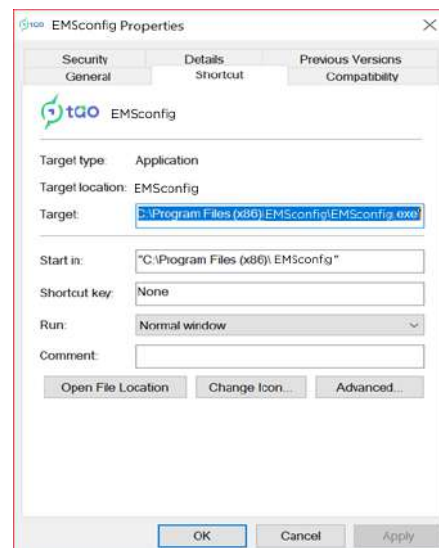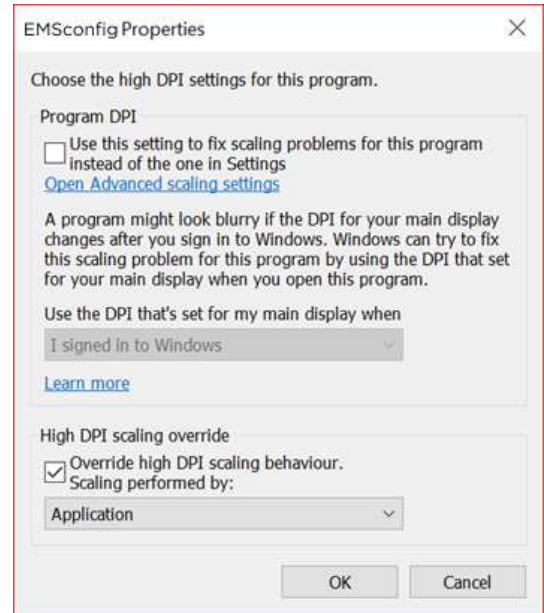
2. Select the "*Compatibility* "tab

3. Click on the "*Change high DPI settings*" button

   Check the box "*Override high DPI scaling behaviour*"

   Set "Scaling performed by:" to "Application"

   Click "*OK*"

Note 2: Most Windows systems have the necessary drivers already installed, but in case the application cannot connect to the EMS you may need to install a new driver.

This is required if the USB connection is not recognised (no bell sound) when connecting the EMS USB cable to computer (first make sure the USB cable is connected to the EMS).

The driver is included in the installation file. It is located in the installation directory: C:/Program Files(x86)/BMSconfig

Double click the application *CH340_driver.exe* and follow the instructions. You should restart your computer after the installation.

If the computer still cannot connect to the EMS, write down all the text in the header and body of any error message that is displayed and contact TAO Performance for support.

The file you have downloaded from the website is in called "BMSconfig_vxxx.dmg" where "vxxx" is the version of the application

1. Double click on the downloaded file to open the installation file: a window opens with the BMSconfig application

2. Drag the BMSconfig application from that window into the "/Applications" folder (you may need an administrator password)

3. Wait for the copy process to finish then eject the DMG (by clicking the eject button in the Sidebar)

Note: The BMSconfig application is not yet "notarized" and will show it is from an unidentified developer

Depending on your system setup you may have an error message when installing or launching the BMSconfig application. If that is the case follow this procedure:

1. Go to "System Preferences > Security & Privacy" and open the "General" tab

2. The BMSconfig will be listed at the bottom of that screen

3. Click "Open Anyway" to confirm your intent to open or install the app

4. The warning prompt reappears, and you can click "Open"

5. The app is saved as an exception to your security settings, and you can open it in the future by double-clicking it

8.2 Launch the application

Connect the computer to the TAO EMS using the supplied cable with a RJ11 plug on one end and a standard USB type A plug on the other end (the RJ11 plug goes in the top connector on the TAO EMS enclosure).

Launch the BMSconfig application with a double-click on the desktop shortcut.

The application scans the USB ports on your computer to locate the TAO EMS and connect to it.   If successful the dot next to the TAO Performance logo turns green and the "Measures / Battery" screen is displayed.
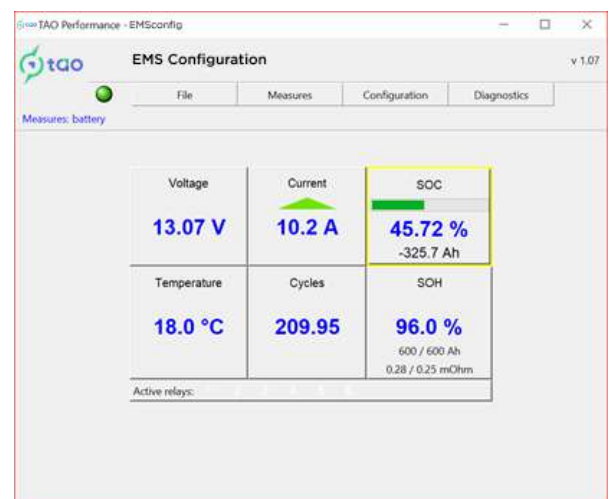
If the application cannot connect automatically to the EMS, a warning message is displayed.
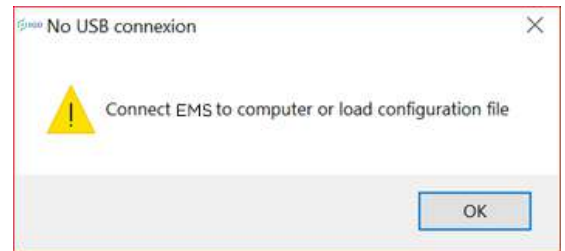
After clicking the "OK" button the "File / Connect to EMS" screen is displayed so that you can either:

- manually select the USB port on which the EMS is connected

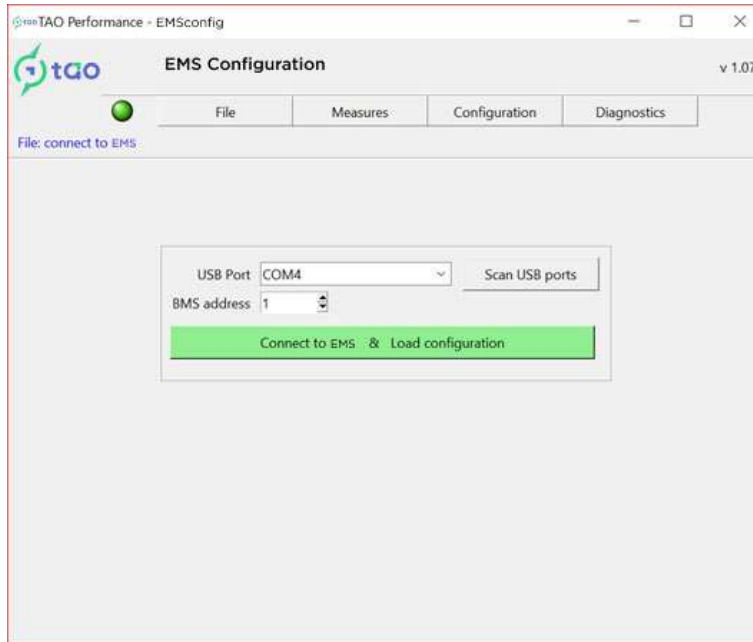- or work off line to create or edit a EMS configuration file

The red dot next to the TAO Performance logo indicates that the application is not connected to the TAO EMS.
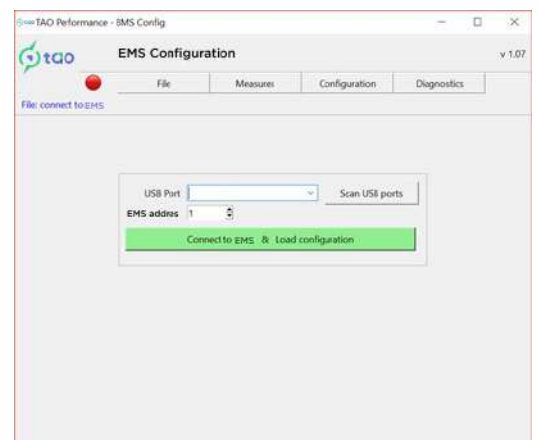
8.3   File menu

Connect to EMS

Select this menu option to access the EMS connection screen.

USB Port: from the drop down list, select the USB port where you connected the TAO EMS if the USB port is not listed, make sure the cable is properly plugged in the EMS and the computer then click the "Scan USB ports" button

EMS address: this should be left to "1" unless you received specific instructions from TAO Performance

Click the "Connect to EMS & load configuration" button to connect. If connection is successful the dot next to the logo turns green and the "Measures / Battery" screen is displayed.

> ### CONNECTION STATUS
>
> The coloured dot next to the TAO Performance logo indicates the TAO EMS connection status:
>
> - Green = connected
> - Red = not connected

> ### If the application cannot connect to the EMS
>
> - make sure the EMS is switched ON
>
> - check the connections, click the "Scan USB ports" button and retry
>
> - you may need to install a driver (see Note 2 in the Installation instructions)

Load configuration file

Select this menu option to load a TAO EMS configuration file (parameters and triggers) you have previously saved.

A file explorer window is opened where you can select the configuration file to load then click the "Open" button.

You then use the "Parameters" menu options to modify that configuration (parameters and triggers).

if the EMS is connected you can upload that configuration file to the EMS (upload the parameters and the triggers independently by accessing the corresponding menu option).

> If you want to reload the configuration file saved in the EMS
> you need to connect again to the EMS

Save configuration file

Select this menu option to save the EMS configuration file (parameters and triggers) currently active in the application (either from the EMS or a configuration file you have previously loaded).

A file explorer window is opened where you can enter the location and name of the configuration file to be saved, then click the "Save" button.
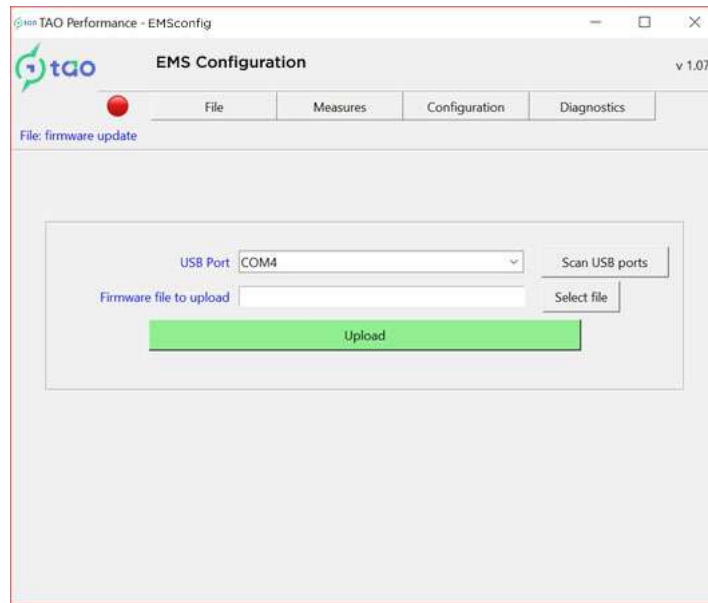
> It is a good idea to save the EMS configuration file after a modification
>
> If you request support from TAO Performance
> we will ask you to email that file to us

Firmware update

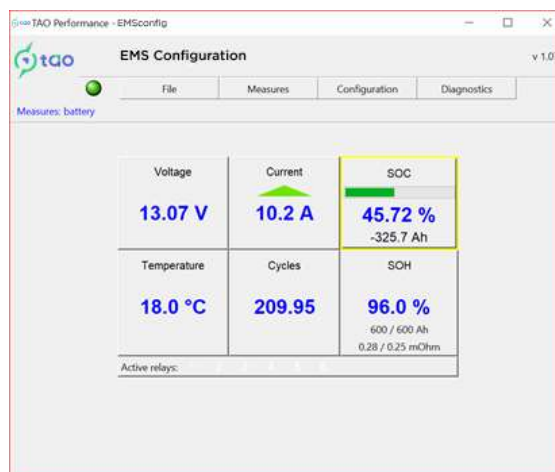Select this menu option to update the TAO EMS firmware.

Before selecting that option, you need to download the latest firmware version from the TAO Performance web site:

https://tao-perf.com/wp-content/uploads/2023/11/TaoEMS_v136.zip

8.4   Measures menu

Battery

Select this menu option to visualise the live measures from the battery:

> If the TAO Shunt is not installed and enabled in the parameters
> only the battery voltage and temperature are displayed
> Current, Cycles, SOC and SOH are blank

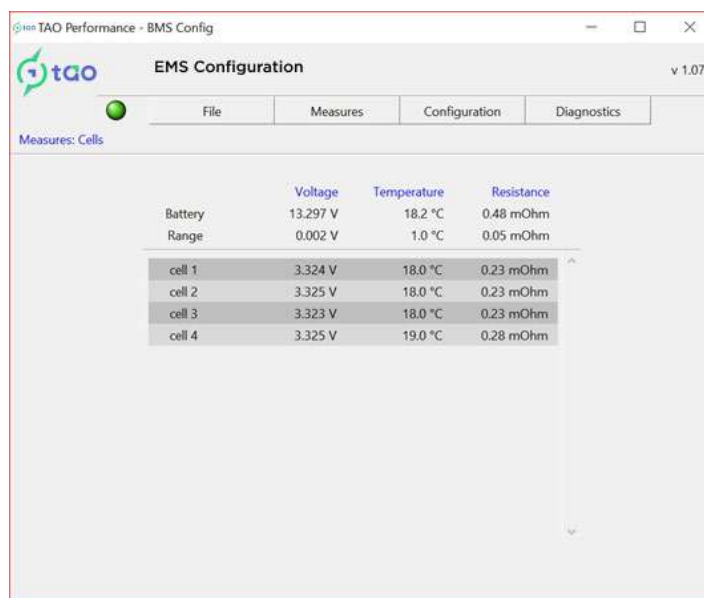Battery voltage and average cell temperature are displayed.

If the TAO Shunt is connected, this screen also displays:

- the current in or out of the battery (red down-arrow when discharging / green up-arrow when charging)

- the battery State of Charge (SOC) and the total energy drawn from the battery in Ah

- the number of full charge cycles

- the battery State of Health index (SOH) with under it:

  ◦ battery effective capacity / nominal capacity (Ah)

  ◦ highest cell internal resistance / nominal cell internal resistance (mOhm)

The bottom line indicates the relay outputs that are active

Cells

Select this menu option to visualise the live measures from individual cells:

Battery: total battery voltage, average cell temperatures are displayed. If TAO Shunt is connected total battery internal resistance is also displayed.

Range: difference between the highest and the lowest cell measures

Cell: for each cell the voltage and temperature are displayed. If TAO Shunt is connected each cell internal resistance is also displayed.
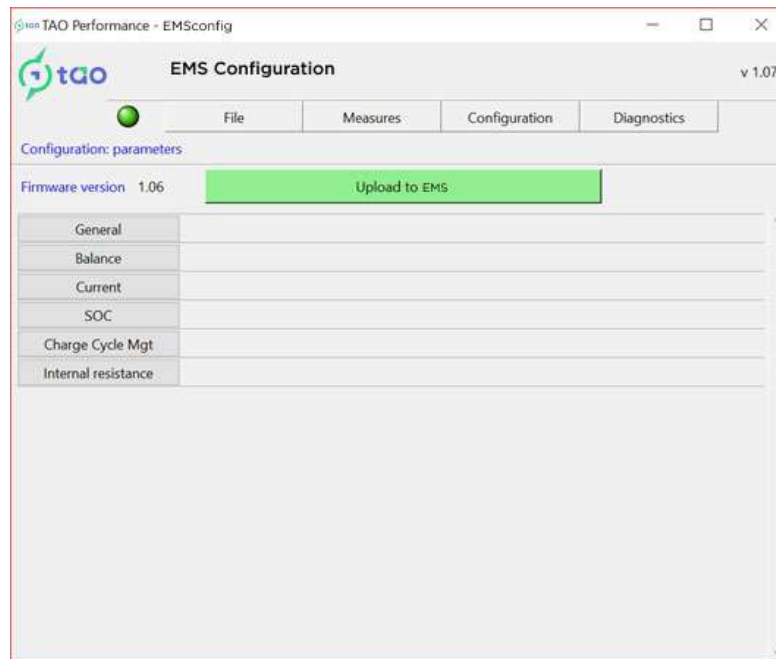
> **CELL BALANCING**
>
> If cells are being balanced there is a ▲ sign next to the cell being charged and a ▼ sign next to the cell being discharged.

8.5   Configuration menu

Parameters

Select this menu option to visualise and edit the configuration data loaded in the application (either form the EMS or from a file):

The EMS firmware version is displayed. You will need that information for any support request

There are multiple tabs that can be opened and closed by clicking on the corresponding button. At any time click the "Upload to EMS" button to update the EMS with the parameters from all the tabs (it will overwrite the parameters currently stored in the EMS).

At any time you can save the parameters in a file with the "File / Save configuration file" menu option

"General" tab
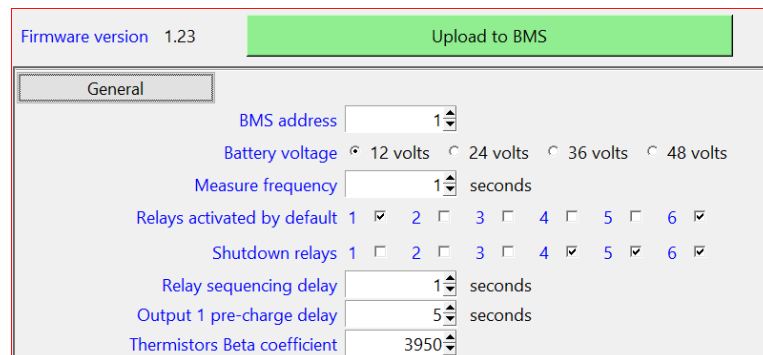
EMS address: this is the Modbus address of the EMS. Should be left to "1" unless you have more than one TAO EMS in your installation (default = 1)

> ### ⚠ DO NOT CHANGE THE EMS ADDRESS
>
> Changing the EMS address may make it difficult or impossible to reconnect to EMS if you do not remember which address you have set

Battery voltage: keep this setting on 12 volts unless you have connected one or more EMS extensions (default = 12 volt)

- for more details see the EMS extension manual
- changing this setting without the appropriate number of EMS extensions connected may damage the EMS and the balancing circuits

Measure frequency: this is the time delay between two consecutive voltage / temperature measures (default = 1 second)

- should be left to one second unless instructed otherwise by the TAO Performance support team

Relays activated by default: check the relay outputs that you want to be activated as soon as the EMS is switched ON and that will be de-activated in case of a fault detected by a trigger linked to that relay output (see the 5.3. Relay outputs for more details

Shutdown Relays: check the relay outputs to be activated when the "Shutdown" button on the led panel is pressed for more than 2 seconds (default = 4, 5, 6)

Relay sequencing delay: delay between relay output activation when a trigger event or the "Shutdown" button activate more than one relay (default = 1 second)

- example: if relay outputs 1, 3, 5 are activated by a trigger event, relay 1 is activated first, then one second later relay 3 is activated, then 1 second later relay 5 is activated
- this can be used to connect a secondary battery to a critical equipment before the "load disconnect" relay is activated
- it can also be useful when disconnecting the chargers by first connecting a secondary battery to the chargers before disconnecting them from the lithium battery

Output 1 pre-charge delay: if the integrated pre-charge feature is used, set this field to the number of seconds required for the pre-charge (default = 0 to disable pre-charge feature)

Thermistor Beta coefficient: should be left on default value unless instructed otherwise by the TAO Performance support team (default = 3950)

"Balance" tab

Balance		
Enable balancing?	⊙ Yes ○ No	
Compensate for internal resistance?	○ Yes ⊙ No	
Mini cell voltage to enable balance	3.400 ⬍	V
Differential cell voltage to start balance	30 ⬍	milliVolts
Duration of balance cycle	300 ⬍	seconds
Delay between balance cycles	30 ⬍	seconds

Enable balancing: whether or not the EMS does automatic cell balancing (default = Yes)

- Yes = the balancing function is active based on the balancing parameters

- No = balancing is deactivated

Compensate for internal resistance: setting this parameter to "Yes" makes the EMS estimate each cell's open circuit voltage based on the cell internal resistance and use that estimated voltage for balancing decision. Should be set to "Yes" if the range of cell internal resistances is wide (default = No)

Mini cell voltage to enable balance: at least one cell voltage must be above this value to enable balancing function (default = 3.400 V)

Differential cell voltage to start balance: the voltage difference between the cell with the highest voltage and the cell with the lowest voltage in order to trigger balancing (default = 30 mV).

- the cell with the highest voltage is discharged and the cell with the lowest voltage is charged

- setting this value below 10mV may create instability with low capacity batteries

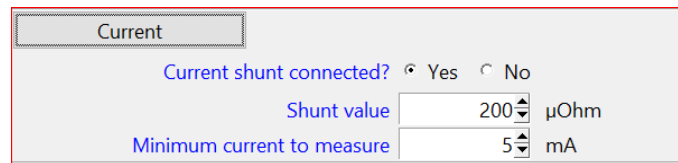Duration of balance cycle: when balancing is triggered, it runs for that time (default = 300 seconds)
the duration of the balancing cycle must be set in relation to the battery capacity and the differential voltage to start balance – to help you set this parameter you can use the "Cells" screen to visualise the impact of balancing on the cells voltage (you do not want the cell voltage to be drifting by more than a few millivolts during one balance cycle:

- reduce duration for low capacity battery

- increase duration for high capacity battery

- reduce duration for lower "differential cell voltage to start balance"

- increase duration for higher "differential cell voltage to start balance"

Delay between balance cycles: time for the battery to rest after a balance cycle ends and before testing the voltage again to decide if more balancing is needed (default = 30 seconds)

- while balancing is in action the cell voltage is slightly impacted - some time is needed for the cell voltage to stabilise after the balancing stops

- this is important only for low capacity batteries

"Current" tab

Current shunt connected: set to "Yes" if you have purchased and connected the TAO Shunt - when set to "Yes", the EMS measures the current and calculates SOC, cell internal resistance, SOH and number of charge cycles (default = No)

Shunt value: this is the resistance of the current shunt in micro-ohms – should not be changed unless instructed by TAO Performance support (default = 200 QOhm)

Minimum current to measure: any current measure below that value is interpreted as a zero current (charge and discharge) – setting this value too high leads to inaccurate SOC (default = 5 mA)

"SOC" tab

Nominal battery capacity: the total capacity of your battery when it was new (in Ah)

Battery efficiency: this is the ratio between the energy the battery is able to provide and the energy charged into the battery (default = 99.000)

- initially set this parameter to the value specified by the manufacturer of your battery

- then the EMS recalculates and adjusts this parameter after each full charge cycle (SOC reset to 100 %)

- if the battery efficiency value entered here is not close to the actual battery efficiency, then the SOC will be inaccurate

SOC reset mini voltage: this parameters is used by the EMS to identify when the battery is full and SOC can be reset to 100% – the battery voltage as to be equal or greater than this value to be considered as full (default=13.80 V)

SOC reset max current: this parameters is used by the EMS to identify when the battery is full and SOC can be reset to 100 % – the battery charge current as to be equal or less than this value to be considered as full (default = 10 A)

- should be set to no more than 2.5 % of the battery capacity (10 A for a 400 Ah battery)

SOC reset mini time: this parameters is used by the EMS to identify when the battery is full and SOC can be reset to 100 % – above conditions ("SOC reset mini voltage" and "SOC reset max current") have both to be met for at least that duration for the battery to be considered as full (default = 30 seconds)

Cell voltage when empty: when any cell's voltage is equal or less than this value, the EMS considers that the battery is empty (default = 2.850 mV)

"Charge Cycle Mgt" tab

Enable charge cycle management: set this to "Yes" to enable the charge cycle management function (default = No)

Relays to disable charge: check the relay outputs that need to be activated to disable the chargers

High SOC: unless a full charge is required, then the chargers will be disabled once the SOC reaches that value

Low SOC: once the SOC reaches or is below that value the chargers will be enabled again

Time between full charges: if a full charge has not been done for at least this number of days, then the charge management function is disabled until the battery has a full charge (default = 30 days)

Please refer to 6.3.6.Charge Cycle Management for more details on the charge cycle management function

"INTERNAL RESISTANCE" tab

Internal resistance		
Cell nominal internal resistance	0.25	mOhm
Number of cells in parallel	1	
Maximum current 1st measure	10	A
Maximum current 2nd measure	80	A
Minimum current differential	20	A

Cell nominal internal resistance: this is the internal resistance of a single cell as specified by the manufacturer of your lithium cells

Number of cells in parallel: in case each of your battery cells is actually made of multiple sub-cells in parallel, this is the number of these sub-cells in parallel – for example if a 12 V / 400 Ah battery is assembled with 8 x 200 Ah cells, the cells (sub-cells) are first connected two by two in parallel to make four groups of 400 Ah cells, then the four groups of sub-cells are connected in series to make a 12 volt battery.

Refer to section 7.3 – EMS setting: Internal resistance for information on the other parameters

> *Triggers*

Select this menu option to list the 20 triggers loaded in the application (either form the EMS or from a file):

Click the "Upload to EMS" button to send all the trigger definitions to the EMS (it overwrites the trigger definition currently stored in the EMS)

Please refer to 2.3. Principle of TAO EMS for an explanation of the "trigger" feature

To edit one trigger, click on the corresponding "Edit" button.

Active : if not active the trigger will be ignored and will not generate events

Unit : the cell measure that is used to define the event generation criteria – can be voltage, temperature (or SOC if the TAO Shunt is used)

Type : defines the logic to generate an event:

- High = a measure for one cell (or SOC) is equal or more than the 'ON value" field

- Low = a measure for one cell (or SOC) is equal or less than the "ON value" field

- Diff = the difference between any two cells' measures is equal or more than the "ON value" field (not applicable for SOC unit)

ON value: refer to the "Type" explanation – can be either in millivolt, °C or % based on the selected unit

OFF value: the value to clear the event after it has been generated – should be slightly different from the "ON value" to create an hysteresis and avoid instability – set this value depending on the trigger type:

- High = must be less that the "ON value"

- Low = must be more that the "ON value"

- Diff = must be less than the "ON value"

Led: the led that will be activated when the event is generated – for each led select the desired state when the trigger generates an event (off / on / blink)

Relays: the relay outputs that are activated when the event is generated – from zero to six relays can be selected

Relay activation delay: the time delay between the generation of an event by the trigger and the activation of the selected relay outputs – when more than one relay is associated with a trigger:

- the selected relay outputs are activated in sequence from 1 to 6

- the "Relay sequencing delay" set on the "Parameters / General" screen defines the time interval between each relay activation

Adjustments

Select this menu option to make some adjustments to data stored in the EMS
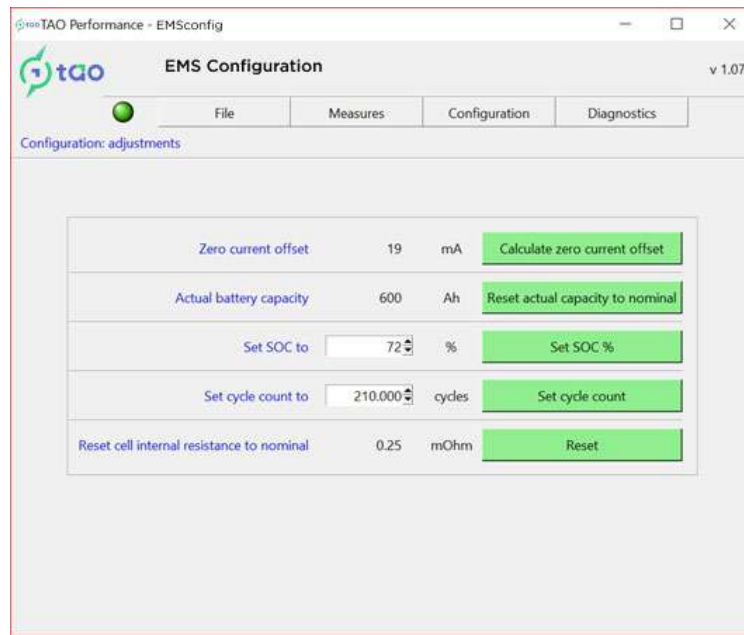
Set zero current offset:

This is a way to compensate for very small currents that may be induced by electromagnetic interferences and/or systematic current measure errors:

- make sure all loads are disconnected from the battery and wait a minute or two (switching off all equipment may not be sufficient as some equipment even if turned off may consume a small current)

- click the "Calculate zero current offset" button and wait for the process to complete

- the "Zero current offset" value takes into account the EMS power consumption

- run this option a few times to be sure the calculated value is stable within 10 mA

Actual battery capacity:

The actual (or effective) battery capacity is calculated by the EMS. This option will set the actual battery capacity to the value entered as "Nominal battery capacity" in the "Parameters" section

Set SOC to:

This option lets you set the SOC value to any value between 0% and 100%. This can be useful after the EMS has been connected to the battery or after a EMS reset.

> In order to achieve an accurate SOC value
> You should fully charge the battery after using this option

Set cycle count to:

if you install the EMS on a used battery, this parameter gives you the ability to set the starting point for cycle counting to be equal to your estimation of the battery full charge cycle count (a full charge cycle corresponds to an accumulated charge equal to the battery capacity – i.e. 400Ah of charge for a 400Ah battery)

- enter the desired "Number of charge cycles"
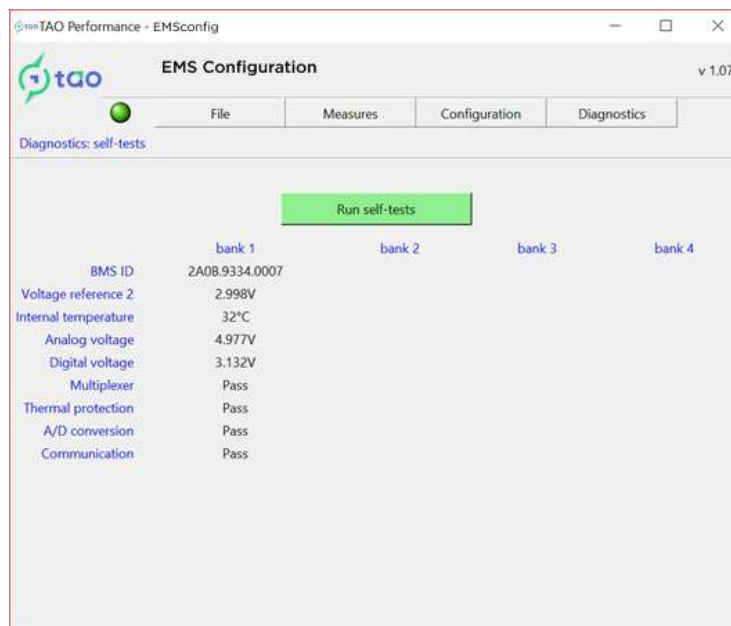- click the "Set cycle count" button

Reset cell internal resistance to nominal:

This option clears the calculated values for the cells internal resistance, and replaces it by the nominal cell resistance entered in the "Parameters" section

8.6   Diagnostics

Self-tests

Select this menu option to visualise the results from the last self-tests performed by the EMS.

Click on the "Run self-tests" button to initiate a new self-tests procedure and display the new results

> If a self-tests error has been indicated on the led panel
>
> make sure to print this screen before running a new self-tests procedure

EMS ID: a unique serial number for each TAO EMS – this is a required information to get support from TAO Performance

Simulation

Select this menu option to simulate individual cell voltage and temperature or to perform manual cell balancing.

This option is used to:

- validate the setting of the triggers

- validate the relay output configuration and connections

- validate the proper operation of external relays and other equipment connected to the relay outputs

- check that balancing operation works properly

> **RUN SIMULATIONS AT REGULAR INTERVALS**
>
> To be sure all your protective measures are operational
> you should run a number of simulations to activate each trigger individually
> and confirm the outcome is what you expect

For each cell, the left column indicates the actual cell voltage or temperature.

In the right column each cell value can be overwritten individually. By checking the "sync" box all the cell values are made equal to the value for cell 1 (this is practical to avoid activating differential type triggers).

When the desired values as set, click the "Start Simulation" button and validate the outcome is what you expect

Click the "Stop Simulation" button to return to normal operation. If the simulation is not stopped in that way, the EMS will stop it automatically after 3 minutes.

To manually balance certain cells, select a cell to be charges and / or a cell to be discharged and click on the "Execute balance" button. The selected cells are charged / discharged for the duration set for "Duration of balance cycle" in "Parameters", then it will stop.

By clicking on the "Execute balance" button while both cell selection fields are set to "0" will stop any balancing activity in progress.

9. TRIGGERS WORKSHEET TEMPLATE

The template can be downloaded from the TAO Performance website:

blank template (PDF): https://tao-perf.com/wp-content/uploads/2023/11/triggers_worksheet_blank-1.pdf

factory defaults (PDF): https://tao-perf.com/wp-content/uploads/2023/11/triggers_worksheet_default_v201-1.pdf

Excel spreadsheet (XLS): https://tao-perf.com/wp-content/uploads/2023/12/TAO_CAN_factory-default_v1.00.zip