

ESS Design & installation manual

1. ESS Introduction & features

What is ESS?

ESS (Energy Storage System) is a way of configuring your grid-tie installation to *usually* behave as though it were an off-grid installation ...thereby enjoying the best of both worlds. When it is able to produce more power than it can use and store, it sells the surplus to the grid; and when it has insufficient stored power, it buys electricity from the grid. This is available from using a combination of standard multipurpose Victron products, setup with an ESS configuration. In the system, there must at least be one inverter/charger and also a Venus-device:

- [Color Control GX](#)
- [Venus GX](#)

Other components can be added when needed, see chapter 2.

When is it appropriate to use ESS?

Use ESS in a self-consumption system; a backup system with solar, or a mixture of both: For example you can use 30% of the battery capacity for self-consumption, and keep the other 70% available as a backup in the event of utility grid failure.

Optimizing self-consumption:

When there is more PV power than is required to run loads, the excess PV energy is stored in the battery. That stored energy is then used to power the loads at times when there is a shortage of PV power.

The percentage of battery capacity used for self-consumption is configurable. When utility grid failure is extremely rare it could be set to 100%. In locations where grid failure is common - or even a daily occurrence - you might choose to use just 20% of battery capacity and save 80% for the next grid failure. African countries for example.

Keep batteries 100% charged:

ESS can also be configured to keep the batteries fully charged. Utility grid failure is then the only time battery power is used - as a backup. Once the grid is restored, the batteries will be recharged either from the grid or from solar panels - when available.

ESS in a system with a generator

Configuring ESS in a system which uses a diesel generator as backup - for extended mains failures - can be achieved. Grid code and Loss of Mains configuration will need special attention, see [here](#).

And on the Venus-device, select 'Generator' as the AC Input type in the Settings → System setup menu. The system will then enable generator charging; ensure that the generator is properly loaded, and will be automatically switched-off as soon as parameters are met.

When not to use ESS

- Off-grid systems - either with or without generator.
- Marine systems.
- Automotive systems.
- Inverter priority, also known as 'Intentional islanding' or 'Ignore AC' input systems.

With and without grid-meter

ESS can be used both with an external grid-meter, or without one.

With grid-meter, a full or partial grid-parallel system.

Without grid-meter: All loads connected to AC-out. And in case of PV Inverters, also connected to AC out.

Optional feed-in of MPPT Solar charger power

Power from an MPPT can be fed back to the grid. Enabled/disabled by a user setting on the CCGX: Settings → ESS.

Fronius Zero feed-in option

By using the Power Reduction feature in Fronius grid-tie inverters, the ESS system can automatically reduce the output of the installed PV Inverters as soon as feed-back is detected; without switching and frequency shifting.

It is not possible to combine ESS with the Fronius Smart Meter; it is not necessary either, since ESS already has metering.

With ESS, it is not possible to disable feed-in a system with other brands of grid-tie inverters. See Chapter 2.1.2 for more information.

ESS Training

- [ESS Webinar 2016-12-19 Youtube \(EN\)](#)
- [ESS Webinar 2016-12-19 Youtube \(DE\)](#)
- [ESS Webinar 2016-12-19 Youtube \(ES\)](#)
- ESS Webinar 2016-12-19 PPT

Advanced control options

See [ESS mode 2 and 3](#).

1.1 Examples

- Residential scale Energy Storage System: MPPT Solar Charger
- Retrofitting on an existing Grid-tie inverter installation
- System with backup genset (using auto genset start/stop from CCGX)

Backup system with Solar

All loads are wired on the output of the inverter/charger. The ESS mode is configured to 'Keep batteries charged'.

When using a grid-tie inverter, it is connected to the output as well.

While the mains is available, the battery will be charged with power from both the mains and PV. When available, loads are powered from PV.

Feed-in is optional, and can be enabled or disabled depending on local regulations.

1.2 Components

Inverter/charger

The Energy Storage system, uses a [Multi or Quattro bidirectional inverter/charger](#) as its main component.

Venus-device

The system is managed by the [Color Control GX \(CCGX\)](#), which also provides extensive monitoring, both locally and remotely via our [VRM Portal](#) and the [VRM App](#).

Battery

[Victron Lithium batteries](#)

- <https://www.victronenergy.com/batteries/lithium-battery-12-8v>
- <https://www.victronenergy.com/batteries/lithium-battery-24v-180ah>

[Lithium and other advanced battery technology batteries from other manufacturers](#)

https://www.victronenergy.com/live/battery_compatibility:start

Lead batteries: OPzS and OPzV

Make sure to take the relatively high internal resistance into account, while designing a system with OPzS or OPzV batteries.

Lead batteries: AGM / GEL

Note that the use of standard AGM and GEL batteries is not recommended for installations configured to fully cycle the battery every day.

Battery Monitor

In most situations, it is not necessary to install a battery monitor:

- Lithium batteries with canbus connection (BYD B-Box, Pylon, LG Resu and others) already have a built-in battery monitor. Adding an external one too will conflict with the internal one. Always use the canbus connection to provide battery status/state of charge for these batteries.
- Redflow ZBM / ZCell zinc-bromide flow batteries with the ZCell BMS also support the same canbus protocol. This is the preferred integration approach for these batteries.
- For batteries that do not have a built-in battery monitor, the built-in battery monitor in the Multi can be used. Which, in an ESS system, will also take the charge currents by MPPT Solar Chargers into account.

The only situation where an external battery monitor is necessary is for systems that have additional sources of power, for example a DC wind generator, and that have a battery type with no built-in battery monitor. For example lead batteries, or [Victron 12.8V lithium batteries](#).

In case an additional battery monitor is necessary, use one of these:

- [BMV-700](#)
- [Lynx Shunt VE.Can](#)

Detailed information is available in the [CCGX manual chapter 2.4](#).

Grid Meter (optional)

For a full or partial grid-parallel installation, an Energy Meter can be installed in the main distribution panel: between the grid and the installation.

<https://www.victronenergy.com/live/energy-meter>

This meter is *only* needed when there is an additional energy source (e.g. PV) connected in between the grid and the *input* side of the Multi/Quattro systems in the installation. If all renewable energy sources are connected 'downstream' (on the output side) of the inverter/chargers, this additional grid meter is not required.

PV (optional)

ESS can work with both Grid-tie PV inverters and/or MPPT Solar Chargers. A mix of both is also possible.

When using Grid-tie PV Inverters, it is recommended to visualize its power on the CCGX. See [CCGX manual](#) for the options.

ESS can also be operated without PV, typically for virtual power plants, clustering a large number of small storage systems together to be used for energy arbitrage on a utility level.

2. System design

2.1 PV

2.1.1 MPPT Solar Charger and/or Grid-tie inverter

ESS can work with either an MPPT Solar Charger or a grid-tie inverter, and a mix of both.

Generally speaking, a MPPT Solar Charger will be more effective than a grid-tie inverter in a small system.

When the majority of the energy consumption takes place in the morning and the evening, an MPPT Solar Charger will be more efficient: it charges the battery with up to 99% efficiency. Whereas the PV energy coming from a grid-tie inverter is first converted from DC to AC, and then back from AC to DC, causing losses up to 20 or 30%.

When the majority of the energy consumption takes place during the day, the best example is an office with air-conditioning, a grid-tie inverter will be more efficient. After (very efficient) conversion to AC, the PV energy is used directly by the air-condition.

No feed-in?

Consider using an MPPT Solar Charger, or otherwise a Fronius PV Inverter and then use the Zero feed-in function. This will lead to a much more stable system.

2.1.2 Feed-in or no feed-in

The rules around feed-in differ all around the world:

1. Energy can be sold or otherwise reduces the electricity bill by running in reverse.
2. Feed-in is no problem, but not wanted either: all energy being fed back is lost, in a sense that it is not being paid for by the utility. But it doesn't hurt either.
3. Feed-in is absolutely not wanted, not even for a few seconds: to illustrate, there are certain prepaid meters in South-Africa that will disconnect the customer when it detects energy being fed back into the grid.
4. Feed-in causes extra charges, as the utility meter will count only one way, which is up: every kWh being fed back is counted as energy being used. In other words, feeding back increases the end-customer's energy bill instead of decreasing it.

Feed-in

Feed-in of PV connected via an MPPT Solar Charger can be enabled and disabled in the Energy Storage Systems menu in the CCGX. Note that when disabled, the PV power will still be used to power AC loads.

Feed-in of PV connected to grid-tie inverters will occur automatically. There are no settings or special design considerations that relate to feed-in. Both when connected on the input and/or on the output of the inverter/charger.

No feed-in

For Victron MPPT Solar Chargers, grid feed-in can be enabled and disabled in the ESS settings menu on the CCGX.

For grid-tie inverters, the only option is to use a Fronius grid-tie inverter and use the Fronius Zero Feed-in function. See chapter 2.1.3.

Using other brands of grid-tie inverters in a no-feed-in system is not recommended. With ESS it is not possible at all to prevent feed-in for this case. And the alternative, using the Hub-2 Assistant, leads to a sub optimal installation as well. Often complaints about flickering lights and even risks of the whole system shutting down in overload when a large load is switched on or off.

2.1.3 Fronius Zero Feed-in

For Fronius grid-tie inverters, ESS has a special feature: zero feed-in.

With the Zero feed-in option enabled, the ESS system will continuously monitor and actively control the output power of the Fronius grid-tie inverter. See chapter 4.3.11 for detailed requirements and settings.

2.1.4 MPPT Solar Chargers

All Victron MPPT solar chargers can be used: both the models with a VE.Direct comm. port as well as the models with a VE.Can comm. port.

2.1.5 Grid-tie inverter in parallel or on AC out?

There are two options when connecting the grid-tie inverter:

- in parallel with the Multi or Quattro.
- on the AC out.

When connected on the AC out, the [factor 1.0 rule](#) needs to be adhered to. There are no exceptions to this. So, also use the factor 1.0 rule in countries where the utility grid rarely fails. And also use it when connecting a Fronius grid-tie inverter on the AC out, and using zero feed-in.

2.2 Battery size

In a grid-parallel system, the battery size is dictated

- Small batteries will be more cost effective: all available storage capacity is used every day
- Small batteries will be charged and discharged with high currents: especially with lead batteries this will reduce battery life time
- Larger batteries, combined with a relatively large PV installation, can store excess power during good days, which can then be used during several consecutive days of bad weather
- Larger batteries provide longer autonomy during a power outage, requires using the UPS output

In a backup system, the battery size is calculated by the required autonomy during a mains failure.

See [AC-Coupling minimum battery capacity](#) for minimum battery sizes of systems with a grid-tie PV Inverter connected on the AC output of the Multi(s) or Quattro(s).

2.3 Inverter/charger size

The required size of the inverter/charger depends on the type of installation.

In a grid-parallel installation, the size of the inverter/charger can be (much) smaller than the highest expected nominal and peak loads. For example, to cover the base load of a two person household, an 800VA inverter/charger might already be sufficient. For a household with one family, a 3000VA inverter/charger can already manage nearly all appliances, when not more than one of them is running at the same time. This means that it can already reduce the power consumption during late spring, summer days and early autumn with sufficient storage to (nearly) zero.

In a backup installation, the inverter/charger needs to be sized according to the loads.

2.4 Anti-islanding

ESS always requires anti-islanding. Also in a no-feed-in-system.

For several countries the built-in anti-islanding in our products can be used. For example the MultiGrid in Germany, and the MultiPlus in the United Kingdom. See certificates on our website for details.

In case there is no certified product available for the country of installation, install external anti-islanding.

More details here: [VEConfigure: grid codes & loss of mains detection](#).

3. Installation

Follow the manuals of each component for its installation.

When installing a single phase ESS in a system with a three-phase connection to the utility grid, make sure to install the ESS on phase one, L1.

Temperature-compensated charging

Multi, MultiPlus, MultiGrid or Quattro

Connect the temperature sensor as supplied with the device. Installations with multiple units in parallel, and/or dual- or three-phase configurations: the temperature sense wire can be connected to any unit in the system. For more information, see the [Parallel, split- and three-phase VE.Bus systems](#).

The Multi itself will -of course- use the measured battery temperature for temperature-compensated charging. Also when charging with power coming from a grid-tie PV Inverter. Both when connected to mains, and, in case of a mains failure, with solar power coming from a grid-tie PV Inverter connected to the output.

Solar chargers

Solar chargers will automatically use the information from the Multi or Quattro to do temperature-compensated charging as well. Both VE.Direct Solar chargers and VE.Can Solar chargers.

Voltage sense wiring

Multi, MultiPlus, Multi Grid and Quattros: wire the voltage sense according to the manuals

VE.Direct solar chargers: there is no voltage sense option: no voltage sense is being used.

VE.Can solar chargers: install a voltage sense wire on one of the solar chargers in each sync group.

4. Configuration

4.1 Update to latest firmware

Update all components to the latest firmware version:

1. Venus-OS v2.00 or newer. Instructions to upgrade to v2.00 [here](#).
2. Multi, MultiGrid, MultiPlus or Quattro to 408 or newer. Instructions [here](#).
3. Solar Chargers, either VE.Can or VE.Direct, to their latest firmware version.

For firmware files and instructions, see the Firmware section in [Victron Professional](#)

4.2 Multi/Quattro and ESS Assistant

Settings to be made in VEConfigure:

1. Configure the country code on the grid tab. A password is required, ask your supplier. **Note:** If you leave this setting as 'None', the system will not discharge battery energy to support local AC loads when the grid is connected. You *do* need to change this setting even if your intention is *not* to export DC energy to the grid.

2. Add the ESS Assistant. Instructions on how to add an Assistant [here](#).
3. In case there is no BMV or intelligent canbus connected battery in the system: Enable the built-in battery monitor on the General tab, and configure the battery capacity.
4. Configure the battery type and charge parameters on the Charge tab. Note that, in ESS, the MPPT Solar Chargers will follow the charge curve as set in VEConfigure. The charge parameters configured in the MPPT Solar Chargers themselves are ignored in an ESS setup.
5. Configure all the other settings.

Notes with regards to the Input current limit and PowerAssist:

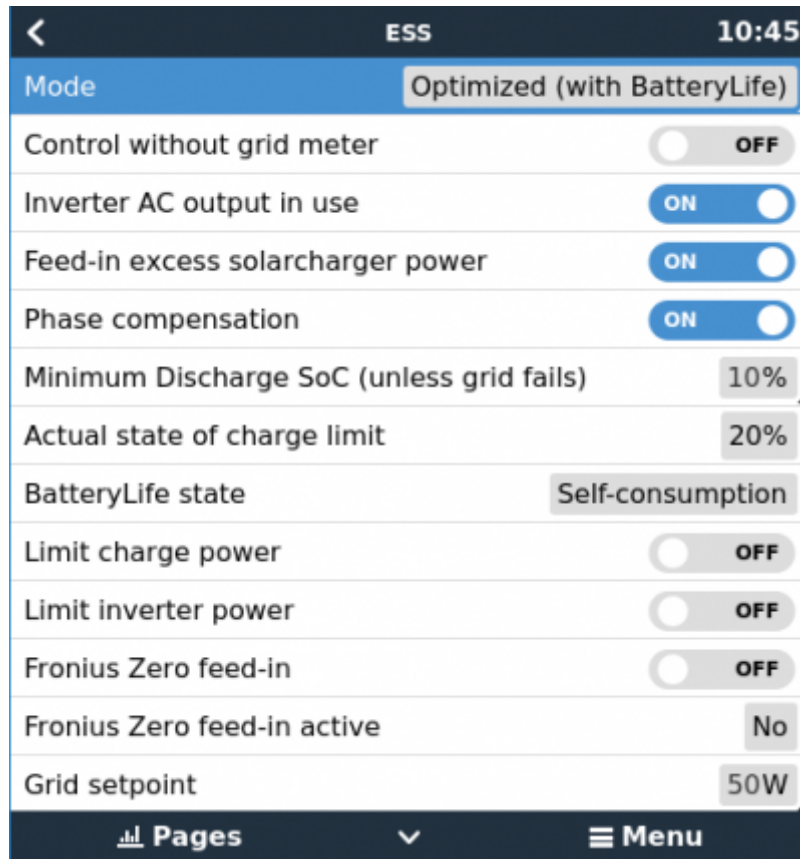
- Input current limiter setting work. The configured limit is used as the threshold for AC current at the ACin of the Multi/Quattro. Notes:
 - Loads in parallel with the Multi/Quattro are not taken into account: therefore, install all loads on the AC-out of the Multi or Quattro in systems that need to AC Input Current limiter functionality. Such systems are systems with a small AC in connection.
 - The current limiter will be used for both directions of the current.
 - The PowerAssist setting in VEConfigure3 will be disabled and ignored when ESS is installed.
- The Dynamic current limiter in VEConfigure3 will be disabled and ignored when ESS is installed.

General notes:

- PV power coming from a grid-tie inverter, either connected in parallel on the AC out, will be used to charge the battery. Charge current and other charge parameters are configured on the Charger tab in VEConfigure3.
- Make sure to keep the lithium batteries checkbox on the charger page consistent with the battery choice in the Assistant.
- When using a VE.Bus BMS and a Multi Compact, check the DIP switches: DIP switch 1 must be on, and DIP switch 2 must be off.

4.3 Venus-device - ESS Settings

Navigate to Settings → ESS, to see this menu:



4.3.1 Mode

Optimized (with BatteryLife) and Optimized (without BatteryLife)

At times when there is excess PV power, the PV energy is stored in the battery. That stored energy is then used later, to power the loads at times when there is a shortage of PV power.

Keep batteries charged

Failures of the utility grid are the only periods at which the battery will be discharged. Once the grid is restored, the batteries will be recharged with power from the grid, and of course also solar, when available.

External control

The ESS control algorithms are disabled. Use this when self-implementing a control loop. [More information.](#)

BatteryLife

For details on BatteryLife operation, see Chapter 6.2. In short, enable BatteryLife for these technologies:

- OPzV, OPzS
- GEL / AGM
- Victron 12.8V Lithium batteries, and other lithium batteries that have passive cell balancing

And, though we recommend to leave it enabled, BatteryLife can be disabled for these battery

technologies:

- Lithium with active cell balancing
- [Redflow ZCell](#)
- [aquion_ahi](#)

Note though, that even for those technologies we recommend to enable BatteryLife. Ask yourself, “Why should the battery be fully discharged, and stay that way? With as a result no reserve power in case of mains failure”.

4.3.2 Control without grid meter

Set to 'On' to enable ESS on a system without grid meter. All loads and (optional) grid-tie inverters need to be installed on the AC out.

4.3.3 Inverter AC output in use

Setting this to Disabled hides the AC-out box from the graphical overview. Use this in systems where there is nothing connected to the output of the Multi or Quattro, which is typical for certain grid-parallel systems in Western Europe.

4.3.4 Feed-in excess solar charger power

Set to 'On' to make the Solar Charger always operate at its maximum power point. The first priority is powering the loads, second priority will be charging the battery. And if there is then even more power available, the inverter/charger will feed that into the utility grid.

4.3.5 Phase compensation

Single phase connection to the utility grid

Phase compensation setting has no effect and can be ignored.

Single phase ESS in a system with a three-phase connection to the utility grid

- P.C. enabled: ESS regulates total power $L1 + L2 + L3$ to 0.
- P.C. disabled: ESS regulates only the power of L1 to 0.

Three phase ESS in a system with a three-phase connection to the utility grid

- P.C. enabled: ESS prevents charging the battery on one phase while at the same time discharging on another.
- P.C. disabled: ESS regulates each separate phase to 0 W. As a result, ESS will at times be discharging on one phase while charging on another: very inefficient.

For more background information, see chapter 7.

4.3.6 Minimum Discharge SOC (unless grid fails)

Configurable minimum SOC limit. Either with or without BatteryLife enabled, ESS will stop discharging the battery once it has been discharged to the here configured level.

Exception: when the utility grid has failed and the system is in Inverter mode, it will keep discharging the battery until one of the other thresholds have been met. See chapter 6.1 for more information.

4.3.7 Actual state of charge limit

(only when BatteryLife is enabled)

This % shows the working limit of the system. The limit will never exceed 80%.

Use this setting to see the current BatteryLife SOC level.

4.3.8 BatteryLife state

The different BatteryLife states are:

- Self-consumption: normal operation (discharge allowed)
- Discharge disabled: the battery has been discharged to the actual SOC limit. The state will return to *self-consumption* whenever the SOC rises 5%.
- Slow charge: ESS will slow charge the battery when the SOC has been below the actual SOC limit for more than 24 hours. It will keep slow charging until the lower limit has been reached again. Then the system switches to *Discharge disabled* again.
- Sustain: the Multi/Quattro has gone into sustain mode after the battery voltage has reached the dynamic cut-off voltage during discharge.

4.3.9 Limit charge power

Limits the charge power by the Multi. Because their power is used by the Multi, this includes power coming from grid-tie PV Inverters.

In other words, this setting limits the flow of power from AC to DC.

Notes:

- This setting does not reduce the charge power coming from MPPT Solar Chargers.
- This setting only applies while connected to AC-in: while in inverter mode, the charge-current setting as configured in VEConfigure is used to throttle power coming from grid-tie PV Inverters.

4.3.10 Limit inverter power

Limit the power drawn by the Multi: ie. all power being inverted from DC to AC.

Notes:

- The losses in the inverter/charger are not taken into account. In case you want to limit the amount of power being taken from the battery, you might have to set this limit extra low to compensate for those losses.
- Power coming from the MPPTs is not taken into account. Using this feature in a system with MPPTs can even cause the output power from MPPT to be reduced.
- This limit only applies while connected to AC-in: while in inverter mode, the AC loads determine how much power is drawn from the battery.

4.3.11 Zero feed-in (Fronius PV inverters only)

- Minimal required Fronius firmware version is 3.7.3-2
- If there are multiple Fronius PV Inverters present in the system, all will be limited
- Zero feed-in is not supported on Fronius IG Plus inverters.

Change the following settings in the Fronius web interface:

- In the Fronius setup menu, set Data export via Modbus to tcp.
- In the same menu, set Sunspec Model Type to int + SF
- In Settings→DNO Editor, make sure dynamic power reduction is set to No limit (this is the default).

Use the [Fronius Zero feed-in active](#) menu item to double check that all above criteria are met. It will show **No** when the firmware requirement, the Data export or the Sunspec Model type settings are not correct.

4.3.12 Grid setpoint

The power taken from the grid when in self-consumption mode. Setting this value slightly above 0W will prevent the system to feed back power to the grid when there is a bit of over-shoot in the regulation. The default is value 50W, but should be set to a higher value on large systems.

4.4 Venus-device - Other settings

4.4.1 Settings -> System setup -> AC Input types

Set the AC Input type to Generator when connected to a generator. The system will then enable charge, and properly load the generator as while it runs.

Note that we recommend to wire the Generator to AC in 1, and the Grid to AC in 2. The reasoning behind that is that this way the Quattro prioritizes the Generator over the Grid. It offers maximum flexibility (force run on the generator even when the grid is available) and control.

4.4.2 Settings -> Generator start/stop

More info [here](#).

4.5 MPPT Solar Charger

In ESS, the MPPT Solar Chargers will follow the charge curve as set in VEConfigure. The charge parameters configured in the MPPT Solar Chargers themselves are ignored in an ESS setup.

Except for the charge current. This still needs to be configured in the MPPTs

MPPT with VE.Direct comm. port

No special configuration necessary.

MPPT with VE.Can comm. port

No special configuration necessary. Do make sure to leave the Device instance configured to 0 (the default). MPPTs in the VE.Can network configured to a different Device instance will not be managed by ESS.

5. Commissioning

MPPT Solar Chargers

The MPPT state, as visible in the menus of the CCGX, of connected MPPT Solar Chargers shows 'Hub'. Or 'ESS'.

On the MPPT itself the Bulk will always be lit. And the Bulk LED will be shortly blinking every 4 seconds. That blink indicates that the MPPT is remotely controlled.

Installations using a Grid Meter

Grid Meter is shown in the Device list of the CCGX

Optimize mode

- Switch or disconnect all loads, while PV is present: the battery should show Charging, and the Grid (red box on the left of the overview) slightly fluctuates around 0W.

Keep batteries charged mode

After configuring the system, the system will immediately start charging the battery.

Steps to verify operation:

1. Disconnect the mains, the system should switch to inverter mode, powering the loads from the batteries. While still assisting the loads with PV.
2. Reconnect the mains, the battery will be charged from both mains and PV.

Fronius Zero feed-in

In the Settings → ESS menu, the Zero feed-in active item shows Yes.

Backup Generator

Start the generator and check that the system starts to charge the batteries.

6. Controlling depth of discharge

(Note: All absolute voltages mentioned in the text below are for a 12V system and should be multiplied by 2 or 4 for a 24V or 48V system.)

6.1 Overview

Mains present

When there is less PV power available than needed by the loads (a PV shortage, at night for example), energy stored in the battery will be used to power the loads. This continues until the battery is considered empty.

While mains is available, there are three parameters that check if the battery is empty:

1. Battery State of Charge: Minimum SOC as configured in the CCGX. When set to 60%, all capacity between 60% and 100% will be used to optimize self-consumption. And 0% to 60% will be used in case of a mains outage. The minimum SOC is parameter is configured in the CCGX. And it is also being updated daily by the [BatteryLife algorithm](#).
2. Battery Voltage. See [Dynamic Cut-off section](#), further down below.
3. Low cell signal from a BMS:
 - Victron VE.Bus BMS
 - 3rd party Canbus enabled BMS

Mains outage

When there is no mains, and the system is in inverter mode, these parameters control the depth of discharge:

- Dynamic cut-off

- Low cell signal from the VE.Bus BMS is still active
- Low cell signals from 3rd party canbus enabled BMS-es are ignored. System relies on the protection inside such a Lithium battery to trip.

What about the Sustain mode?

The Sustain voltages do not effect when the system stops discharging the battery: Sustain is activated only after the battery has been flagged as empty. See Sustain section below for more information.

6.2 BatteryLife

What does BatteryLife do?

In case the expected Solar energy reduces, because of less sunshine, the system will automatically increase its low SOC limit. So that, with this reduced expected Solar Energy, the battery will still be fully charged at the end of the day to approx 100%.

In case the expected Solar energy increases, because of more sunshine, the system will automatically decrease its low SOC limit. So that, with this increased expected Solar Energy, the battery will still be fully charged at the end of the day to approx 100%.

Ask yourself, "Why should the battery be fully discharged, and stay that way? With as a result no reserve power in case of mains failure, and possible also a damaged battery".

Details

The BatteryLife feature prevents low battery state of charge over a long period. For example in winter, when there is insufficient PV power available to recharge the battery every day.

BatteryLife ensures that, on average, the battery will be recharged to 100% SOC, every day.

It has several advantages:

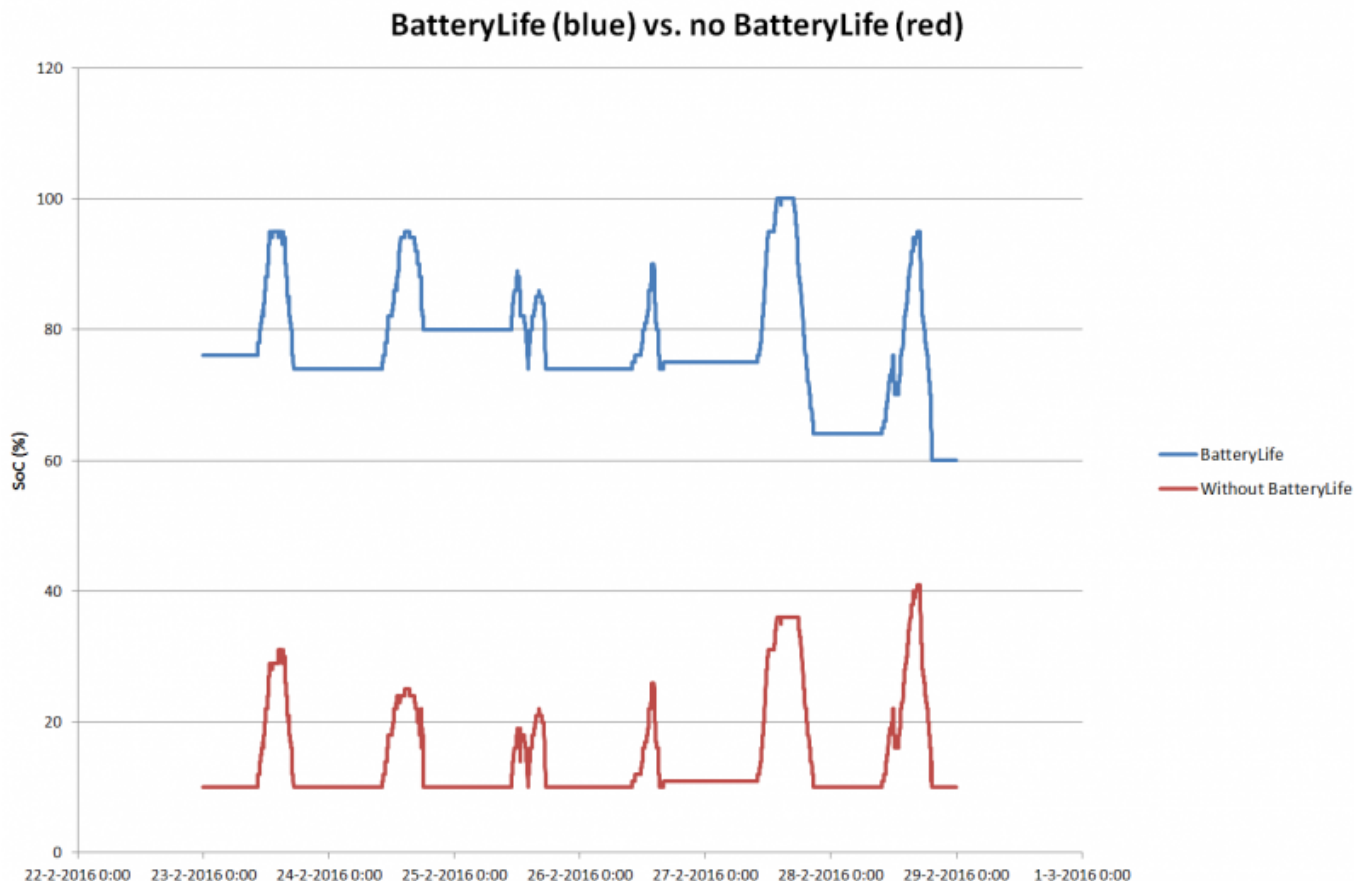
- Operating in a partial state of charge is bad for lead acid battery life
- Certain lithium batteries need to be fully charged regularly, in order to balance. This includes the [Victron 12.8V lithium batteries](#), and therefore it is also mandatory to enable BatteryLife for those batteries.
- In case of mains failure, it is best to have spare energy available to power the loads from the battery. Continuously operating in a low state of charge serves no purpose.

To do this we introduce a dynamic lower limit on the state of charge. Discharging is allowed only if the state of charge exceeds the limit. The limit is adjusted every day. On days with little or no surplus PV power the limit will be raised. And on 'good' days the limit is lowered again. When the battery SOC is below the SOC limit for more than 24 hours, it will be slow charged until the lower limit has been reached again.

The limit indicates how much surplus PV power we expect during the day; a low limit means we

expect a lot of PV power available to charge the battery. Ensuring that the system will not discharge more energy at night than it is expected to charge the next day.

This graph shows a system in the spring, battery state of charge graphed over time. During the week progressing, more solar energy is becoming available, and you see the depth of discharge being increased. The red line shows how this system would operate without BatteryLife.

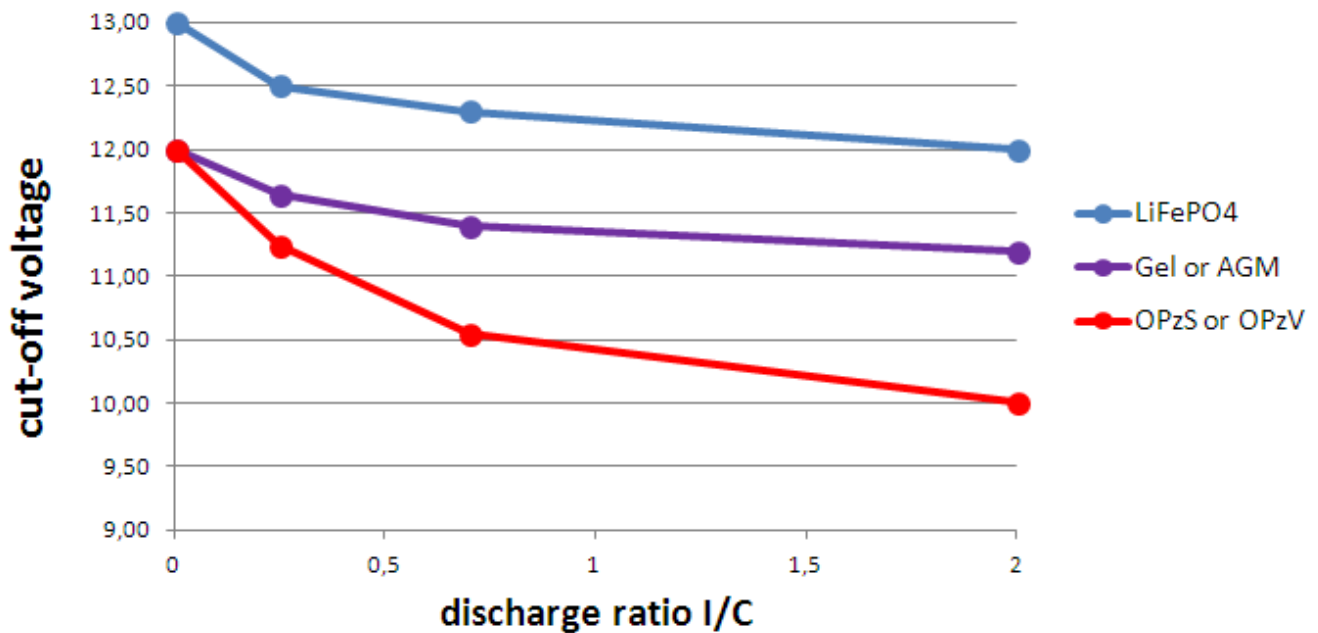


6.3 Dynamic Cut-off

The ESS Assistant includes Dynamic Cut-off. This feature makes the DC-input low shut-down level a function of the battery current drawn from the battery. When a high current is being drawn from the battery, a lower shut-down voltage threshold is being used. For example 10 V. And similarly, when the battery is only being discharged slowly, a high DC cut-off voltage is used, for example 11.5 V.

This way, voltage drop caused by the internal resistance in the battery is compensated. Making battery voltage a much more reliable parameter to stop discharging when a battery is empty.

The picture below shows the default 'Discharge' vs. 'DC input low shut-down voltage' curves for the different battery types. The curve can be adjusted in the assistant.



Notes:

- Dynamic cut-off is useful for batteries with a high internal resistance. For example OPzV and OPzS. And it is less relevant for LiFePO4 batteries, because of their low internal resistance. See graph, showing a much flatter curve for the charge current vs disconnect voltage.
- All three DC input low parameters (-shut-down, -restart and -pre-alarm) on the Inverter tab are not effective. They are overridden by the Dynamic cut-off levels, together with the restart level. Which are all configured in the ESS Assistant.
- The Dynamic cut-off mechanism is in effect both when mains is available, and during a mains failure (system is in Inverter mode)

6.4 Sustain Mode

Sustain prevents battery damage caused by leaving batteries in a deeply discharged state.

The Sustain Mode is entered after the battery has been flagged as discharged. The two conditions that trigger that are:

- Battery voltage below Dynamic cut-off
- Low cell signal from the VE.Bus BMS

While Sustain is active, the battery voltage will be maintained at the *sustain-voltage-level*:

- Lithium batteries: 12.5V
- Other batteries: 11.5 V for the first 24 hours, and after that it is raised to 12.5 V

In case the battery voltage is below the sustain level, the battery will be charged up to the *sustain-voltage-level* with a little bit of power from the grid. After that the charger will maintain at that voltage level, still using power from the grid when necessary. The maximum charge current used for this is 5 Ampère per unit. The 5 A is the same for all voltages (12 / 24 / 48 V).

Of course, excess solar power will also be used to charge the batteries.

Sustain mode is stopped after there has been enough solar power available to raise the battery voltage 0.1 V above the *sustain-voltage-level*. Normal operation will then continue: solar deficits are complemented with power from the battery again. This 0.1 V is the threshold for 12 V systems, for 24 V it is 0.2 V and for 48 V it is 0.4V.

7. Phase compensation

Use the Phase compensation setting in systems with a three-phase connection to the utility grid. The setting defines how the ESS interacts with the different phases.

When enabled (default), ESS balances the total power (L1 + L2 + L3) to zero. When disabled, ESS balances each phase separately to zero.

For single phase systems, this setting, either enabled or disabled, has no effect, and can therefore be ignored.

Phase compensation is by default enabled. Its effects depend on the type of ESS installed: a single-phase ESS (in a three-phase system) vs a three-phase ESS.

7.1 Single phase ESS in a three-phase system

With Phase compensation enabled, the (single phase) ESS uses the battery to balance to total of all phase to 0 Watt.

See the following example, where the ESS is connected to L1, and by compensating for phase L2 and L3 as well, it regulates the total power at the distribution panel to 0 W.

	L1	L2	L3	Total
Load	100 W	400 W	200 W	700 W
ESS	-700 W	0 W	0 W	-700 W
Distribution box	-600 W	400 W	200 W	0 W

With Phase compensation disabled, the (single phase) ESS uses the battery to balance only L1 to 0 Watt. L2 and L3 are visible on the CCGX, but not used by the ESS in any way.

Make sure to install the ESS on L1. When installed on another phase, the visualisation will be wrong.

7.2 Three-phase ESS

In a three-phase ESS system, there is at least one Multi installed on each phase. We recommend leaving phase-compensation setting to its default: enabled.

Installation details

- The Multis need to be configured as a three-phase system. Use VE.Bus Quick Configure or VE.Bus System Configurator for this.

- Install the ESS Assistant in all units: all the phase-masters but also all slaves (if any)
- Three phase loads: it is possible to connect three-phase loads to the AC out of the Multis, also called the UPS-output in a Hub-4 system. Those loads will be powered from the battery during a power failure.

Phase compensation enabled (default & recommended)

ESS balances the total power (L1 + L2 + L3) to 0 W.

Intelligence to optimize the balance between the phases

ESS intelligently optimizes the balance between the phases as much as possible. While doing so, it will never charge on one phase and discharge on another phase at the same time. To better understand how it works, closely read these examples:

When the phases are in balance, the solution is simple. Take this example: each phase is consuming 500 W, and there is only a little bit of PV, 100 W on each phase. Which makes the total requirement per phase 400 W, a total of 1200 W. The system will discharge the battery with 400 W on each phase, making the total system draw from the grid 0 W. And also each separate phase will be at 0 W individually.

When the phases are not in balance, it becomes more complicated:

For example, at a certain moment the PV is exceeding the loads on L1 with 1300 W. And on L2 and L3 there are only loads, 200 W each phase. Looking at the sum, the house as a whole is selling 900 W to the grid. Which for ESS means that it wants to charge the battery with 900 W.

A simple strategy could be to distribute this 900 W of excess power over all the phases: charging the battery with 300 W per phase:

	PV + Load	ESS	On the meter
L1	-1300 W	300 W	-1000 W
L2	200 W	300 W	500 W
L3	200 W	300 W	500 W
Sum	-900 W	900 W	0 W

The table shows that this is not optimal: the system is now selling on L1 and buying on L2 and L3, while as a whole its buying power.

Another solution could be to match each phase. In other words, regulate each single phase to 0 W: charge on L1 with 1300 W, and discharge L2 and L3 each with 200 W. Also not optimal: total power being converted from AC to DC and back is 1700W. While only 900W is required to keep the total power to 0: 800 W is being converted, and creating losses into heat, without purpose.

	PV + Load	ESS	On the meter
L1	-1300 W	1300 W	0 W
L2	200 W	-200 W	0 W
L3	200 W	-200 W	0 W
Sum	-900 W	900 W	0 W

(Note that this is what happens when the Phase compensation setting is disabled)

Then the last solution: when the balance of the total system is positive, ie. producing energy, the battery is charged by the phases that produce energy. And, the other way around, when the system as a whole is using energy, the battery is discharged onto the phases that are using energy. In the above example this means that the required charging of the battery is done on L1, with 900 W:

	PV + Load	ESS	On the meter
L1	-1300 W	900 W	-400 W
L2	200 W	0 W	200 W
L3	200 W	0 W	200 W
Sum	-900 W	900 W	0 W

Phase compensation disabled

ESS balances the power of each separate phase to 0 W.

Beware: using the system this way causes significant losses, as power will flow from one AC phase to another through the DC connections. Incurring losses while converting from AC to DC on one phase and then from DC to AC and the other phase.

Note on the maximum charge current

In a multi-phase system, the charge current is configured per phase. There is not a total charge current which the system adheres to. This means that, for example when there is a relatively small battery bank, and a huge over production of PV on L1, and not on the other phases, only part of that over production on L1 will be used to charge the battery.

8. Comparison to Hub Assistants

The Hub-1, Hub-2 and Hub-4 Assistant are deprecated, in favor of the ESS Assistant. See below for details.

8.1 Hub-1 Assistant -> ESS Assistant

Policies

Hub-1 policies that are deprecated in favor of ESS:

- Policy 1: Connected to mains, feedback: use ESS and enable solar charger feed-in.
- Policy 2: Keep batteries charged: Use ESS, select the “Keep batteries charged” mode. And enable “Feed-in excess solar charger power”
- Policy 4: Prevent feeding energy to the grid: two options, one use ESS and do not enable Solar charger excess feed-in and it will always be connected to the grid. Or, use the Virtual Switch with ignore AC-Input.

- Policy 5: Connected to mains, no feedback: Use ESS, select the “Keep batteries charged” mode.

Above leaves us one policy where the Hub-1 Assistant can do things that ESS cannot.

- Policy 3: Disconnect from the mains when possible: Keep Hub-1 Assistant or, often a simpler and therefore better solution, use the Virtual Switch with Ignore AC-Input.

Load shedding feature: deprecated

Loadshedding is a feature in Hub-1 that is not often used, and therefore we did not implement it in the ESS Assistant. Instead of sticking to Hub-1, which we do not recommend and also not support(1), consider using other options.

For example (mis-)use the genset/start stop in CCGX.

8.2 Hub-2 (v3) Assistant -> ESS Assistant

Comparison per Hub-2 Policy

- Disconnect at night: disconnecting at night is not possible with the ESS Assistant, but why would you want to do that? Disconnecting only causes problems with overload, flickering, etc. With the ESS Assistant it's possible to power your loads from the battery while staying connected to the grid. Which allows for the the same or even a better level of self-consumption without nightly disconnects and their issues.
- Invert priority: this is not possible we th ESS. Use the virtual switch instead.
- Connect to AC input when available: use ESS Assistant, and select one of the two Optimized modes.
- Connect to AC when available, keep batteries charged: use ESS Assistant, and select the “Keep batteries charged” mode.

Make use of 'off peak tariffs'

Not available in the ESS System yet, but is on the agenda to be implemented.

Winter mode

The ESS battery life feature will Make sure that the batteries are not unnecessarily cycled at their low end of SOC.

And see also the Keep batteries charged option in the CCGX.

Load shedding

Load shedding is a feature in Hub-2 that is not often used, and therefore we did not implement it in the ESS Assistant. Instead of sticking to Hub-2, which we do not recommend and also not support(!), consider using other options.

For example (mis-)use the genset/start stop in CCGX.

Prevent feeding energy back to the grid

The ESS can do this when you have a Fronius inverter. See the Zero feed-in option.

For other brands of PV Inverters, use the Hub2 v3 Assistant. Or even better, use an alternative, like installing MPPT Solar Chargers, leaving feed-back enabled, or install a Fronius PV Inverter.

8.3 Hub-4 Assistant -> ESS Assistant

- Battery capacity is no longer asked for by the Assistant. Instead, enable battery monitor, and enter the capacity on the General tab in VEConfigure.
- The PV Inverter Assistant is included in the ESS Assistant: it is no longer necessary to separately add it.
- Fixed overload and high temperature bugs

9. FAQ

Q1: Is power from MPPT used to power the loads, even when feedback is disabled?

Yes. ESS will always (with and without feed-in enabled) reduce grid usage to a minimum, preferably 0W. For that it will make sure the MPPT Solar Chargers keeps operating, even when the batteries are full.

A bit more detail per mode: In Keep batteries charged mode there is no power coming from the batteries to power the loads, unless grid fails. And PV power, when available, will always be used to power the loads.

In Optimize mode there is power coming from the batteries. Small load, big load, doesn't matter. Grid meter will read 0W until either the battery is empty or load is too high for the inverter to compensate for it.

Q2: I've enabled optimize mode, but do not see grid-power being used to charge the battery?

Indeed, in optimize mode, the goal is to only charge the battery with power coming from PV. Which is what ESS will do. Except for two situations, both related to battery health and preventing to unnecessarily shorten its life time.

1. Sustain: the battery has been discharged so deeply that the sustain safety mechanism was disabled. See chapter 6.4
2. Force charge: BatteryLife is enabled, and the system is in Force Charge. See chapter 4.3.7

Q3: Even when the battery is full, the system is still connected to AC-in

This question is typically asked by users or installers that are familiar with our previous configurations, for example Hub-1 or Hub-2, in a series installation rather than a grid-parallel installation. In that config, the system would switch to inverter mode when the batteries were full enough.

Which is nice in a way, but also had several disadvantages. An inverter offers a much weaker voltage supply than the public grid does. Which may lead to:

1. Lights flickering issues
2. Inverter shutdown in overload when a large load is switched on

With ESS, in Optimize mode, the system will always remain connected. Even when the batteries are full. And though connected, it will not draw any substantial power from the grid. Which offers the stability of the grid for free.

Q4: Why is the VE.Bus state in pass-through?

In ESS, the conditions for the VE.Bus system to be in pass-through, are:

- When the CCGX is no longer receiving data from the grid meter. Note that this is only for systems that are configured with an external grid meter. For systems without grid meter, see the Settings → ESS → Control without grid-meter setting.
- Systems with a canbus connected lithium system only: when it the Ccgx is no longer receiving information from the battery, via the canbus.
- When charging the battery is not allowed (BMS max charge current = 0A, or max charge power = 0W) and there is excess PV power.
- When discharge is not allowed (BMS max charge current = 0A, or low SoC, etc...) and loads on AC-Out force the Multi/Quattro to exceed the AC input current limit

Q5: How to suppress the low battery warnings?

Background: in an off-grid or backup system it makes sense to get a warning when the battery is almost empty. But in a system where the battery is only use to optimize self-consumption, it is totally normal to fully deplete the battery every day, and it does not make sense to receive daily notifications about that.

- disabling the Multi's low battery warning pop up on the CCGX is done by going to the Multi or Quattro menu, then into Setup and finally into Alarms, and then set the Low DC voltage alarm to Alarm only.

- suppress the email notifications by logging into the VRM Portal, and there set the Automatic alarm monitoring to Only alarms.

Q6: Optimize mode, no feed-in: AC Input current heavily fluctuates, even negative?

That is correct, the current shown is the RMS current. Which does not lead to real power, and therefore also not to real energy being fed into the grid.

Especially around 0 Watt real power, you'll see that the RMS current is very high. This is caused by the X-capacitors in the Multi.

Look at the Input power readings instead. They'll fluctuate a lot less, and are a better representation for power and energy.

Q7: How do the charge states work in ESS?

- The MPPTs are always in the `ESS` state. This indicates that the MPPT is being controlled by the Multi or Quattro. So to see in which state the system is, look at the VE.Bus State.
- While discharging, and connected to the grid, the state can still show a charge state, such as Bulk, Absorption or Float. Even though it is not charging. This is normal, nothing to worry about.
- When in float, the system will restart a new charge cycle when the battery voltage has been below the restart-voltage during a certain time. This voltage depends on the chosen battery type, on the charger tab in VEConfigure:
 - Lithium: restart-bulk-voltage = Vfloat - 0.2V (max 13.5V)
 - Others: restart-bulk-voltage = Vfloat - 1.3V (max 12.9V)

Note that explained charge cycle-restart mechanism differs from the stand-alone MPPT Solar Charger algorithm: they restart the charge cycle every day. See the solar charger manuals for more information about this.

Q8: My system switches off in overload?

In case system switches off in overload, while connected to the grid, this is caused by the active Loss of Mains (LOM) detection, linked to the country code as configured in VEConfigure3.

This behavior occurs when the AC supplied on the AC-in of the Multi or Quattro is 'weak'. With 'weak' we mean that the AC connection to the utility has a higher impedance than usual. For example a generator, or a country house connected with a long (too) thin wire to the utility.

For the solution and configuration options, see [VEConfigure: grid codes & loss of mains detection](#).

Q9: Why does my Multigrid refuse to feed-in?

A Multigrid system can enter a state where feed-in (more precisely: converting DC to AC while connected to the grid) is disabled.

This happens when, at the moment of connection to the grid, there is not enough DC power to perform the required relay test. (n.b. this relay test is part of the grid code specification and is mandatory). In order to perform this test the Multigrid must be able to run from battery during some time (depending on the selected grid code but this time is about 1 minute).

If this is not possible, the system would enter a deadlock situation if no precautions were taken, since

it is not allowed to connect to grid.

Therefore the following exception is made: When the device cannot perform the relay test, it still switches to grid but will not feed-in. Once a minimum amount of time is passed (about 15 minutes) and the battery voltage is risen to at least 14V (for a 12V system) the Multigrad assumes that there will be enough DC power to run from the batteries and it will automatically switch to Invert, perform the relay test and switch back to grid. Only then feed-in will be enabled again.

Conclusion: no need to worry, the system will resume feed-in automatically once the battery has been charged.

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