Technical Information

Battery Management of the Sunny Island

Gentle charging control for lead-acid batteries based on current state of the battery

Content

Exact determination of the state of charge is a basic requirement for the correct operation of lead-acid batteries. Only with proper operation can the battery reach the service life promised by the manufacturer. Battery management of the battery inverter Sunny Island is thus based on precise determination of the state of charge. By combining the three most common methods for determining the state of charge, the Sunny Island minimizes its measurement deviation to only 5%. This can reliably prevent overcharging and deep discharging of the lead-acid batteries. A further feature of battery management is the extremely gentle charging control. It automatically selects the optimum charging strategy for the battery type and the operating conditions in which it is used.

Battery management of the Sunny Island inverter supports type **FLA** and type **VRLA** lead-acid batteries.

Lithium-ion batteries may also be used in Sunny Island systems ("Intended Use" see the installation manual of the Sunny Island inverter at www.SMA-Solar.com). Lithium-ion batteries suitable for operation with the Sunny Island have their own battery management, which usually is programmed by the manufacturer and integrated in the battery. SMA Solar Technology AG has no influence on the mode of operation of this external battery management. The following sections describe the battery management of the Sunny Island inverter and solely apply to lead-acid batteries.

1 State of the Battery

1.1 Nominal Capacity and Battery Aging

The usable capacity of a **new** battery corresponds to the nominal capacity, specified by the manufacturer, for a ten-hour electric discharge (C10). As the battery ages, its usable capacity drops due to the following reasons:

- **Calendrical Aging**

  If not used, the usable capacity of the battery drops over time.

- **Cycling**

  The battery ages through the number of discharge cycles.

Battery aging is also influenced by various other factors, e.g. by insufficient charging, excessive charging voltages, deep discharge or temperature. With the correct choice of the battery parameters, battery management can influence these factors and conserve the battery.

1.2 Current State of Charge (SOC)

The Sunny Island shows the current state of charge (SOC) of the battery using the parameter **BatSoc**. The parameter **BatSoc** is determined by combining those methods:

- Ampere-hour counting incl. full-charge detection
- Voltage recalibration: Recalibration of the SOC based on the battery voltage.

Ampere-hour counting:

Ampere-hour counting is a simple method that uses battery current integration (Coulomb counting) for SOC estimation. Since the original state of charge is normally unknown and the DC current measurement not accurate enough, a SOC value based exclusively on ampere-hour counting is also inaccurate. That is why ampere-hour counting from SMA Solar Technology AG includes other features that improve this simple method.

First of all, the algorithm used by SMA Solar Technology AG is capable of estimating battery leakage current (side reactions within the battery), which is both voltage and temperature dependent. Additionally, due to the typical charging characteristic of lead-acid batteries (see section 2.1, page 4), the algorithm performs what is known as full-charge detection. Different measured values such as temperature, battery voltage, charging current and time are taken into account. Furthermore, full-charge detection enables the adjustment of different parameters via self-learning processes, thus significantly improving the accuracy of the SOC value

The estimated state of charge error is indicated by the parameter **BatSocErr**. The state of charge error provides information regarding the accuracy of the current SOC calculation. The error has its lowest value after a full or equalization charge. It starts increasing again after several battery cycles until the next full or equalization charge is completed.

SOC recalibration

The Sunny Island constantly monitors the battery voltage and SOC. There are two different approaches to the recalibration of the SOC based on the battery voltage.

- In one case the recalibration of SOC is performed under virtually no load conditions (low load). The state of charge based on the measured open-circuit voltage is compared to the state of charge based on ampere-hour counting. If deviations occur, the state of charge is recalibrated upwards or downwards.
- Another approach to recalibration of the SOC on the basis of the battery voltage is the continuous supervision of the battery voltage and SOC during discharge. The main purpose of this recalibration is to provide deep discharge protection for the battery. In the event that the Sunny Island detects a unexpectedly sharp battery voltage drop while discharging, meaning a lower battery voltage for the given discharging current than expected at a certain SOC, then a recalibration of the state of charge to 20% will be performed.

Recalibration to 20% allows the Sunny Island to protect the battery from deep discharge and prevents potential damage. However, this type of recalibration must be given special treatment. Consequently the following messages will be displayed in order to attract the user's/installer's attention:

- **E224**: 20% recalibration is being performed
- **W222**: 20% recalibration resulted in a jump of more than 10%

Frequent SOC recalibrations to 20% might be caused by poor battery maintenance, aged batteries, or installation errors (see section 4, page 8).

1.3 State of health of the battery (SOH)

Battery management shows the current usable battery capacity expressed as a percentage of the nominal capacity as the value state of health (SOH). After commissioning, the Sunny Island adopts the set nominal capacity (Parameter **BatCpyNom**) as available battery capacity and thus sets the state of health initially to 100%.

During operation, the Sunny Island learns to define the adopted state of health of 100% more and more precisely. This learning process only works in Sunny Island systems where there is cycled operation of the lead-acid battery. There also must be recurring longer idle phases during which the battery does not get charged and is only operated with low electrical load. A low electrical load corresponds to approximately 1.5% of the nominal capacity for a ten-hour electric discharge, e.g. 150 W for a 10 kWh battery.

Especially in the first months after commissioning of the Sunny Island system it is therefore important to regularly check the state of health.

- If the state of health exceeds 100% after commissioning of the Sunny Island, the available battery capacity is higher than the nominal capacity set in the Sunny Island. In this case ensure that the nominal capacity specified by the manufacturer based on a ten-hour electric discharge (C10) is actually set on the Sunny Island.
- If the state of health decreases by a few percent per year or per 100 load cycles during continuous operation, this decrease relates to the expected aging of the battery. No further measures are required.
- If the state of health decreases by several ten percent within the first months after commissioning, this decrease indicates a potential error (see section 4, page 8).
- If the state of health does not deviate from 100% within the first few months, this indicates that the state of health cannot be learned due to the mode of operation of the Sunny Island system.

The Sunny Island is able to determine the state of health with an accuracy of ±15 %. To determine a more accurate state of health value, the battery capacity must be measured in accordance with DIN EN 60896, for example. Electrically qualified persons with special measuring equipment must be on site, e.g. service staff of the battery manufacturer.

Effect of the Battery Temperature on the Currently Available Battery Capacity:

The current usable battery capacity depends on the temperature of the battery. With temperatures of 20°C and below, the usable capacity of a battery drops significantly. Battery management corrects the usable battery capacity by − 1% per °C starting from 20°C.

1.4 Battery Temperature

Battery management continuously monitors the battery temperature. The Sunny Island adjusts the current usable battery capacity and charging voltage for the current battery temperature (see Section 2.3 “Automatic Temperature Compensation”, page 6).

Battery management issues a warning message if one of the following events occurs:

- The battery temperature is within 5°C of the maximum permissible battery temperature.
- The battery temperature is less than − 10°C.

If the maximum permissible battery temperature is exceeded, the Sunny Island switches itself off. As soon as the battery has cooled down to a predefined temperature, the Sunny Island starts again.

2 Charge Control

2.1 Charging Phases

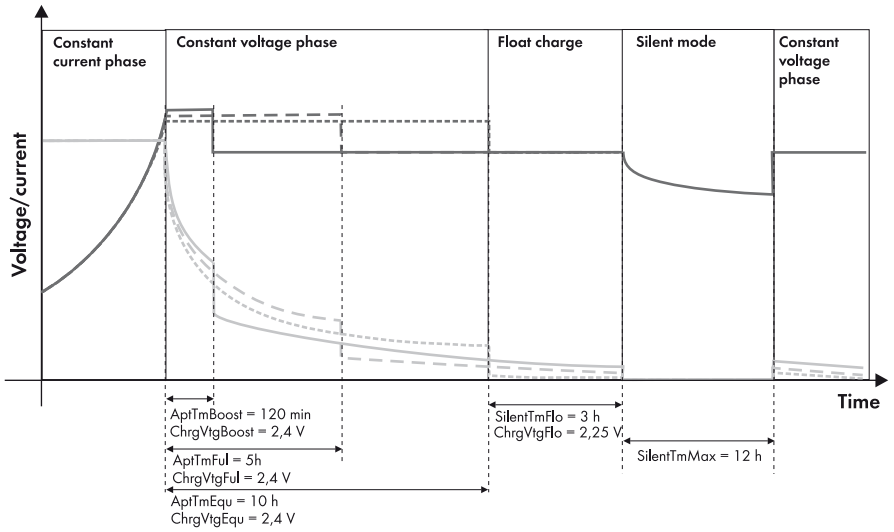

Figure 1: Sunny Island charging phases with sample values for an AGM battery. The parameters specified can be adjusted for the battery used according to manufacturer specifications.

The Sunny Island controls the charging of the battery in the following three phases:

- Constant current phase (I phase/bulk phase)
- Constant voltage phase (absorption phase/Vo phase)
- Float charge/V phase

There is also the idle phase in the case of electricity grid operation with activated silent mode.

Constant Current Phase

During the constant current phase, the primary task of battery management is to limit the current to the maximum permissible battery current. You can adjust the maximum charging current by changing the parameter **BatChrgCurMax** to the value specified by the battery manufacturer.

The available battery charging current is also limited by two other parameters:

- Nominal currents of the external energy sources (parameters **GdCurNom** and **GnCurNom**)
- Maximum AC charging current of the Sunny Island (parameter **InvChrgCurMax)**

The value that is reached first limits the charging current of the battery. While the charging current is maintained within the defined thresholds, the battery voltage increases as the battery is charged. The constant current phase ends when the cell voltage of the battery reaches the setpoint specified for the relevant battery type.

Constant voltage phase

In the constant voltage phase, the battery voltage is controlled at a constant value. As a result, the battery current decreases continuously.

For the constant voltage phase, battery management selects one of the following three charging processes (see Section 2.2 “Charging Process During the Constant Voltage Phase”, page 5):

- Boost charge
- Full charge
- Equalization charge

For each of these three charging processes, you can adjust the level of battery voltage and the charging time in the Sunny Island to the specifications of the battery manufacturer. When the required charging time has been reached, the constant voltage phase ends and Sunny Island switches to float charge.

Float charge

The purpose of float charge is to maintain the battery in a fully charged state without overcharging it. At the beginning of float charge, battery management reduces the charging voltage in steps until the setpoint specified for float charge has been reached. Battery management then maintains this charging voltage until the end of float charge. Float charge ends when one of the following conditions is met:

- The total of all electric discharges of the battery has reached 30% of the nominal capacity.
- The current state of charge is less than 70% of the available charging capacity.

Battery management switches from float charge to the constant current phase. If the stand-alone grid is connected to the electricity grid, battery management can also switch from float charge to silent mode.

Silent Mode

In silent mode, Sunny Island switches to standby and thus saves energy.

If the set time for the float charge (parameter **SilentTmFlo**) has expired in systems with electricity grid operation, battery management switches to silent mode and any connected loads are supplied exclusively from the electricity grid. The Sunny Island leaves silent mode at definable intervals (parameter **SilentTmMax**) or whenever the battery voltage per cell drops by 0.14 V. This way, the battery always remains fully charged.

2.2 Charging Process During the Constant Voltage Phase

When moving to the constant voltage phase, battery management selects one of the following charging processes:

- Boost charge
- Full charge
- Equalization charge

Boost charge

For boost charge, a high charging voltage is applied to the battery. The battery is to be charged to between 85% and 90% of its current usable capacity in a very short time.

You can adjust the charging voltage (parameter **ChrgVtgBoost**) and the time period (parameter **AptTmBoost**) in accordance with the recommendations for the battery used.

Full charge

The objective of full charge is to recharge the battery to a state of charge of at least 95%. This should compensate for effects caused by any insufficient charging and should also increase the service life of the battery.

The Sunny Island carries out a full charge of the battery whenever one of the following conditions is met:

- The defined cycle time for the full charge has expired (parameter **CycTmFul**).
- The total of all electric discharges since the last full charge corresponds to eight times the rated capacity of the battery.

You can adjust the charging voltage (parameter **ChrgVtgFul**) and the time period (parameter **AptTmFul**) in accordance with the recommendations for the battery used.

Equalization charge

With the equalization charge, the Sunny Island cancels out differences in the state of charge of individual battery cells which have arisen due to the different behaviors of the battery cells. This way, the Sunny Island prevents the premature failure of individual battery cells and extends the service life of the battery.

The Sunny Island carries out an equalization charge of the battery if the automatic equalization function is activated and if one of the following conditions is met:

- The defined cycle time for the equalization charge has expired (parameter **CycTmEqu**).
- The total of all electric discharges since the last equalization charge corresponds to 30 times the nominal capacity of the battery.

You can adjust the charging voltage (parameter **ChrgVtgEqu**) and the time period (parameter **AptTmEqu**) in accordance with the recommendations for the battery used.

To maintain or service the battery in systems that are only operated seasonally, you can start an equalization charge manually (see Sunny Island operating manual or www.SMA-Solar.com).

2.3 Automatic Temperature Compensation

The charging capability of the battery is dependent on temperature. To prevent overcharging and insufficient charging of the battery, battery management is equipped with automatic temperature compensation.

With temperatures above 20°C, battery management decreases the charging voltage. With temperatures below 20°C, battery management increases the charging voltage.

3 Battery Protection Mode

Battery protection mode protects the battery.

If the state of charge of the battery falls below the thresholds, battery protection mode is activated. In battery protection mode, the Sunny Island switches to standby mode or switches itself off. The battery protection mode has three levels. One state of charge threshold can be set for each level. Levels 1 and 2 of the battery protection mode have specific start and end times and are therefore dependent on the time of day.

Level 1

If the state of charge falls below the threshold for level 1, the Sunny Island switches to standby between the start time and end time. As a result, you can enter times at which, in the event of a lack of energy, you prefer the stand-alone grid to switch off.

Level 2

If the state of charge falls below the threshold for level 2, the Sunny Island switches to standby. During the day, when PV inverters could supply energy, the Sunny Island attempts to charge the battery.

Using the start time and end time, you define the time period during which the Sunny Island starts every two hours in order to charge the battery. If no energy is available to charge the battery, the Sunny Island remains on standby.

Level 3

If the state of charge falls below the threshold for level 3, the Sunny Island switches itself off. This protects the battery against deep discharge and severe damage. To charge the battery again, the Sunny Island must be switched on and started manually.

At all three levels, the Sunny Island will only switch to standby mode or switch itself off if no charging current flows into the battery within six minutes.

You can adjust the thresholds for battery protection mode to suit the system (see Changing Battery Protection Mode in the Sunny Island installation manual).

4 First Remedial Actions in the Event of SOC and SOH Deviations

No direct measurement is possible for estimating SOC and SOH. Therefore, the values indicated are always an estimation based on available measurable values, implemented algorithms as well as on parameter settings. A deviation in estimates of actual values is to be expected. Keep in mind that both incorrect installation and wrong parameter settings will negatively influence the accuracy of the estimation. The actual values of SOC and SOH can only be obtained through capacity tests which cannot be performed in field for most applications.

During normal operation and assuming the battery is healthy and the correct settings have been made, the jumps in SOC of less than 10% can be observed due to recalibration procedures (see section 1.2, page 2). The recalibration to a SOC of 20% and jumps of more than 10% are not likely to happen under these conditions (healthy battery and correct installation and settings). Thus, fast changes in SOC and jumps in estimated SOC values can be used as an indicator of incorrect settings, premature battery aging or battery errors.

Some typical causes of such behavior is shown in the following table:

Possible causes:	Measures
The battery parameters of the Sunny Island might be set incorrectly.	• Check the battery parameters, especially regarding **BatTyp** and **BatCpyNom** as well as regarding full charge and equalization charge (the Sunny Island inverter operating manual).
Not enough energy can be provided for charging the battery due to the unfavorable design of the Sunny Island system.	• Check system sizing (see Sunny Island inverter planning guidelines).
The cross-section of the battery cables might be insufficient, especially when long battery cables are used. Due to the voltage drop in cables, the charging voltage on the battery might be less than intended.	• Check battery cable (see Sunny Island inverter installation manual).
The battery cable resistance may be configured incorrectly.	• Configure the battery cable resistance correctly (see the Sunny Island inverter installation manual).
The terminal connectors of the battery cables might be mounted improperly, e.g. wrong torque or contaminated contact surfaces.	• Check the mounting of the terminal connectors on the Sunny Island (see the Sunny Island inverter installation manual). • Check the mounting of the terminal connectors on the battery (see documentation of the battery manufacturer).
It is possible that the battery has a lower capacity than indicated by the manufacturer.	• Perform capacity test (see documentation of the battery manufacturer).
It is possible that the individual cells of the battery might be defective.	• Replace battery cells (see Sunny Island inverter operating manual).

The exact cause must be determined as quickly as possible to prevent avoidable damage to the battery.
SMA Solar Technology AG recommends initiating an equalization charge and closely observing how the system reacts. In some cases, it may be necessary to contact the SMA Service Line or to consult the battery manufacturer.

Provided that no irreversible damage has occurred yet, the state of health will increase again after eliminating the cause of error. The adjustment of the state of health can however take several weeks.