Design of Off-Grid Systems with Sunny Island 4.4M / 6.0H / 8.0H Devices

SMA

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1 Off-Grid Energy Supply

1.1 Necessity for an Off-Grid Energy Supply

The European Union estimates that 1 billion people worldwide live without access to electricity, which represents 13% of the world population.

The high capital expenditure costs involved in expanding the utility grid coupled with low electricity demand often preclude remote areas from being connecting to the utility grid. Off-grid systems based on photovoltaic systems and other energy sources provide a viable alternative here, and are often an economically better solution.

1.2 Off-Grid Systems

Off-grid systems are autonomous utility grids that are fed with energy from various energy generators.

Off-grid systems can consist of the following components:

Components	Description
PV arrays	A PV array consists of several PV modules that produce direct current from solar energy.
PV inverter	The PV inverter (e.g. Sunny Boy or Sunny Tripower) converts the direct current produced by the PV array into grid-compliant alternating current and feeds this into the alternating current grid.
	The PV inverter and the PV arrays must be dimensioned according to the chosen power (see Section 3.5, page 16).
DC/DC charge controller	In an off-grid system, the direct current provided by the PV arrays can be used to charge a battery directly. A charge controller is necessary for this.
Batteries	Batteries store electrical energy and support the grid when other energy generators are not producing sufficient electricity. If more energy is produced than is consumed, the batteries can be charged again.
	The capacity, nominal power and battery type must be taken into consideration when designing the batteries (see Section 3.4, page 14).
Battery inverter	As a voltage source, the battery inverter (e.g Sunny Island) forms the stand-alone grid. The battery inverter regulates the balance between the energy that is generated and the energy that is used and incorporates a battery, PV array and load management system (see Section 2.1, page 8).
DC fuse	The external DC fuse protects the battery connection lines of the battery inverter. Furthermore, the DC fuse enables DC-side disconnection of the battery inverter.
Generators	Fuel powered generators (e.g. diesel generators) are often installed to supplement the energy supply when the state of charge of the batteries drops and there is insufficient energy being supplied by the PV array. These generators supply alternating current directly.
Wind turbine systems	Wind turbine systems convert wind energy into electrical energy and supply alternating current directly.
Hydroelectric power plants	Hydroelectric power plants use the kinetic energy of water to produce electrical energy. The hydroelectric power plant generators supply alternating current directly or are equipped with inverters to convert direct current into alternating current.

Off-grid systems can supply individual houses, settlements or even entire villages with electricity.

Various underlying conditions have to be taken into consideration when planning, designing and selecting an off-grid system. The optimum design of an electricity supply system depends on the following factors:

- Necessary connected rating
- Energy consumption
- Type of loads
- Utilization period
- Underlying meteorological conditions

1.3   Off-Grid System Types

1.3.1   AC Coupled Off-Grid Systems
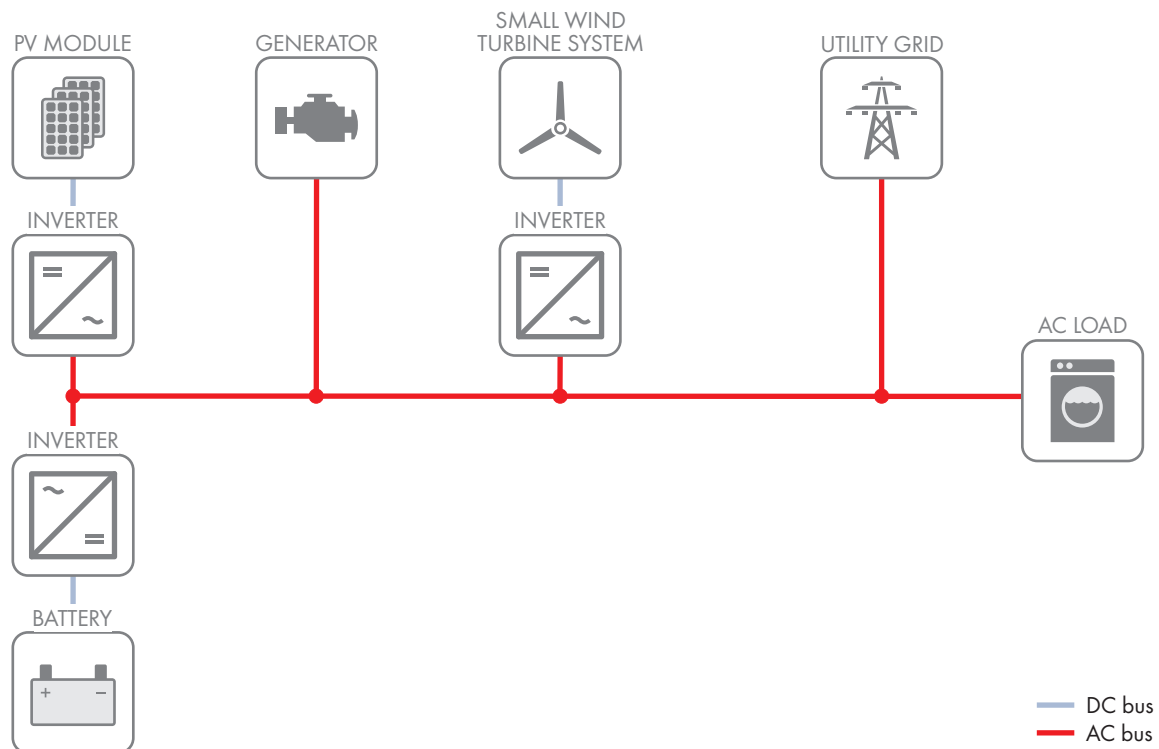
Figure 1: Example of an AC coupled system

In an AC coupled system, all loads and energy sources are coupled via an alternating current grid. The advantage here is that the off-grid system can be built and expanded flexibly with modular standardized components.

Depending on the application and availability, both renewable and conventional energy sources can be integrated. The connected energy sources charge the batteries and supply energy when necessary. Connection to the utility grid is possible, provided that the battery inverter and the combustion equipment are designed for this. AC coupled off-grid systems can be easily expanded with additional energy sources. Thus, they are able to satisfy increasing energy demands.

AC coupled off-grid systems can be used to supply conventional alternating current loads. They are therefore ideally suited for use in rural areas in developing- and newly industrialized countries, but also in industrialized countries in regions where a utility grid is not available.

The battery inverter connected to the battery, e.g. a Sunny Island inverter, forms the AC current grid.

In the medium-power range (1 kW to 300 kW), off-grid systems with a battery-storage system are significantly more attractive from an economic point of view than systems that are only equipped with generators. This is due to the high maintenance requirements, the short service life and the very low partial load efficiency of generators.

1.3.2　DC Coupled Off-Grid Systems

PV MODULE

DC/DC CHARGE CONTROLLER

DC LOAD

BATTERY

DC bus

Figure 2: Example of a DC coupled system

In a DC coupled system, all energy sources are coupled via direct current. The PV array is integrated via special DC/DC charge controllers. During the day, the battery stores energy generated by the PV array. This stored energy is then available in the evening for operating the lighting.

DC coupling is suitable for simple system constellations and is beneficial in cases where the electricity supply is primarily used to operate lighting. An example of this application is the Solar Home System (SHS) with a power range of a few hundred watts.

Alternating current loads in a DC coupled off-grid system can only be operated via an additional small inverter.

1.3.3   Hybrid AC and DC Coupled Off-Grid Systems
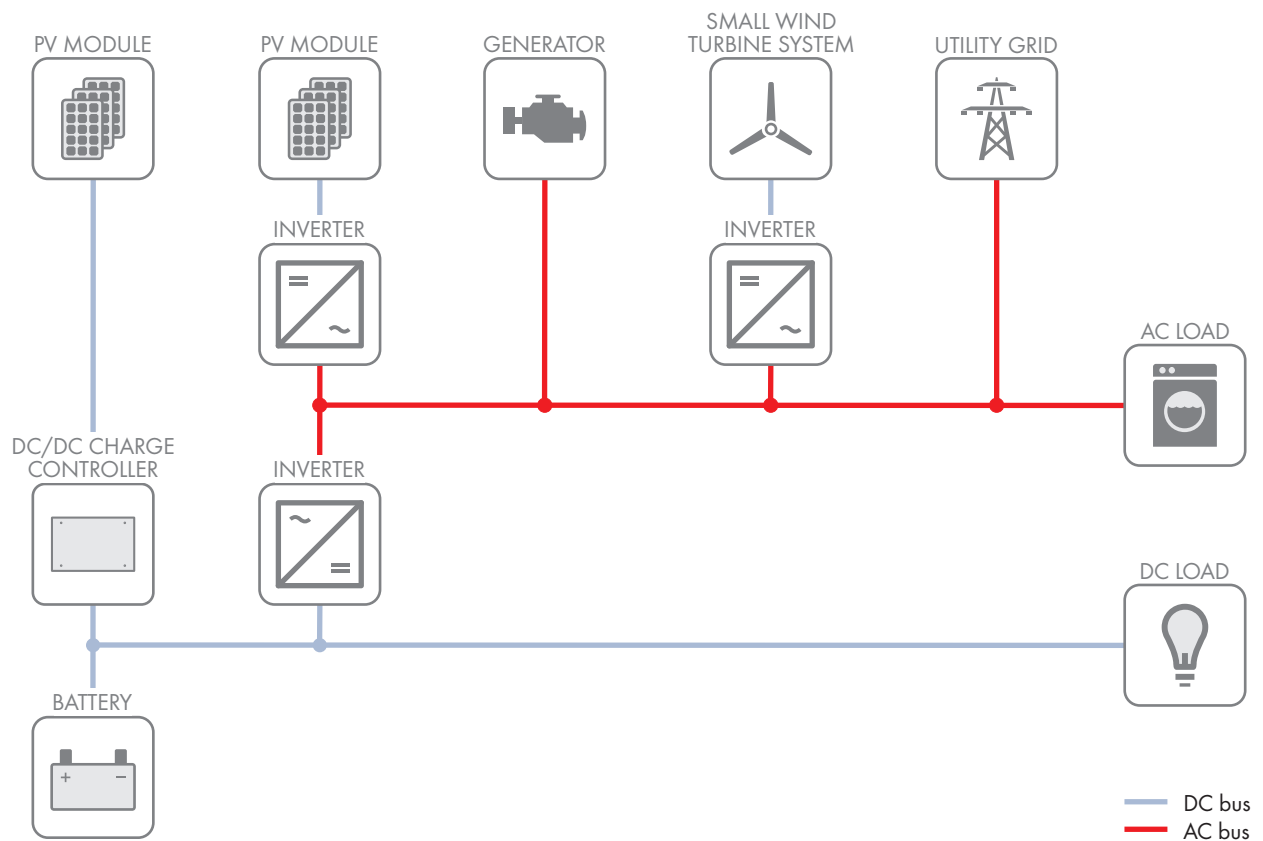
Figure 3: Example of a hybrid system with AC and DC coupling

Hybrid systems with AC and DC coupling are particularly well suited for coupling alternating current loads in the medium power range with DC energy sources. In hybrid systems, the battery can be charged via a generator at the same time. Hybrid systems are suited to supplying remote loads and satisfy higher energy demands. Accordingly, hybrid systems are used in ranches, smaller factories and on farms.

When designing the system, it must be ensured that the nominal power of the inverter is sufficient to supply the power to be consumed by the intended loads. Even if there is more power available from a PV system or wind turbine system, the inverter is the decisive factor in how much power is available on the AC side. The design of hybrid systems is much more complex than the design of purely AC coupled systems.

2 Off-Grid System with Sunny Island

2.1 Working Principle of the Sunny Island Inverter

The Sunny Island is a battery inverter that is connected directly to a battery-storage system. The Sunny Island forms the alternating current grid of the off-grid system and at the same time regulates the voltage and frequency in the alternating current grid.

Both electrical loads and energy generators are connected directly to the alternating current grid. Energy generators, e.g. PV inverters, feed into the alternating current grid of the off-grid system and thus supply the electrical loads.

The Sunny Island regulates the balance between the energy fed in and energy used and features a management system that manages the battery, generators and loads. If there is excess energy available (e.g. high solar irradiation and low consumption), the Sunny Island redirects energy from the alternating current grid and uses this to charge the battery. If there is insufficient energy available (low or no solar irradiation and high consumption), the Sunny Island supplies the alternating current grid with energy from the batteries.

The Sunny Island automatically checks the availability of the alternating current grid and system components. Therefore, additional control- and monitoring units are not necessary. This simplifies system operation and reduces capital expenditure.

2.2 Advantages of the Sunny Island Inverter

- Ideal for energy supply systems from 1 kW to > 300 kW
- Flexible configuration as a single system, single-phase parallel system or three-phase system
- Multicluster technology – combination of three-phase systems for the simple formation of a powerful energy supply.
- Expandable thanks to modular design
- Excellent overload characteristics
- Suitable for installation in extreme climate conditions
- Optimized battery management and state of charge monitoring for long lead-acid battery battery lives
- Compatible with many lithium-ion batteries (see technical information "List of Approved Batteries" at www.SMA-Solar.com)
- Cost-efficient integration of alternating current loads, regenerative energy sources and generators
- Simple off-grid system commissioning
- Clear remote visualization
- Remote parameterization possible via Sunny Portal powered by ennexOS from Sunny Island firmware version 3.30.12.R

2.3   Modular Design

2.3.1   Single System
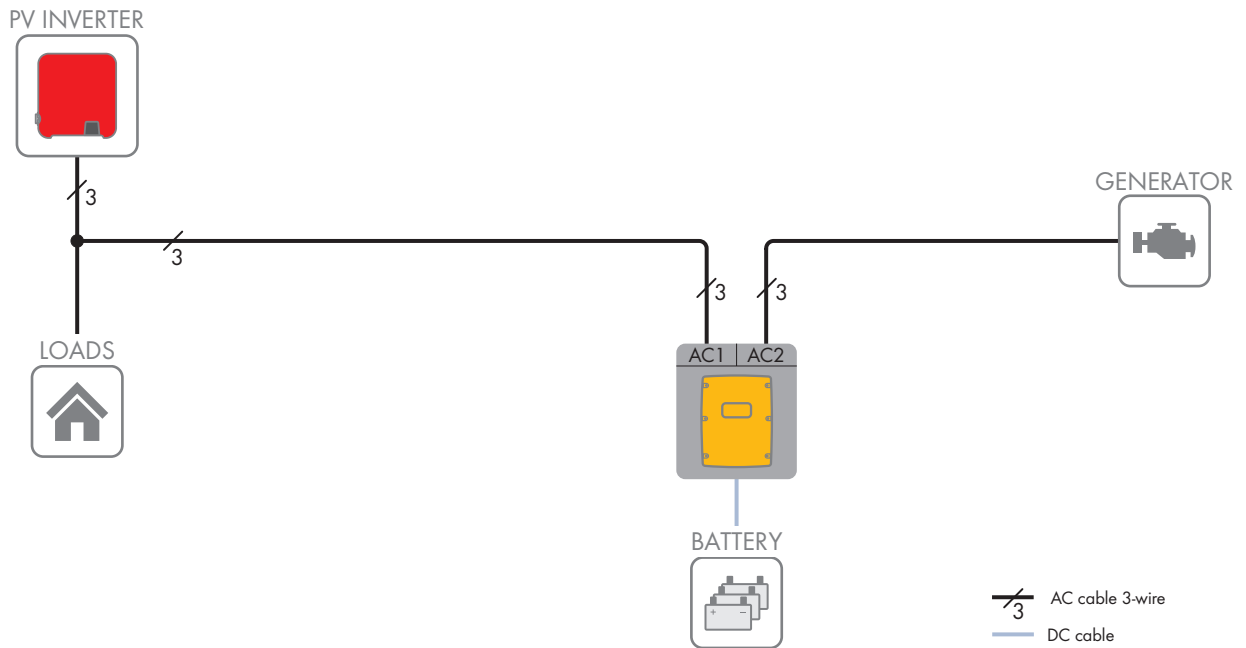
Figure 4: Principle of a single system

In a single system, one Sunny Island forms a single-phase stand-alone grid.

2.3.2   Single-Cluster System (Single-Phase)

ℹ Required device types for single-phase single-cluster systems

In single-phase single-cluster systems, the Sunny Island inverters must be of the same device type (see Section 6.6, page 50). SI 4.4M devices cannot be used in single-phase single-cluster systems.
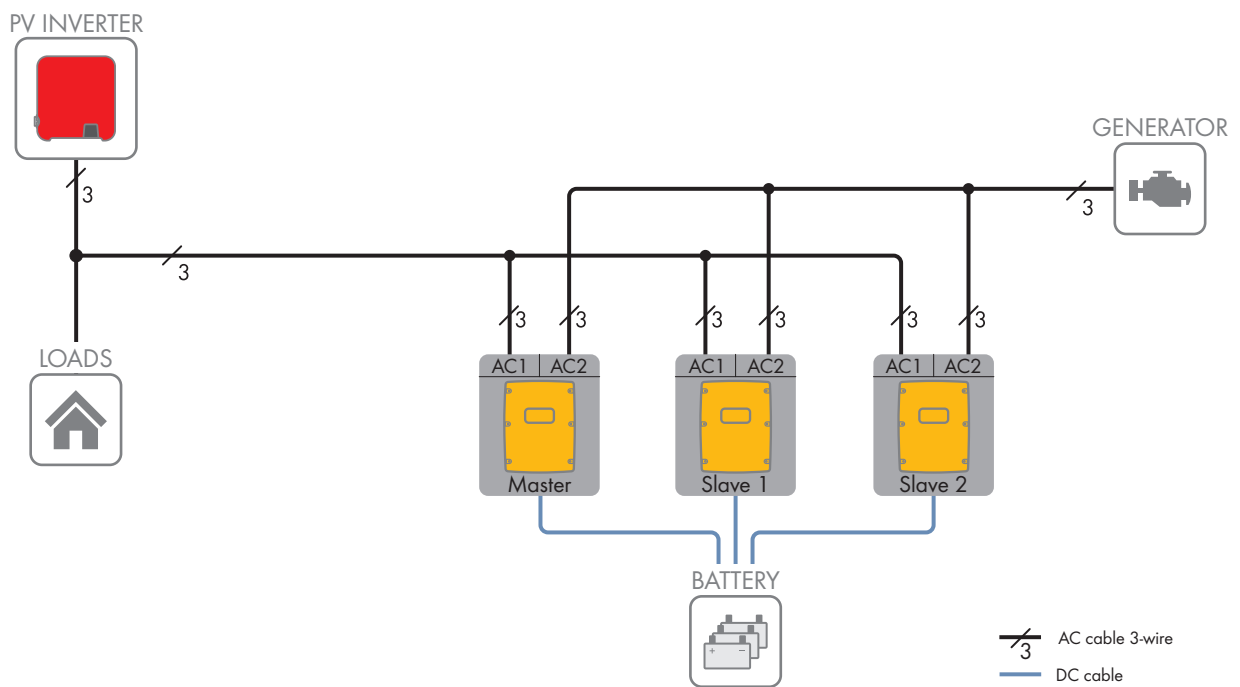
Figure 5: Principle of a single-phase single-cluster system

In a single-phase single-cluster system, up to 3 Sunny Island inverters are connected to one battery forming a cluster. The Sunny Island inverters are connected on the AC side to the same line conductor.

2.3.3 Single-Cluster System (Three-Phase)
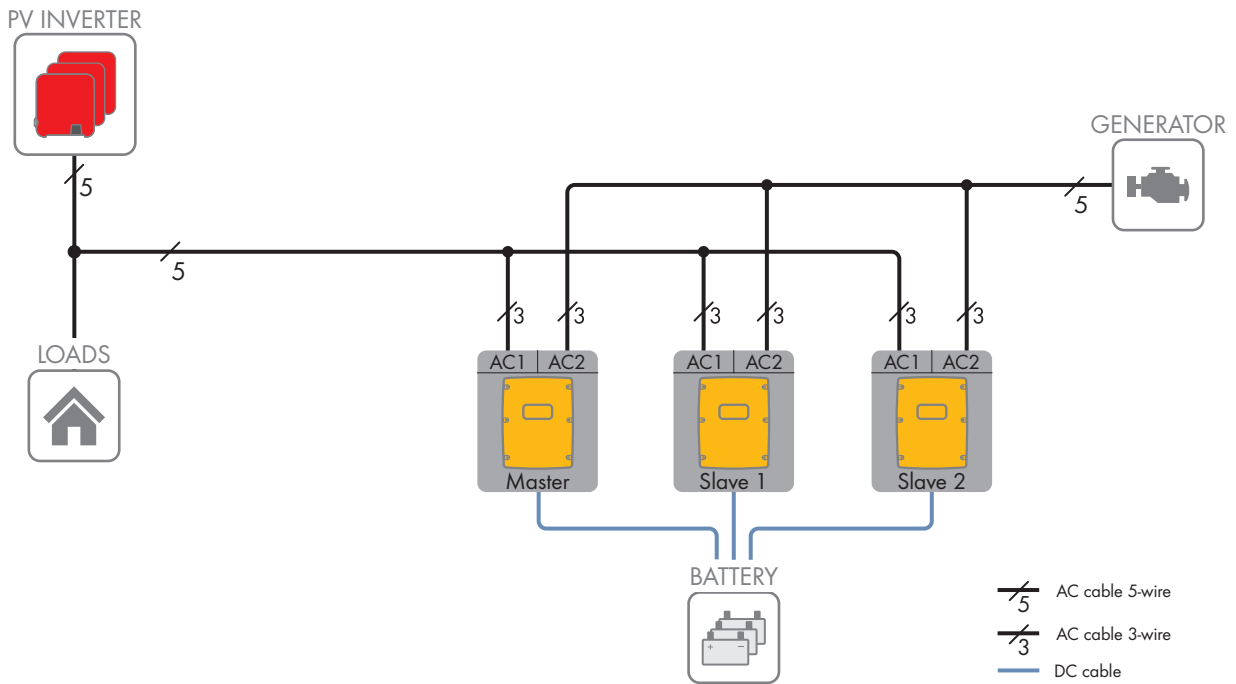
Figure 6: Principle of a three-phase single-cluster system

In a three-phase single-cluster system, up to 3 Sunny Island inverters are connected to one battery forming a cluster. On the AC side, the Sunny Island inverters are connected to 3 different line conductors. All device types must be the same (see Section 6.6, page 50).

2.3.4 Multicluster System
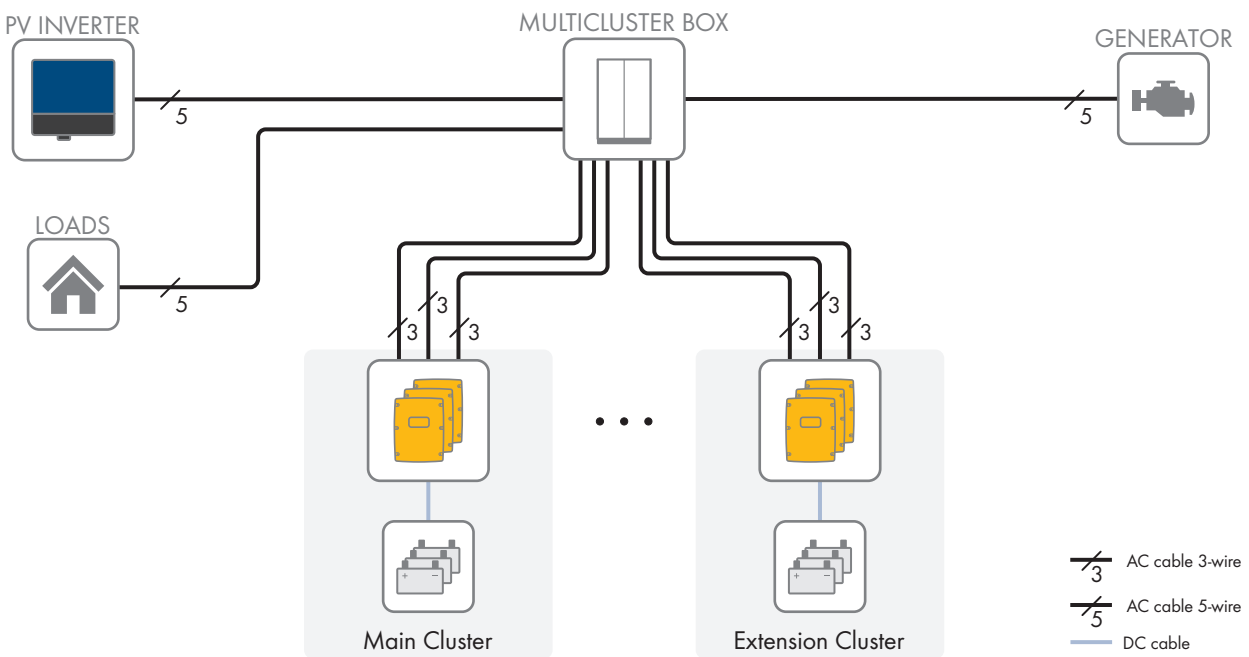
Figure 7: Principle of a multicluster system

Multicluster systems consist of several three-phase clusters. The individual clusters must be connected to a Multicluster-Box. The Multicluster-Box is a feature of the SMA multicluster technology for off-grid systems and battery-backup systems.

The Multicluster-Box is a main AC distribution board to which up to twelve clusters can be connected. Only device types with the same output power may be installed in a cluster (see Section 6.6, page 50).

| i | **The device type SI4.4M must not be used in multicluster systems.**

3 Designing an Off-Grid System

3.1 Procedure

It is fundamentally important for the economic viability and operational reliability of an off-grid system that it is designed based on demand. Aligning an off-grid system to the availability of PV energy as determined by geographic conditions as well as to the the energy behavior of the system user are both important components of the design.

As much information regarding an off-grid system is to be gathered as possible in order to facilitate an optimum design. It is imperative that information be gathered regarding the following:

- Intended purpose of the planned system
- Loads and utilization times
- Geographic characteristics of the planned installation site
- Possible energy generators
- Solar fraction (SF): Amount of PV energy as a proportion of the total energy supply in an off-grid system
- Battery bridging time

An initial design can be drawn up using the data gathered here which can provide information on the magnitude, the suitable energy suppliers and components.

The following sections describe the procedure for designing an off-grid system and build in part on one another. Following the sequence of the individual sections is recommended (for an example of designing an off-grid system, see (see Section 4, page 22)).

You can use the planning tools provided by SMA Solar Technology AG as a support aid:

- Off-Grid Questionnaire (see www.SMA-Solar.com)
- Sunny Design (see www.SMA-Solar.com)

3.2 Estimating the Electrical Loads

The power and energy consumption of the loads is of significant importance in off-grid systems. The main questions to be answered here are:

- Which electrical loads are to be supplied by the off-grid system?
- How high will the energy consumption be per year or per day?
- What will be the maximum power in a day?

For orientation purposes, the following table gives an overview of popular loads, their power and their typical operating times per day.

Electrical loads	Nominal power	Typical operating time per day	Energy consumption per day
Air conditioner	3000 W	2 h	6 kWh
Dryer	1000 W	4 h	4 kWh
Washing machine	2000 W	1 h	2 kWh
Cooker (hob and oven)	2300 W	0.75 h	1.7 kWh
Dishwasher	1300 W	1 h	1.3 kWh
Water pump	200 W	3 h	0.6 kWh
Computer	250 W	2 h	0.5 kWh
Freezer 200 L	100 W	5 h	0.5 kWh

Electrical loads	Nominal power	Typical operating time per day	Energy consumption per day
Kettle	1800 W	0.25 h	0.45 kWh
Refrigerator	90 W	5 h	0.45 kWh
Vacuum cleaner	1800 W	0.25 h	0.43 kWh
Television (screen size 28")	100 W	4 h	0.4 kWh
Microwave oven	1200 W	0.25 h	0.3 kWh
Toaster	1200 W	0.25 h	0.3 kWh
Hairdryer	1000 W	0.25 h	0.25 kWh
Iron	1000 W	0.25 h	0.24 kWh
Printer	100 W	2 h	0.2 kWh
Amplifier	100 W	2 h	0.2 kWh
Heating circulation pump	70 W	2 h	0.14 kWh
Energy saving lamp	15 W	4 h	0.06 kWh
Satellite receiver	18 W	3 h	0.054 kWh
Mixer	200 W	0.25 h	0.05 kWh
DVD player	15 W	2 h	0.03 kWh
Sewing machine	80 W	0.25 h	0.02 kWh
Radio	5 W	3 h	0.015 kWh
Shaver	15 W	0.25 h	0.0038 kWh

3.3   Sunny Island and Multicluster-Box Design

3.3.1   Recommendations on the Selection of Sunny Island / Multicluster-Box

The following information is necessary in order to determine the number of Sunny Island devices necessary in single-phase systems:

- Maximum power drawn by the loads per day (P_{max})
- Power of the Sunny Island inverter for 30 minutes at 25°C ($P_{30\ min}$)

Calculation:

Number of inverters Sunny Island = P_{max} : $P_{30\ min}$

Information on three-phase systems

The number of devices necessary in three-phase systems can be determined using the same method as that specified for single-phase systems. The result must, however, be rounded up to the next highest number that is divisible by three. This ensures that the inverters can be distributed symmetrically across the line conductors (see Section 3.3.2, page 14). Loads and generators must be distributed evenly over the 3 line conductors.

3.3.2 Sunny Island Inverter Selection

☐ **Power-temperature curve**

The active power specified for the Sunny Island is dependent on the ambient temperature (see the Sunny Island inverter datasheet for the power to temperature ratio). If constantly high ambient temperatures are to be expected at the planned installation site, a Sunny Island with a higher rated power than is necessary for the load requirements should be selected.

Device type	Rated power	Power for 30 minutes at 25°C	Application			
			Single System	Single-phase single-cluster system	Three-phase single-cluster system	Multicluster system
SI4.4M-12 / SI4.4M-13 (Sunny Island 4.4M)	3300 W	4400 W	yes	no	yes	no
SI6.0H-12 / SI6.0H-13 (Sunny Island 6.0H)	4600 W	6000 W	yes	yes	yes	yes
SI8.0H-12 / SI8.0H-13 (Sunny Island 8.0H)	6000 W	8000 W	yes	yes	yes	yes

3.3.3 Multicluster-Box Selection

Device type	Rated power	Number of inverters	Number of clusters
MC-BOX-6.3-11 (Multicluster-Box 6)	55 kW	6	2
MC-BOX-12.3-20 (Multicluster-Box 12)	138 kW	12	4
MC-BOX-36.3-11 (Multicluster-Box 36)	300 kW	36	12

3.4 Battery-Storage System Design

The battery capacity necessary, the battery voltage and the suitable battery type are decisive factors when selecting the battery.

Battery capacity

The starting point when selecting a battery is the necessary battery capacity. The necessary battery capacity depends primarily on the following factors:

- Bridging time

  The bridging time is the time period, in days, for which the off-grid system can supply the loads exclusively from the battery. For off-grid systems with generators, a bridging time of 1 day should be expected.

- Energy consumption per year (E_{Anno})

  The energy consumption in the off-grid system to be expected per year is dependent on the loads installed and their energy requirements (see Section 3.2, page 12).

- Average battery efficiency during electric discharge (η_{Batt})

  For off-grid systems, the average battery efficiency when discharging is approximately 0.9.

The battery capacity is normally specified in kWh or Ah.

Calculation:

$$\text{Usable battery capacity [kWh]} = \frac{\text{Bridging Time} \cdot \dfrac{E_{Anno}}{365}}{\eta_{Batt}}$$

$$\text{Usable battery capacity [Ah]} = \text{Battery capacity [kWh]} \cdot \frac{1000}{\text{Nominal battery voltage}}$$

[i] **Observe the usable battery capacity**

In order to achieve the longest possible battery service life, only the usable range of the battery should be used for charging and discharging. The battery capacity calculated here is based on this usable range. With lead-acid batteries, a usable range of approximately 50% of the nominal capacity is typical, with that of lithium-ion batteries being approximately 80% (see battery manufacturer documentation). If the battery manufacturer specifies a depth of discharge of 100%, SMA recommends for safety reasons that a depth of discharge of only 90% be expected.

[i] **Observe standard sizes**

Batteries are not available in all sizes. Battery manufacturers offer standard sizes. Selecting the next highest standard size is to be recommended. Observe the usable battery capacity when selecting.

[i] **Not the minimum battery size**

Minimum battery capacity in terms of lead-acid batteries: 100 Ah per installed kWp of a PV system
Minimum battery capacity in terms of lithium-ion batteries: 50 Ah per installed kWp of a PV system

[i] **Lithium-ion batteries in off-grid systems**

In order to meet the requirements of off-grid applications, the Sunny Island has a high overload capacity. To be able to use this overload capacity, the output powers and output currents must be taken into consideration when selecting the battery. Clarify whether the battery can supply these currents. Note the list of approved batteries (see Technical Information) and the data sheets as well as the minimum configuration list of the manufacturer, if applicable.

Nominal battery voltage

All Sunny Island devices use batteries with a nominal voltage of 48°V.

Battery type

The Sunny Island is compatible with the following battery types:

- Lead-acid batteries

  The battery room must be ventilated in accordance with the battery manufacturer specifications and with the locally applicable standards and directives (see battery manufacturer documentation).

  Lead-acid batteries of the designs VRLA and FLA are used with Sunny Island devices.

- Lithium-ion battery

  If connecting a lithium-ion battery, the following must be observed:

  – The battery must comply with the locally applicable standards and directives and must be intrinsically safe.

  – The lithium-ion battery must be approved for use with the Sunny Island. The list of lithium-ion batteries approved for the Sunny Island is updated regularly (see the technical information "List of Approved Batteries" at www.SMA-Solar.com).

  – If none of the lithium-ion batteries approved for use with the Sunny Island can be used, lead-acid batteries must be used.

DC fuse

The external DC fuse protects the battery connection lines of the battery inverter. Furthermore, the DC fuse enables DC-side disconnection of the battery inverter.

A DC fuse must always be installed between the battery and the Sunny Island. SMA Solar Technology AG recommends the use of a DC fuse specially aligned for use with the Sunny Island from enwitec electronic GmbH & Co.KG.

The fuse links in the DC fuse must also be aligned for the Sunny Island (see Sunny Island battery inverter installation manual).

3.5   PV System Design

3.5.1   Estimation of the Nominal PV System Power

Influencing factors

The nominal PV system power depends on the following factors:

- Energy consumption per year (E_{Anno})
- System efficiency (η_{Sys})

  The system efficiency is approx. 0.7.

- Solar fraction (SF): Amount of PV energy as a proportion of the total energy supply in an off-grid system

  The solar fraction depends on the amount of PV energy typically available at the installation site.

- Specific PV energy yield (E_{PV})

  The specific energy yield depends on the amount of energy typically available at the installation site and on the nominal PV system power.

Energy yield from PV energy and reasonable proportion of PV energy in the off-grid system:

Region (examples)	Specific energy yield per year[1]	Solar fraction of the energy supply
Germany	800 kWh / (kWp × a) to 900 kWh / (kWp × a)	50% to 70%
Southern Europe	1300 kWh / (kWp × a) to 1450 kWh / (kWp × a)	60% to 90%
North Africa, South Africa or South America	1450 kWh / (kWp × a) to 1700 kWh / (kWp × a)	60% to 100%
Saudi Arabia	1800 kWh / (kWp × a)	60% to 100%

Calculation:

An approximation of the nominal PV system power can be calculated using the above listed values.

$$P_{PV} = E_{Anno} \cdot \frac{1}{\eta_{Sys}} \cdot \frac{SF}{E_{PV}}$$

Information on design

The design of the PV array and selection of the PV inverter is based on the required nominal PV system power.

- The nominal PV system power results from the rated powers of the PV inverter used (see Section 3.5.2, page 17).

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[1] Example: 1000 kWh / (kWp × a) corresponds to a specific energy yield of 1000 kWh in 1 year per 1 kWp of installed nominal PV system power.

- In off-grid systems, the nominal PV system power may not be more than double the total nominal AC power of the Sunny Islands inverters (see Section 3.3, page 13).
- When using lead-acid batteries, the battery capacity per installed kWp of the PV array must be at least 100 Ah. Example: The minimum battery capacity is 500 Ah in case of a PV array with 5 kWp (see Section 3.4, page 14).
- When using lithium-ion batteries, the battery capacity per installed kWp of the PV array must be at least 50 Ah. Example: The minimum battery capacity is 250 Ah in case of a PV array with 5 kWp (see Section 3.4, page 14).

3.5.2 Selecting the PV Inverter

You can install the following PV inverters in off-grid systems. The PV inverters must be equipped with the firmware version stated in the table or higher. If this is not the case, perform a firmware update (see PV inverter documentation).

PV inverter	from firmware version	Information
Sunny Boy (SB)		
SB1.5-1VL-40 / SB2.0-1VL-40 / SB2.5-1VL-40	2.05.01.R	–
SB3.0-1AV-40 / SB3.6-1AV-40 / SB4.0-1AV-40 / SB5.0-1AV-40	1.2.18.R	–
SB3.0-1AV-41 / SB3.6-1AV-41 / SB4.0-1AV-41 / SB5.0-1AV-41 / SB6.0-1AV-41	1.2.18.R	–
SB 3000TL-20 / SB 4000TL-20 / SB 5000TL-20	2.51.02.R	–
SB 3000TL-21 / SB 3600TL-21 / SB 4000TL-21 / SB 5000TL-21 / SB 6000TL-21	2.60.03.R	–
Sunny Tripower (STP)		
STP3.0-3AV-40 / STP4.0-3AV-40 / STP5.0-3AV-40 / STP6.0-3AV-40 / STP8.0-3AV-40 / STP10.0-3AV-40	2.13.07.R	[2]
STP 8000TL-10 / 10000TL-10 / 12000TL-10 / 15000-TL-10 / 12000TL-10	2.22.17.R	[2]
STP 5000TL-20/STP 6000TL-20/STP 7000TL-20/STP 8000TL-20/ STP 9000TL-20/STP 10000TL-20/STP 12000TL-20	2.50.01.R	[2]
STP 15000TL-30 / STP 20000TL-30 / STP 25000TL-30	2.83.03.R	[2]
STP 50-40 / STP 50-41	1.1.19.R	[2]
STP 12-50 / STP 15-50 / STP 20-50 / STP 25-50	1.10.12R	[2]
Sunny Highpower (SHP)		
SHP 100-20	3.10.04.R	[2]
SHP 100-21	4.02.02.R	[2]

Maximum PV system power

In off-grid systems, the maximum PV system power depends on the total power of the Sunny Island inverters.

- Maximum output power of the PV system per SI4.4M: 4600 W
- Maximum output power of the PV system per SI6.0H: 9200 W

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[2] Can only be used in three-phase off-grid systems

- Maximum output power of the PV system per SI8.0H: 12000 W

The maximum output power of the PV system must be observed to ensure stable operation of the off-grid system.

Configuration of Stand-Alone Mode

All mentioned inverters can be configurated for the stand-alone mode. To do this, there must be selected a country data set valid for the stand-alone mode or a valid set country standard (see the PV inverter documentation).

3.6 Generator Design

The nominal power of the generator(s) should be approximately 80% to 120% of the total nominal power of the planned battery inverter. Preferentially, this value should be below 100%; this ensures that the utilization of the generators will always be optimal. This will ensure a long service life as well as good utilization of the fuel, e.g. the diesel.

3.7 Estimating the PV System Costs

Using the rough design laid out here, an initial estimation of the PV system costs can be calculated. The costs in the estimation shown here comprise of:

- Battery inverter costs
- Battery-storage system and DC fuse costs
- PV system costs (modules and PV inverter)
- Generator costs
- Mounting and installation costs

Due to the variety of options for the systems, not all possible positions can be taken into consideration. Additional positions can be taken into consideration in a more specific calculation.

3.8 Planning Tools

3.8.1 Data Gathering with the Off-Grid Questionnaire

The SMA Solar Technology AG Off-Grid Questionnaire enables the systematic gathering of all information that is necessary for designing an off-grid system (download available at www.SMA-Solar.com). The Off-Grid Questionnaire can be used as preparation for designing the PV system later.

3.8.2 PV System Design with Sunny Design

Sunny Design is a software package for planning and designing PV systems and PV hybrid systems. Sunny Design provides you with recommendations on possible designs for your PV system or your off-grid system.

The print version of the Sunny Design user manual can be found in the download area at https://www.sma.de/service/downloads.html.

The online version Sunny Design Web can only be used via the internet (www.SunnyDesignWeb.com).

After registration in Sunny Design Web, different PV systems can be calculated and saved for further calculations or adjustments.

We will show you the design of an off-grid system in the following example:

1. On the home page under **Projects > New**, select **Off-grid system** as new project.
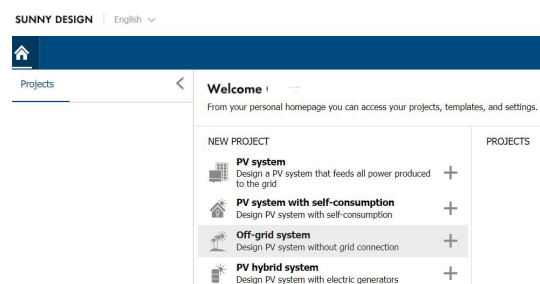
2. Enter the project data such as **Project name**, **Location of the building** and **Electrical connection of the system** in the **Project data** menu.
   Once all required data have been entered, select [**Define load profile**].
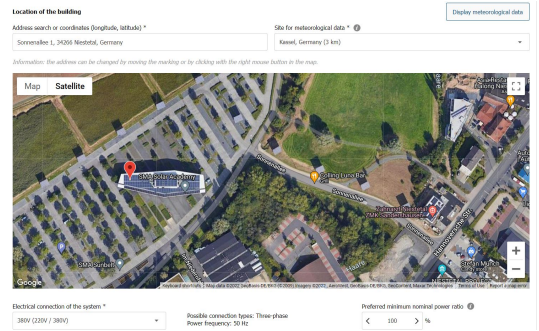
3. In the **Load profile** menu, the load profile must be defined.
   On the YouTube channel by SMA Solar Technology there are videos in German and English that exactly describe how you can define a load profile with Sunny Design.
   In addition, there are also predefined load profiles to choose from.
   After entering the data, click on [**Configuration of the PV system**].

4. In the **PV system** menu, first configure the **PV arrays**. These can be defined visually depending on the roof or manually.
   When you select **Manual planning**, you can enter the PV array power manually or have it calculated automatically via the **System assistant** of the program.

5. When you select [**Calculate system proposal**], the system assistant calculates a proposal which you can edit and accept.
   Information: This calculation should definitely be verified.
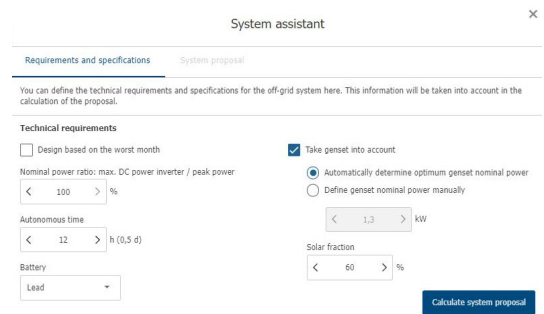
☑ The system assistant also calculates the size and power of battery and photovoltaics as well as their inverters.

6. To verify the calculation made by the system assistant, either select [**Battery system configuration**] or **Battery system** in the menu bar.
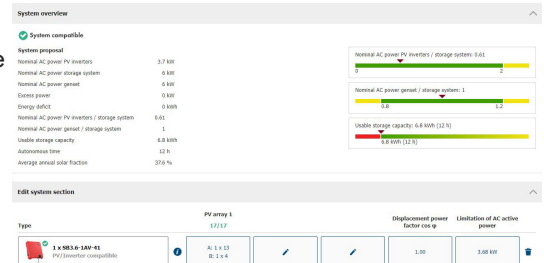
7. If a diesel generator is present, this can be adjusted in the **Genset** menu. The automatically calculated size of the generator (kVA), should be verified by you.

8. To calculate the cable cross-sections either select [**Cable sizing**] or **Cables** in the menu bar.

☑ In the menu **Analyses of the energy and power in the system**, energy and power of the PV system are displayed in an overview as well as in a simulation of how these values are distributed within the system and which energy sources the system supplies. The solar irradiation different by the month is shown in the annual distribution forecast.

Analyses of the energy and power in the system ⓘ

You will receive an analysis of the energy flows and the power distribution in the system here.

Power

✓ System compatible

System proposal

Nominal AC power PV inverters	3.7 kW
Nominal AC power storage system	6 kW
Nominal AC power genset	6 kW
Excess power	0 kW
Energy deficit	0 kWh
Nominal AC power PV inverters / storage system	0.61
Nominal AC power genset / storage system	1
Usable storage capacity	6.8 kWh
Autonomous time	12 h
Average annual solar fraction	37.6 %

Nominal AC power PV inverters / storage system: 0.61

0 — 2

Nominal AC power genset / storage system: 1

0.8 — 1.2

Usable storage capacity: 6.8 kWh (12 h)

6.8 kWh (12 h)

Energy

Energy distribution

2,242 kWh

3,728 kWh

4,028 kWh ➡ ➡ 2,557 kWh

Details

Annual energy consumption	4,500 kWh
Max. available PV energy	4,007 kWh
Used PV energy	2,242 kWh
Directly consumed PV energy	1,449 kWh
Intermediately stored PV energy	793 kWh
Annual nominal energy throughputs of the battery	294
Annual energy generation of the genset	3,728 kWh
Annual fuel consumption	1,256 l
Average annual solar fraction	37.6 %

Solar fraction

The solar energy flows per month are represented in this stack diagram. The solar fraction is the combined share of directly consumed and intermediately stored PV energy.

Solar fraction

Month

■ PV direct consumption ■ PV intermediate storage

☑ In the **Results** menu all information on your PV system is compiled:

Results ⑦

This overview shows the entries, results and current information on the design of the system. Check the information before creating the project documentation.

Project	New project	Customer	
Location	Sonnenallee 1, 34266 Niestetal, Germany	Address	

Project information

PV system		Storage system	
Total number of PV modules	17	Number of battery inverters	1
Peak power	4.08 kWp	Nominal AC power	4.60 kW
Number of PV inverters	1	30 minute peak AC power of the Sunny Island	6.00 kW
Nominal AC power of the PV inverters	3.68 kW	Batteries	Lead
AC active power	3.68 kW	Total nominal capacity	54.79 kWh
Active power ratio	90.2 %	Usable storage capacity	27.40 kWh
Max. available PV energy	4,007 kWh	Annual nominal energy throughputs of the battery	70
Energy usability factor	99.9 %	Intermediately stored PV energy	2,127 kWh
Spec. energy yield	982 kWh/kWp		
Line losses (in % of PV energy)	---	**Genset**	
Unbalanced load	3.68 kVA	Apparent power	6.00 kVA
Used PV energy	3,575.94 kWh	Active power	4.80 kW
Used PV share	89.2 %	Annual energy generation of the genset	1,892.95 kWh
PV share of the energy supply (during the day)	167.6 %	Annual fuel consumption	518 l
Average annual solar fraction	65.4 %	Average energy efficiency	---

System overview

Upload images	PV arrays:	17 x .SMA SMA Demo Poly 240W (PV array 1) Azimuth angle: 0 °, Tilt angle: 30 °, Mounting type: Roof, Peak power: 4.08 kWp
	PV inverter:	🟥 1 x SB3.6-1AV-41
	Battery inverter:	🟨 1 x Sunny Island 6.0H
	Batteries:	1 x Lead (54.8 kWh)

You can find further information on the design of off-grid system with Sunny Design Web in a tutorial on the YouTube channel of SMA Solar Technology AG.

A user manual specifically for the Sunny Design software can be downloaded in our download area at https://portals.sma.de.

4   Example of a Design of an Off-Grid System without Software

Initial values and necessary information

The following example describes designing an off-grid system in North Africa and serves as orientation and a starting point for in-depth system planning.

The following initial values have been specified:

- The energy requirements of the electrical loads is approximately 4500 kWh/year (see Section 3.2, page 12).
- The maximum power needed per day by the loads is 5 kW.
- The bridging time of the off-grid system is to be 2 days.
- The off-grid system is to be single-phase.
- One generator is to be installed to support the energy supply when the PV power available is low.

The following information is needed:

- How many Sunny Island inverters are to be installed?
- What is the battery capacity to be?
- Which PV inverters are to be installed and how many?
- What is the nominal power of the generator to be?

Step 1: Determining the number of Sunny Island inverters necessary

In this example, the Sunny Island 6.0H is to be installed (see Section 3.3.2, page 14).

Number of inverters Sunny Island = $P_{max} : P_{30\,min}$

Number of Inverters Sunny Island = 5 kW : 6 kW = 0.8

The result must be rounded up. Therefore, in this example 1 Sunny Island 6.0H is necessary.

Step 2: Determining usable battery capacity

The average system efficiency when discharging the battery is made up of the Sunny Island inverter efficiency and the battery efficiency. A good empirical value is the factor 0.9.

$$\text{Usable battery capacity [kWh]} = \frac{\text{Bridging Time} \cdot \dfrac{E_{Anno}}{365}}{\eta_{Batt}}$$

$$\text{Usable battery capacity [Ah]} = \text{Battery capacity [kWh]} \cdot \frac{1000}{\text{Nominal battery voltage}}$$

$$\text{Usable battery capacity [kWh]} = \frac{1 \text{ day} \cdot \dfrac{4500 \text{ kWh}}{365}}{0.9} = 13.7 \text{ kWh}$$

$$\text{Usable battery capacity [Ah]} = 13.7 \text{ kWh} \cdot \frac{1000}{48 \text{ V}} = 285 \text{ Ah}$$

In this example, the usable battery capacity is 13.7 kWh or 285 Ah.

In this example, for lead-acid batteries, the total or gross battery capacity would be 13.7 kWh / 50 % = 27.4 kWh or 570 Ah; for lithium-ion batteries it would be 13.7 kWh / 80 % = 17.125 kWh or 357 Ah.

| i | **Note the temperature limits of the manufacturer**

The temperature has impact on the usable battery capacity.

- Read the documentation of the battery manufacturer.

Based on the necessary battery capacity and the usable range of the nominal capacity, the battery to be used in the off-grid system can be selected (see Section 3.4, page 14).

Step 3: Determining the nominal PV system power

The off-grid system is to be installed in North Africa. This furnishes us with additional initial values to be used in the following calculation:

- It is recommended to accept the specific energy yield with 1450 kWh per year and per kWp of the nominal PV system power.

- It is recommended to accept the proportion of the PV energy of the energy supply of an off-grid system with 70%.

$$P_{PV} = E_{Anno} \cdot \frac{1}{\eta_{Sys}} \cdot \frac{SF}{E_{PV}}$$

$$P_{PV} = 4500 \text{ kWh/a} \cdot \frac{1}{0.7} \cdot \frac{70\%}{1450 \text{ kWh/(kWp} \cdot \text{a)}} = 3.10 \text{ kWp}$$

In this example, the nominal PV system power is 3.1 kWp. This means that a PV inverter with a rated power of at least 3100 W must be used in this system. The maximum rated power of the PV inverter is based on the selected Sunny Island. In the present example, the rated power can therefore be up to 9200 W (see Section 3.5.2, page 17).

A suitable design for the PV modules and the PV inverter as well as the correct cabling can be calculated simply using Sunny Design (see Section 3.8.2, page 18).

Step 4: Determining the nominal power of the generator

The nominal power of the Sunny Island inverter is 4600 W. This means that the nominal power of the generator should be between 3680 W (80%) and 5520 W (120%). In order that the generator is ideally utilized, a nominal power of less than 4600 W (100%) is recommended (see Section 3.6, page 18).

5 Visualization in Sunny Portal powered by ennexOS

For off-grid and remote PV systems, having the option of remote visualization and parameterization of the PV system parameters, PV performance, PV production and battery state of charge, diesel fill level, etc. is of great importance. Off-grid systems by SMA offer this functionality together with the Data Manager M or Data Manager M Lite via the Sunny Portal powered by ennexOS.

Figure 8: Sunny Portal powered by ennexOS, dashboard

In the **Monitoring > Energy balance** menu, you can choose from different diagrams.

If you select **Energy bar** on the right in the drop-down menu, a clear graphic of the energy flow of the system as well as the aggregated state of charge of all Sunny Island clusters is shown:

Figure 9: Representation of the energy flows in the energy balance menu

If you select **Energy sources** on the right in the drop-down menu, the different energy sources are shown:

Figure 10: Representation of the energy sources in the energy balance menu

In the **Monitoring > Energy and power** menu, all available energy and power values are shown.

The energy and power values of the batteries are shown under **Monitoring > Energy and power - battery**:
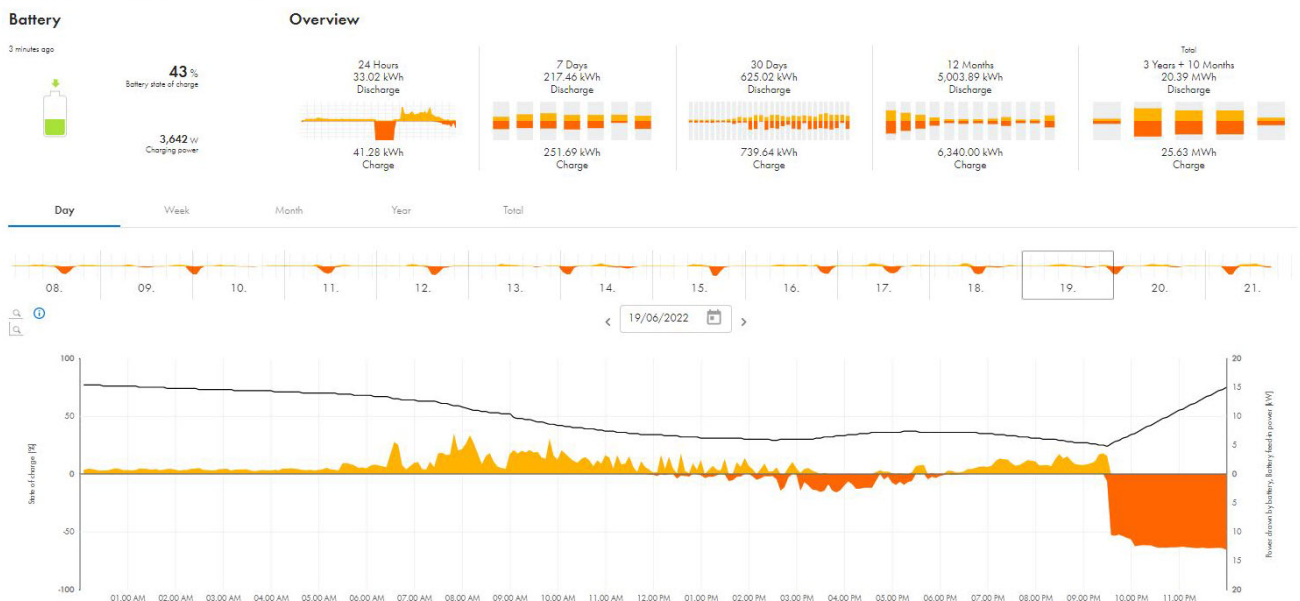
Figure 11: Energy and power values of the batteries (example)

The energy and power values of your PV system are shown under **Monitoring > Energy and power - PV**:
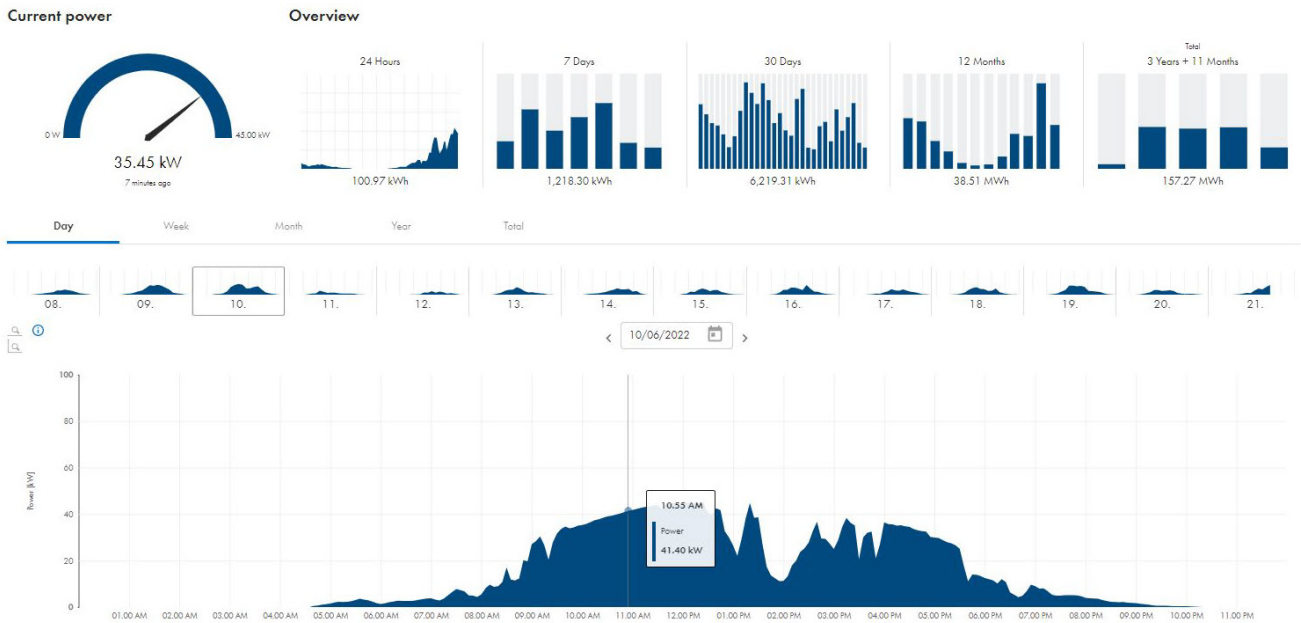
Figure 12: Energy and power values of the PV system (example)

The energy and power values of the diesel generator are shown under **Monitoring > Energy and power - diesel**. It also possible to add a diesel generator as a virtual generator in Sunny Portal powered by ennexOS which will then be shown in the energy balance. The associated measured data can be called up via the internal measurement of the Sunny Island, but also via an external meter.
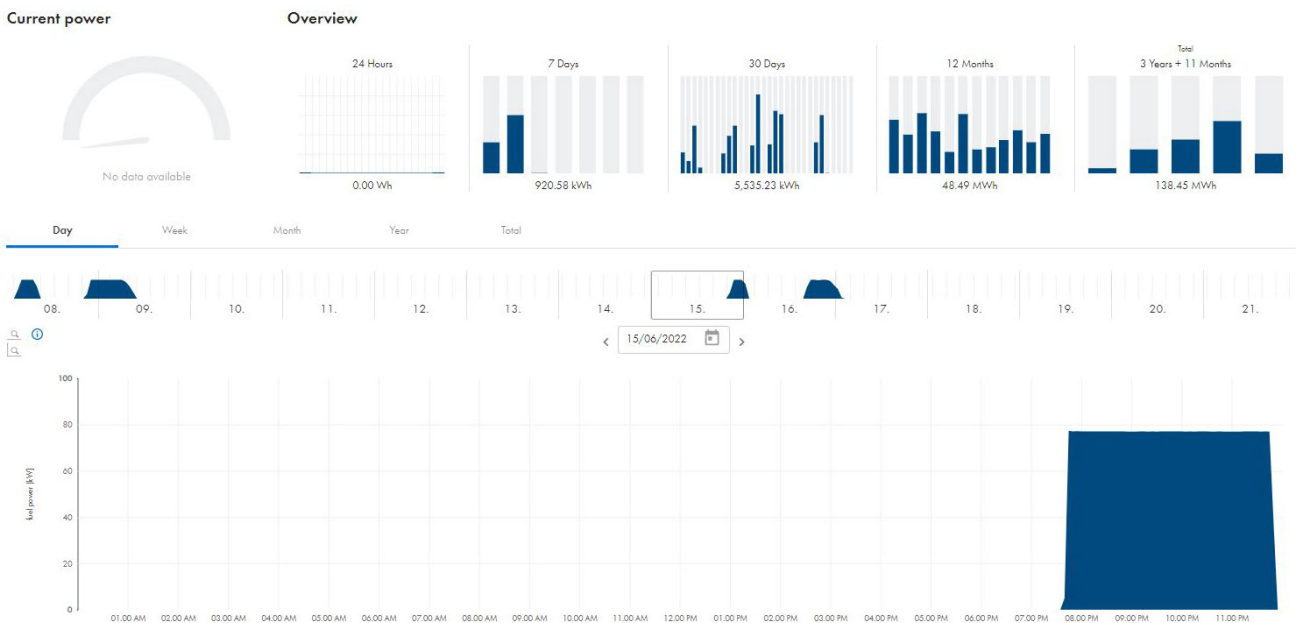
Figure 13: Energy and power values of the diesel generator (example)

In the menu **Analysis > Analysis Pro** it is possible to analyze a number of recorded AC and DC measured values as well states, warnings and error messages of the devices (PV inverters, battery inverters, etc.):
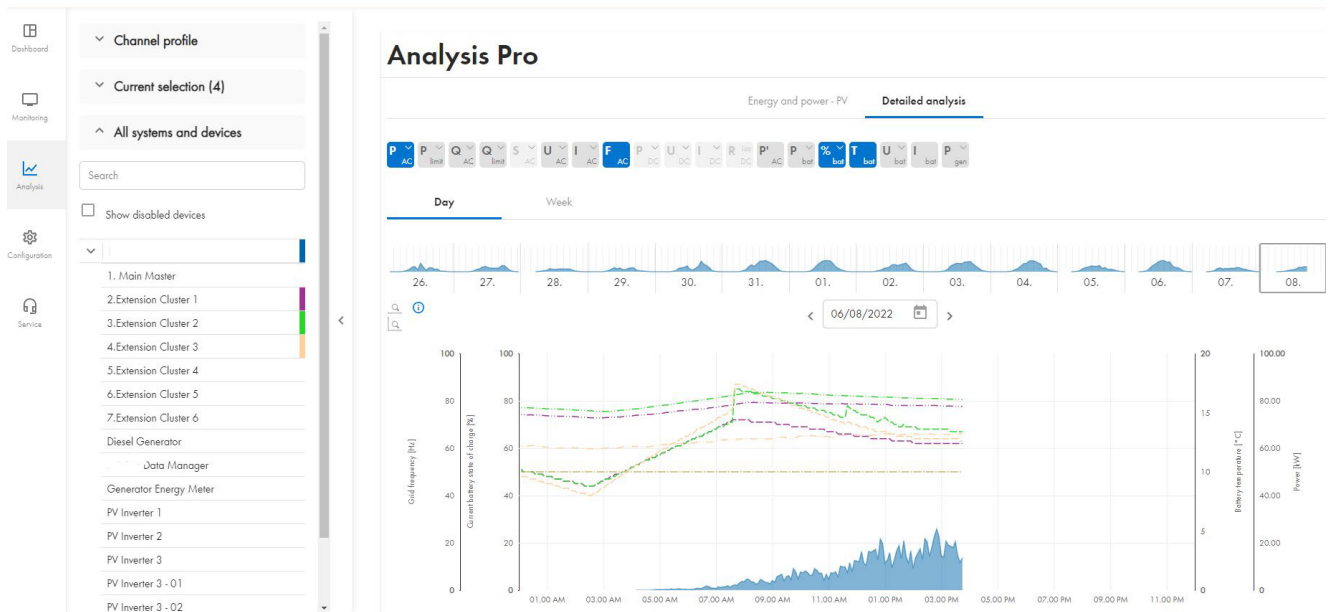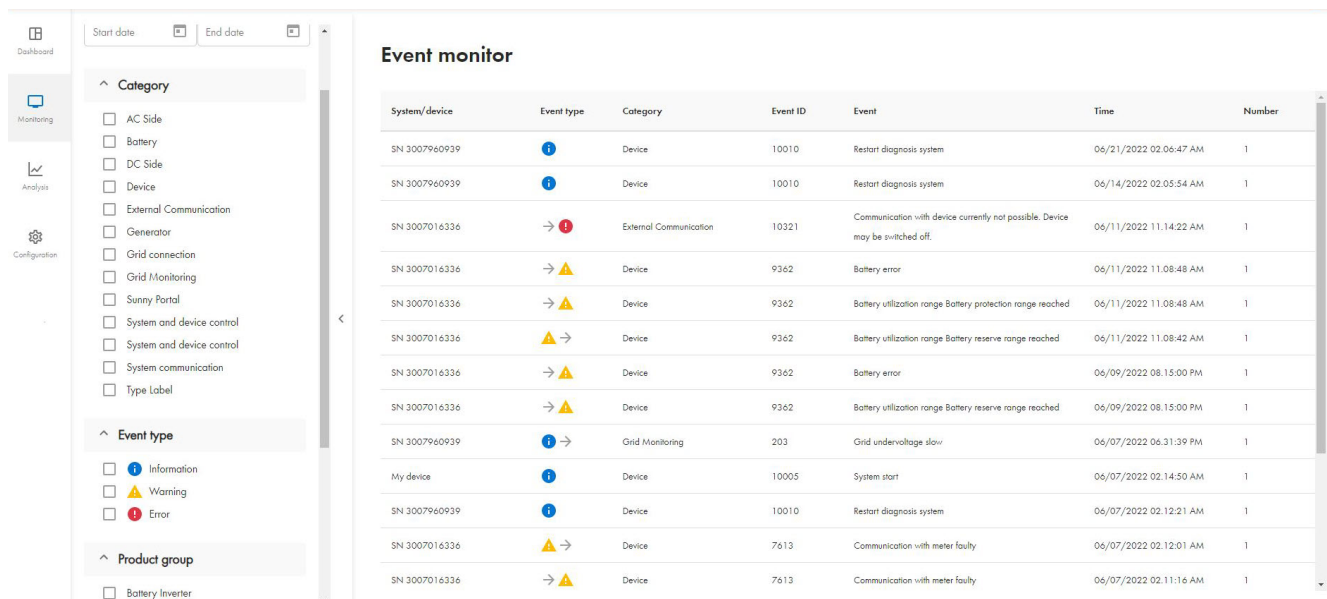
Figure 14: Data on the Analysis Pro page (example)

> **i** In the menu Analysis Pro, the measured data are always shown on the device with which they were measured. Therefore, the power of a diesel generator, for example, cannot be found among the virtual devices, but e.g. under the main cluster or an external energy meter.

Analysis Pro offers many more options for representation and analysis, for example:

- Comparison of PV production and PV inverter production
- Comparison of battery state of charge, voltage, charging and discharging current as well as with several clusters, the comparison of these values in various clusters
- Representation of AC frequency and voltage per line conductor
- Representation of active power, reactive power and apparent power per line conductor
- Representation of AC current per line conductor
- Representation of the energy balance of a virtually added diesel generator
- Via freely configurable analog and digital inputs, the fill level of a diesel tank can be displayed, for example.
- If you have solar irradiation, wind speed or temperature sensors installed, you can visualize and compare these data.
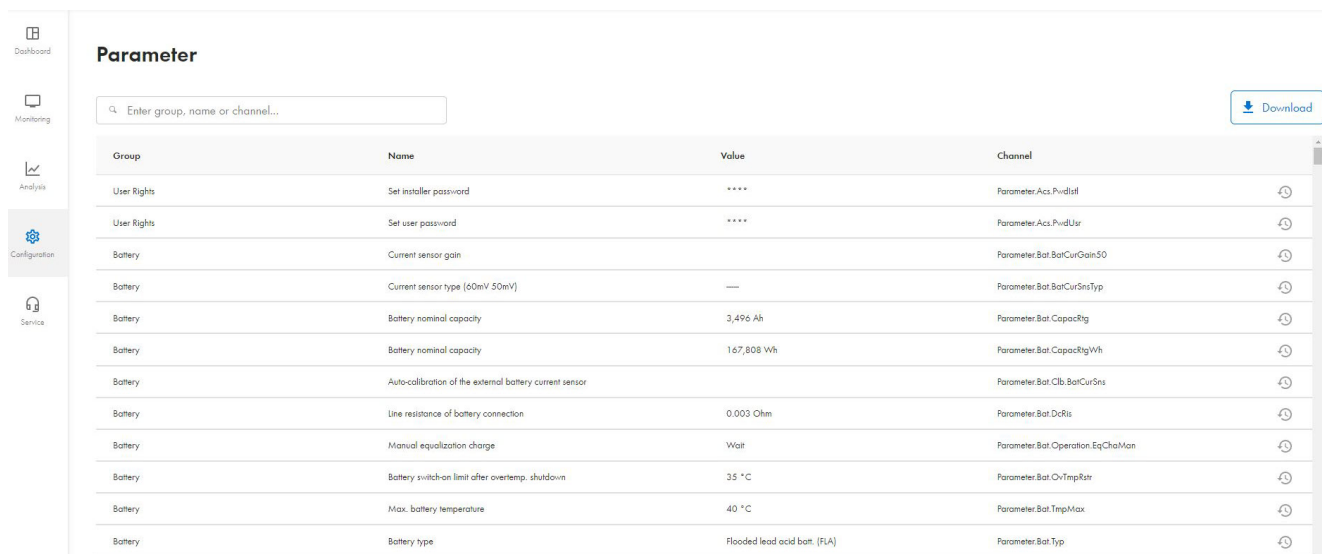
In the **Event monitor** area of the **Analysis Pro** menu, you can monitor information, warnings and error messages of the devices:

Figure 15: Data in the area Event monitor of the Analysis Pro page (example)

In the **Configuration** menu, you can carry out the remote parameterization of PV systems via the **Parameter** page For PV systems with Sunny Island, this is possible from firmware version 3.30.12.R.

> ℹ️ Many Sunny Island parameters can only be adjusted if the device is in standby mode. However, since the Sunny Island does not provide an AC grid in standby mode, you first must ensure the stand-alone mode either via the diesel generator or at least supply the Data Manager M and the internet router using an uninterruptible power supply (UPS) or a DC-DC converter with power from the battery.

The Sunny Portal powered by ennexOS has many other functions such as displaying additional measuring points (e.g. of certain loads) by means of installed energy meters. Various user rights can also be assigned as well as individual devices monitored separately.

6 Appendix

6.1 Accessories

The following overview provides a summary of the accessories available for your product. If required, these can be ordered from your distributor.

Designation	Brief description	SMA order number
SI-SYSCAN.BGx	Communication interface for communication between clusters in a multicluster system	SI-SYSCAN-NR
BAT-TEMP-SENSOR	Battery temperature sensor of the type KTY with connection line (length: 10 m)	BAT-TEMP-SENSOR

6.2 Additional Sunny Island Inverter Functions in the Off-Grid System

6.2.1 Grid- and Generator Management

6.2.1.1 Typical External Energy Sources

The Sunny Island enables switching over to the external energy source grid and disconnection from the grid. External energy sources are voltage sources and determine the voltage and frequency of the electricity grid. Typical external energy sources are generators and the utility grid.

Generators as an external energy source

A generator is used as an energy reserve in the off-grid system. If there is insufficient energy available for the loads from AC sources in the stand-alone grid (e.g. PV inverter), the Sunny Island can use the energy provided by a generator.

Possible generators	Explanation
Autostart generators	These generators are started and stopped with a single contact. This means that the Sunny Island can control the generator directly.
Generators without an autostart function	These generators do not have electric starting devices. These generators are started via a cable pull or a crank, for example.
Generators that can be remote-started electrically and do not have their own control system	These generators have 2 control contacts: one contact for the starter and one contact for ignition or for preheating. An external generator control device is necessary.

The utility grid as an external energy source

With the Sunny Island, you can use the utility grid in various ways:

- As an energy reserve
- As the main supplier of loads in the stand-alone grid

  If the utility grid is the main supplier of the loads, then this is a battery-backup system. If the utility grid fails, the Sunny Island disconnects the stand-alone grid from the utility grid and switches to stand-alone mode. In stand-alone mode, the Sunny Island supplies the stand-alone grid with energy from the battery.

Generators and the utility grid as external energy sources

The utility grid and a generator can also be connected to the off-grid system in combination. This is particularly useful in the event of long-term grid failures where the battery capacity is no longer sufficient to bridge the grid failure after a period of time. In the event of long-term grid failures, you can switch to the generator.

The generator and utility grid cannot feed electricity into the off-grid system at the same time. Therefore, switching between the generator and utility grid operation must be possible. Since the Sunny Island does not have an integrated automatic transfer switch, an external automatic transfer switch is necessary in systems with both a generator and the utility grid connected as external energy sources.

In multicluster systems with the Multicluster-Box 12 (MC-BOX-12.3-20), for example, the Grid-Connect-Box takes on the role of the automatic transfer switch.

6.2.1.2   Synchronization of the Stand-Alone Grid with External Energy Sources

Synchronization enables the Sunny Island to connect the stand-alone grid to the external energy source.

If external AC voltage is present at the Sunny Island, the Sunny Island synchronizes the stand-alone grid with the external AC voltage. When the stand-alone grid is synchronized with the external energy source, the Sunny Island closes its internal transfer relay. When the internal transfer relay is closed, the external energy source determines the voltage and frequency in the stand-alone grid.

6.2.1.3   Interactions between External Energy Sources and the Stand-Alone Grid

External energy sources have an influence on the power control of the AC sources (e.g. on PV inverters). The Sunny Island regulates the power output of the connected AC sources via the stand-alone grid frequency. The higher the stand-alone grid frequency, the lower the amount of power that is fed into the stand-alone grid from the PV inverters and the wind power inverters (see Section 6.2.3, page 31).

If you start a generator manually, the Sunny Island synchronizes the frequency of the stand-alone grid with the frequency of the generator voltage and connects the stand-alone grid to the generator voltage. This means that the Sunny Island can no longer use the frequency of the stand-alone grid to regulate the AC sources in the stand-alone grid. Power regulation of the AC sources in the stand-alone grid is not possible during synchronization.

6.2.2   Load Control

6.2.2.1   Overload Capacity

The Sunny Island is optimized for both thermal- and electrical overload conditions. It adjusts the maximum power directly to the ambient conditions.

With the patented OptiCool cooling system, SMA Solar Technology AG offers a technical solution that combines both passive- and active cooling together. The intelligent temperature management system comprises of a two-chamber system with a water-tight area for the electronics and an airflow-ventilated area with the relevant heat sources. This ensures exceptional protection with extraordinary overload behavior and the greatest level of reliability.

In the event of high inrush currents, soft start functions are activated: The Sunny Island 6.0H/8.0H can supply a current of 120 A for 60 ms. The inverter supplies overcurrent at a magnitude of 2.5 for up to 3 s. Only then – for example in the event of a permanent short circuit – is the device disconnected for safety reasons. 16 A circuit breakers with B characteristic are triggered within 100 ms, also satisfying the safety requirements of grid-parallel installations.

6.2.2.2   Load Shedding

Load shedding prevents battery deep discharge and controls the supply of energy to the loads. Load shedding provides the option of disconnecting specific loads from the system.

Load shedding is necessary for an off-grid system that is exclusively supplied with PV energy or wind energy.

The Sunny Island controls up to two load-shedding contactors depending on the state of charge of the battery. You can install two types of load shedding:

- One-level load shedding
  If the battery state of charge limit has been reached, one load-shedding contactor disconnects all loads at the same time. Depending on the configuration, the load-shedding contactor closes when the battery has been sufficiently charged or when the stand-alone grid has been switched to an external energy source.

- Two-level load shedding
  In two-level load shedding, there are two thresholds for the state of charge of the battery in order to control two load-shedding contactors. When the first threshold for the state of charge of the battery is reached, the first load-shedding contactor disconnects a group of loads. When the second threshold for the state of charge of the battery is reached, the second load-shedding contactor disconnects the remaining loads.

6.2.3 Frequency Shift Power Control

If PV inverters are connected on the AC side in stand-alone mode, the Sunny Island must be able to limit their output power. This limitation becomes necessary when, for example, the Sunny Island inverter battery is fully charged and the PV power available from the PV system exceeds the power requirement of the connected loads.

To prevent the excess energy from overcharging the battery, the Sunny Island recognizes this situation and changes the frequency at the AC output. This frequency change is monitored by the PV inverter. As soon as the power frequency increases beyond the value specified in **f Start Delta**, the PV inverter limits its output power accordingly.
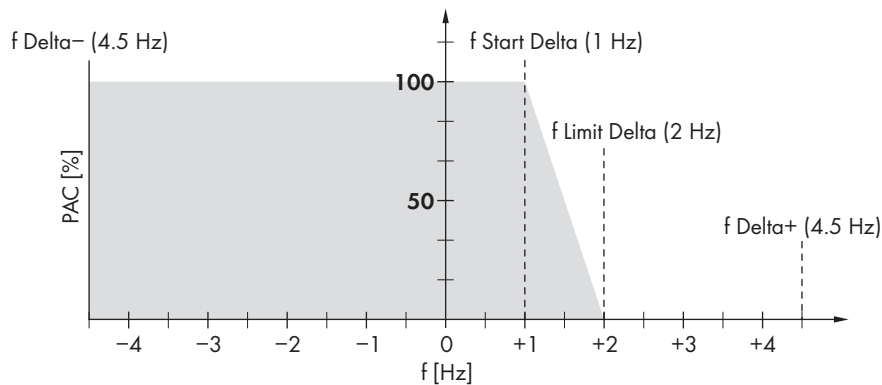
Figure 16: Function of the frequency shift power control

Designation	Explanation
f	Base frequency of the stand-alone grid (50 Hz)
f Delta- to **f Delta+**	Maximum range in relation to the base frequency in which the PV inverter is active.
f Start Delta	Frequency increase in relation to the base frequency, at which point the power regulation via frequency begins.
f Limit Delta	Frequency increase in relation to the base frequency, at which point the power regulation via frequency ends.
	The power of the PV inverter at this point is 0 W.

If the frequency falls below the limit **f Delta-** or exceeds the limit **f Delta+**, the PV inverters disconnect from the stand-alone grid. If a generator is operating in the stand-alone grid, the generator determines the frequency and the PV inverters react to certain frequency changes due to the generator. With generators, the frequency of the output voltage under load is 50 Hz. For this reason, in most cases the PV inverters will feed their entire power into the stand-alone grid, even when the generator is in operation. If the current battery voltage is greater than the rated battery voltage and is also to be synchronized with a generator, the Sunny Island will temporarily increase the frequency and the PV inverters will disconnect from the stand-alone grid via frequency control (overfrequency). The Sunny Island then synchronizes with the generator.

6.2.4 Control and Monitoring via Internal Multifunction Relay

Using 2 multifunction relays, each Sunny Island can control various functions and can display operating states and warning messages.

Possible function or output	Explanation
Control of generators	The multifunction relay activates if a generator request is received from the Sunny Island inverter's generator management system. With the multifunction relay, you can control generators with an electrical remote-start function or connect a signal generator for generators with no autostart function.
Controlling load-shedding contactors	The multifunction relay is activated depending on the state of charge of the battery. Depending on the configuration, you can install a one-level load shedding with 1 multifunction relay or a two-level load shedding with 2 multifunction relays. You can also adjust the thresholds for the battery state of charge to be dependent on the time of day (see the Sunny Island inverter installation manual).
Time control for external processes	The multifunction relays can be time-controlled (see the Sunny Island inverter installation manual).
Display of operating states and warning messages	Each multifunction relay can display either one event or one warning message (see the Sunny Island inverter installation manual).
Control of a battery-room fan (applies to lead-acid batteries)	The multifunction relay is activated when the charging current causes the lead-acid battery to emit gasses. A connected battery room fan is switched on for at least one hour (see the Sunny Island inverter installation manual).
Control of an electrolyte pump (applies to lead-acid batteries)	Depending on the nominal energy throughput, the multifunction relay is activated at least once a day (see the Sunny Island inverter installation manual).
Use of excess energy	In off-grid systems, a multifunction relay is activated during the constant voltage phase, and thus controls additional loads (see the Sunny Island inverter installation manual). By switching on additional loads, any excess energy that may be available and which would otherwise have to be dissipated can be put to good use.

6.2.5 Operation and User Guide

The basis of the Sunny Island inverter operation concept is the "single point of operation". All settings, switching procedures and system variables can be summarized and thus displayed and changed on a single display.

The "single point of operation" allows for a closed system overview and enables the setting of parallel units and connected charge controllers to be performed from one device. Information on external sources or loads can be viewed, because all automatic switching procedures are also activated via the battery inverter. Via an internal communication structure, all relevant information is shared between system components that support this function.

6.2.6 Data Recording and Data Storage

A major part of the internal operation menu is concerned with the history of all operating states arising. Peak values and important information and events are stored in an internal, permanent memory. An integrated data recording system records all measurements, calculations and evaluations. Thus, a comprehensive picture of all activities – from charging procedures through to automatic load shedding – can be built up.

With the SMA Cluster Controller, the Sunny Island inverter data recording capabilities can be expanded simply. For example, simple and comprehensive remote monitoring is made possible.

6.3   Further Information on Battery Management for Lead-Acid Batteries

6.3.1   Advantages of Battery Management

The Sunny Island inverter battery management system for lead-acid batteries is based on a very accurate determination of the state of charge. By combining the three most common methods for recording the state of charge, the Sunny Island reaches a measuring accuracy of more than 95%. This way, battery overcharge and deep discharge are avoided.

Another feature of the battery management system is the extremely gentle charging control. It automatically selects the optimum charging strategy for the battery type and the situation in which it is used. This means that overcharging can be reliably prevented and that the battery can be fully charged regularly. Use of the available charging power is always optimized.

6.3.2   Battery State

6.3.2.1   Nominal Capacity and Battery Aging

| i | **Nominal capacity as specified by the battery manufacturer**

> The nominal capacity is specified by the battery manufacturer as being the amount of energy that can be drawn from the battery over a specified discharging period. If, for example, a current of 20 A can be drawn from a fully charged battery for ten hours, then this battery has a nominal capacity of 200 Ah. Because of the ten-hour discharge duration, the specification of the nominal capacity of 200 Ah must be accompanied by the suffix C10.
>
> In order to be able to compare the nominal capacity of different batteries meaningfully, the nominal capacity of each battery must be based on the same discharge duration (see battery manufacturer documentation).

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**

  The usable battery capacity drops over time (even if the battery is not used).

- **Cycling**

  The battery ages through use. This aging is mainly influenced by the depth of the discharge cycles.

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

6.3.2.2   Current State of Charge

The battery management system displays the current state of charge of the battery (SOC) as the parameter **Current battery state of charge** and the estimated error of the state of charge as the parameter **Fault battery state of charge**.

The estimated error of the state of charge provides information regarding the accuracy of the currently calculated battery state of charge. The estimated error is at its lowest immediately after a full charge or equalization charge and then increases over time until the next completed full charge or equalization charge.

6.3.2.3   Current Usable Battery Capacity

The battery management system displays the current usable battery capacity expressed as a percentage of the nominal capacity as the value SOH (state of health). After commissioning, the Sunny Island adopts the set nominal capacity (Parameter **Rated battery capacity**) as the usable 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 in which the battery is operated cyclically. Furthermore, there must also be regular idle phases during which the battery is not charged and is only operated under low electrical loads. A low electrical load is approximately 1.5% of the nominal capacity for a ten-hour electric discharge, e.g. 150 W for a 10 kW battery. It is therefore important to regularly check the state of health, especially in the first few months after the Sunny Island has been commissioned.

The Sunny Island is able to determine the state of health with an accuracy of ±15%. To determine a more accurate state of health, the battery capacity must be measured. For this, electrically qualified persons with special measuring equipment must be on site, e.g. members of the battery manufacturer service staff.

Effect of the battery temperature on the current usable battery capacity

The current usable battery capacity depends on the temperature of the battery. At temperatures of 20°C and below, the usable capacity of a battery drops significantly. The battery management system corrects the usable battery capacity state of health by -1% per °C, starting from 20°C.

6.3.2.4   Battery Temperature

The battery management system continuously monitors the battery temperature. The Sunny Island adjusts the specification of the current usable battery capacity and the charging voltage to the current battery temperature (see Section 6.3.5, page 36).

The battery management system 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 off. As soon as the battery has cooled down to a specified temperature, the Sunny Island restarts.

6.3.3   Charging Phases

The parameters stated can be adjusted to the values specified by the manufacturer of the installed battery.
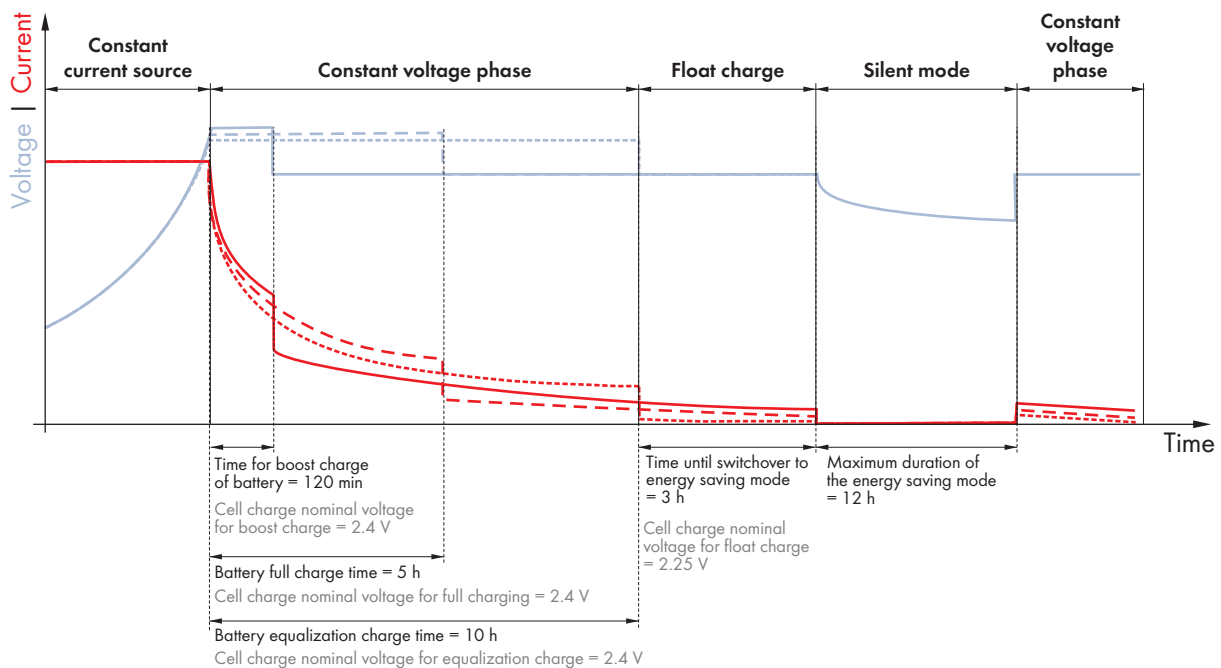

Figure 17: Sunny Island inverter charging phases with sample values for an AGM battery.

The Sunny Island regulates 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 phase (V phase)

When operating on the utility grid and Silent Mode is active, there is also a silent phase.

Constant current phase

During the constant current phase, the primary task of the battery management system is to limit the current to the maximum permissible battery current. The maximum charging current can be limited to the value specified by the battery manufacturer by changing the parameter **Max. battery charging current**. The battery charging current available is also limited by the following parameters:

- Nominal currents of the external energy sources (parameters **Maximum current from public grid** and **Rated generator current**)
- Maximum AC charging current of the Sunny Island inverter (parameter **Maximum AC battery charge current**)

The first value to be reached limits the battery charging current. While the charging current is maintained within the thresholds specified, 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 respective battery type.

Constant voltage phase

In the constant voltage phase, the battery voltage is kept at a constant value. As a result, the battery current decreases continuously. For the constant voltage phase, the battery management system selects one of the following three charging processes (see Section 6.3.4, page 36):

- Boost charge
- Full charge
- Equalization charge

For each of these three charging processes, you can adjust the voltage and charging time to the levels specified by the battery manufacturer in the Sunny Island. Once the specified charging time has been reached, the constant voltage phase ends and the Sunny Island switches to the float charge phase.

Float charge

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

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

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

Silent mode

In silent mode, the Sunny Island switches to standby, thus saving energy. Once the time set for the float charge (parameter **Time until change-over to energy saving mode**) expires in systems connected to the utility grid, the battery management system switches to silent mode and any connected loads are supplied exclusively from the utility grid. The Sunny Island leaves the silent mode in adjustable intervals (parameter **Maximum duration of the energy saving mode**) or when the battery voltage per cell drops by 0.14 V. This way, the battery always remains fully charged.

6.3.4   Charging Processes

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

- Boost charge
- Full charge
- Equalization charge

Boost charge

With the boost charge process, 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 **Cell charge nominal voltage for boost charge**) and the duration (parameter **Battery boost charge time**) in accordance with the recommendations for the battery used.

Full charge

The objective of the full charge process 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 performs a full charge of the battery when one of the following conditions is met:

- The specified cycle time for the full charge has expired (parameter **Cycle time full charge**).
- The sum of all discharges since the last full charge is eight times the nominal capacity of the battery.

You can adjust the charging voltage (parameter **Cell charge nominal voltage for full charging**) and the duration (parameter **Battery full charge time**) in accordance with the recommendations for the battery used.

Equalization charge

With the equalization charge process, the Sunny Island neutralizes any differences in the state of charge of individual battery cells which have arisen due to the different behaviors of the battery cells. By doing so, the Sunny Island prevents the premature failure of individual battery cells and extends the service life of the battery.

Further information on the equalization charge of lead-acid and lithium-ion batteries is contained in the Sunny Island operating manual (see www.SMA-Solar.com).

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

- The specified cycle time for the equalization charge has expired (parameter **Cycle time equalization charge**).
- The sum of all discharges since the last equalization charge is 30 times the nominal capacity of the battery.

You can adjust the charging voltage (parameter **Time for equalization charge**) and the duration (parameter **Battery equalization charge time**) in accordance with the recommendations for the battery used.

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

6.3.5   Automatic Temperature Compensation

The charging capability of the battery is dependent on temperature. To prevent overcharging and insufficient battery charging, the battery management system is equipped with automatic temperature compensation. At temperatures above 20°C, the battery management system decreases the charging voltage. At temperatures below 20°C, the battery management system increases the charging voltage.

6.3.6   Battery Protection Mode

The battery protection mode protects the battery. If the battery state of charge falls below the thresholds, the 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. In this way, you can specify preferred times for the stand-alone grid to be switched off in the event of insufficient energy.

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 are able to supply energy, the Sunny Island attempts to charge the battery. Using the start time and end time, you specify 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 has flowed into the battery for six minutes. You can adapt the thresholds for battery protection mode to the system (for setting the battery protection mode, see the Sunny Island inverter installation manual)

6.4 Further information on Generator Management

6.4.1 Generator Management Tasks

The Sunny Island inverter generator management system performs the following tasks:

- Requesting the generator in automatic generator operation.
- Controlling the Sunny Island inverter for switching the stand-alone grid to the generator voltage.
- Maintaining generator run times in order to prolong the generator service life.
- Protecting the generator against overload and backfeed.
- Controlling the switching operations in the Sunny Island for disconnecting the generator.
- Making reactive power available for the generator.

The generator management system enables the use of generators that have a low output power in relation to the nominal load of the Sunny Island inverter (see the technical document "Sunny Island - Generator White Paper" at www.SMA-Solar.com).

6.4.2 Generator Request Dependencies

In order to adapt the generator management system to the requirements of the off-grid system, you can change the generator request dependencies.

Generator request	Explanation
State-of-charge-dependent generator request	The generator management system requests the generator for battery charging depending on the state of charge. In this way, the battery management system prevents the battery from being discharged too deeply. Tip: You can also configure the generator request to be dependent on the time of day, e.g. to avoid starting the generator at night wherever possible.
Load-dependent generator request	If the load in the stand-alone grid exceeds a configured limit, the generator management system requests the generator. The generator then supplies the loads. This reduces the load on the battery. Where necessary, the Sunny Island and the generator supply the loads in the stand-alone grid together. The sum of the two power sources is available to the stand-alone grid.

Generator request	Explanation
Time-dependent generator request	You can configure on which day, at which time and for how long the generator management system requests the generator.
Charging-procedure-dependent generator request	The generator is requested for full charge and equalization charging. You can configure whether the generator is requested for full charge, equalization charge or both charging processes.

6.4.3   Electrical Generator Thresholds

Through the configuration of electrical thresholds, the generator management system can prevent the generator from becoming overloaded and can detect and react to malfunctions.

Configurable limit	Explanation
Maximum generator current	The generator management system limits the consumption of generator current to a set maximum value. This prevents the generator from becoming overloaded.
Frequency of generator voltage	The thresholds for the frequency and magnitude of the generator voltage define the range within which the Sunny Island and the generator operate. These thresholds directly affect the power quality in the stand-alone grid.
Generator voltage magnitude	
Maximum generator reverse power	Reverse power in the generator can occur if AC sources in the stand-alone grid supply more current than is required in the off-grid system. The generator is powered by the generator reverse power. Depending on the generator, the generator reverse power leads to the automatic disconnection, instability or destruction of the generator.
	You can set the active power of the reverse power and the permitted time for reverse power. If the reverse power exceeds the thresholds, the generator management system disconnects the generator from the stand-alone grid. This protects the generator.

6.4.4   Generator Run Times

Generator run times specify time frames for generator operation. The generator run times are only interrupted in the event of a fault. This allows the generator management system to operate the generator with as little wear as possible and energy-efficiently. The energy efficiency increases due to the generator management system being able to use an operating generator for as long as possible at a high generator efficiency.

You can adjust and optimize the run times to suit the generator and the off-grid system requirements.

Generator run time	Explanation
Warm-up time	So as not to subject the generator to a load when it is cold, the generator warms up during the warm-up time. The warm-up time reduces generator wear. After the warm-up period, the Sunny Island connects the stand-alone grid to the generator.
Minimum run time	The minimum run time begins after the warm-up time has ended. During the minimum run time, the generator supplies current in order to charge the battery and to supply the loads. The minimum run time prevents short generator run times.

Generator run time	Explanation
Power-down time	Once the minimum run time has expired and the reason for the generator request no longer exists, the generator management system disconnects the generator from the stand-alone grid. The power-down time starts upon disconnection. During the power-down time, the generator operates without a load and the operating materials slowly cool down.
Minimum stop time	The minimum stop time begins after the power-down time. The generator does not operate during the minimum stop time. In this way, the generator management system prevents frequent generator starts. Frequent starts result in the generator motor wearing faster.

6.4.5   Generator Operating Modes

The generator management system differentiates between automatic generator mode and manual generator mode.

Manual generator mode

In manual generator mode, you can control generators with an autostart function and generators with external generator control at any time via the user Sunny Island interface. The following options are available for controlling the generator:

- Starting the generator at the Sunny Island.

  If you start the generator manually at the Sunny Island, you must also stop it manually.

- Stopping the generator at the Sunny Island.
- Starting the generator for one hour at the Sunny Island.

  With this option, you do not have to stop the generator again. The generator runs for 1 hour.

Automatic generator mode

In automatic generator mode, the generator management system controls the generator.

i **Automatic generator mode and generators without an autostart function**

The generator management system can control a signal generator via a multifunction relay. The signal generator can send you a signal when you are to start or stop the generator.

In automatic generator mode, the generator can be started and stopped manually at any time. If the generator has stopped and the minimum stop time has expired, automatic mode is continued.

6.4.6 Operating Procedure for Generator Control

6.4.6.1 Operating Procedure with Generators with Autostart Function

Event or state	Result	Internal transfer relay
The generator management system requests the generator.	The Sunny Island starts the generator.	Open, the stand-alone grid is not connected to the generator.
The generator starts.	The generator voltage builds up.	
	The generator management system measures the time until the generator voltage is within the configured thresholds for voltage and frequency. If a maximum time is exceeded, the generator management system terminates the generator start.	
The generator voltage is within the configured thresholds for voltage and frequency.	The generator management system starts the warm-up time.	
The warm-up time is running.	–	
The warm-up time ends.	The Sunny Island synchronizes the stand-alone grid with the generator voltage.	
The stand-alone grid is synchronized.	The Sunny Island connects the stand-alone grid to the generator.	Closed, the stand-alone grid is connected to the generator.
The stand-alone grid is connected to the generator.	The generator feeds current into the stand-alone grid.	
	The generator management system starts the minimum run time.	
The minimum run time is running.	Even if the generator management system no longer requests the generator, the stand-alone grid remains connected to the generator.	
The minimum run time ends.	If the generator management system continues to request the generator, the stand-alone grid remains connected to the generator.	

Event or state	Result	Internal transfer relay
The generator management system no longer requests the generator.	The Sunny Island supplies the stand-alone grid and carries out load-free disconnection of the generator from the stand-alone grid.	Open, the stand-alone grid is not connected to the generator.
	The generator management system starts the power-down time.	
The power-down time is running.	During the power-down time, the generator management system cannot request the generator again and the Sunny Island cannot reconnect the stand-alone grid to the generator.	
The power-down time ends.	The Sunny Island stops the generator.	
	The generator management system starts the minimum stop time.	
The minimum stop time is running.	The Sunny Island cannot start the generator. It is also not possible to perform a manual start at the Sunny Island.	
	The generator management system cannot request the generator.	
The minimum stop time ends.	The generator management system can request the generator.	
	The generator can be started at the Sunny Island.	

6.4.6.2 Operating Procedure with Generators without an Autostart Function

Event or state	Result	Internal transfer relay
The generator management system requests the generator.	The Sunny Island triggers a signal generator. The signal generator signals that you should start the generator.	Open, the stand-alone grid is not connected to the generator.
You start the generator (e.g. via a cable pull).	The generator starts.	
	The generator voltage builds up.	
You close the load-break switch between the generator and the Sunny Island.	The generator is connected to the Sunny Island.	
The generator voltage is within the configured thresholds for voltage and frequency.	The generator management system starts the warm-up time.	
The warm-up time is running.	–	
The warm-up time ends.	The Sunny Island synchronizes the stand-alone grid with the generator voltage.	

Event or state	Result	Internal transfer relay
The stand-alone grid is synchronized.	The Sunny Island connects the stand-alone grid to the generator.	Closed, the stand-alone grid is connected to the generator.
The generator is connected.	The generator feeds current into the stand-alone grid.	
	The generator management system starts the minimum run time.	
The minimum run time is running.	Even if the generator management system no longer requests the generator, the generator remains connected to the stand-alone grid.	
The minimum run time ends.	–	
The generator management system no longer requests the generator.	The Sunny Island stops triggering the signal generator. The signal generator signals that you should disconnect the generator from the Sunny Island.	
You open the load-break switch between the generator and the Sunny Island.	The Sunny Island opens the internal transfer relay.	
	The Sunny Island continues to supply the stand-alone grid without interruption.	
	The generator management system starts the minimum stop time.	
The minimum stop time is running.	The Sunny Island does not detect when you restart the generator.	
	The generator management system cannot request the generator. The signal generator is not triggered.	
You stop the generator.	–	
The minimum stop time ends.	The generator management system can request the generator.	
	The Sunny Island detects a generator start.	

6.4.6.3 Operating Procedure with Generators with External Generator Control

Event or state	Result	Internal transfer relay
The generator management system requests the generator.	The Sunny Island signalizes to the external generator control that the generator has been requested.	Open, the stand-alone grid is not connected to the generator.
The external generator control starts the generator.	The generator voltage builds up.	
The warm-up time set at the external generator control begins.	The generator management system measures the time until the external generator control signals to the Sunny Island that the warm-up time has expired. If a maximum time is exceeded, the generator management system terminates the generator start.	
The external generator control signalizes to the Sunny Island that its warm-up time has successfully expired.		
The Sunny Island synchronizes the stand-alone grid with the generator voltage.	–	
The stand-alone grid is synchronized.	The Sunny Island connects the stand-alone grid to the generator.	Closed, the stand-alone grid is connected to the generator.
The stand-alone grid is connected to the generator.	The generator feeds current into the stand-alone grid.	
	The generator management system starts the minimum run time.	
The minimum run time is running.	Even if the generator management system no longer requests the generator, the stand-alone grid remains connected to the generator.	
The minimum run time ends.	If the generator management system continues to request the generator, the stand-alone grid remains connected to the generator.	

Event or state	Result	Internal transfer relay
The generator management system no longer requests the generator.	The Sunny Island supplies the stand-alone grid and carries out load-free disconnection of the generator from the stand-alone grid.	Open, the stand-alone grid is not connected to the generator.
	The generator management system signalizes to the external generator control that the generator is no longer being requested.	
The power-down time set at the generator management system begins.	–	
The power-down time is running.	During the power-down time, the generator management system cannot request the generator again and the Sunny Island cannot reconnect the stand-alone grid to the generator.	
The power-down time ends.	The external generator control stops the generator.	
	The external generator control signalizes to the Sunny Island that its power-down time has expired.	
The generator management system starts the minimum stop time.	–	
The minimum stop time is running.	The Sunny Island suppresses every generator request. It is also not possible to perform a manual start at the Sunny Island.	
The minimum stop time ends.	The generator management system can request the generator.	
	The generator can be started at the Sunny Island.	

6.5 Further Information on the Grid Management Service

6.5.1 Tasks of the Grid Management Service

The grid management service performs the following tasks:

- The grid management service recognizes failures, disturbances and return of the utility grid.
- The grid management service controls the transition from stand-alone mode to grid operation.
- The grid management service controls the transition from grid operation to stand-alone mode.
- If the utility grid is being used as an energy reserve, the grid management service automatically connects the utility grid when required.

6.5.2 Dependencies for Requesting the Utility Grid

In order to adapt the grid management service to the requirements of the battery-backup system, you can change the dependencies for requesting the utility grid.

Requesting the utility grid	Explanation
State-of-charge-dependent request	The grid management service requests the utility grid for battery charging depending on the battery state of charge. In this way, the grid management service prevents the battery from being discharged too deeply. Tip: You can also configure the request to be dependent on the time of day.
Load-dependent request	If the requirements of the electrical loads in the battery-backup grid exceed a specified limit, the grid management service requests the utility grid. The utility grid then supplies the loads. This reduces the load on the battery.
Charging-procedure-dependent request	You can configure whether the utility grid is requested for full charge, equalization charge or both charging processes.

Requirement:

☐ The Sunny Island is in operation.

Procedure:

1. Log into the user interface of the Sunny Island.
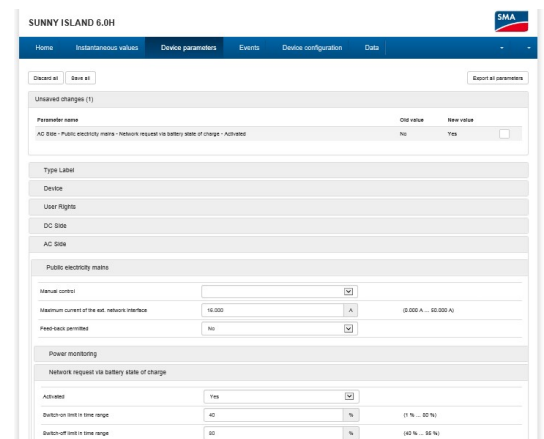
2. Select **AC Side** in the menu **Device parameters**.
3. To set the parameters, open the menu item **Public electricity mains** and select **Network request via battery state of charge**.
4. Select **Yes** under Activated.
5. Setting the load-dependent requirement can be enabled under the menu item **Network request via power**.
6. The request depending on the charging procedure can be enabled under **Network request via charge type**.

6.5.3   Electrical Thresholds for the Utility Grid

If the utility grid exceeds the electrical thresholds, the grid management service detects a failure, disturbance, or overload of the utility grid.

Configurable limit	Explanation
Maximum grid current	The grid management service limits the drawing of current from the utility grid to a configurable maximum value.
Frequency of the utility grid voltage	You can adjust the thresholds for frequency and voltage to the applicable local standards and requirements. The frequency and voltage in the utility grid directly affect the power quality in the battery-backup grid. If the utility grid exceeds the thresholds, the Sunny Island disconnects the utility grid from the battery-backup grid and switches to stand-alone mode.

6.5.4   Operating Modes of the Utility Grid

The Sunny Island differentiates between the operating modes charge mode and energy-saving mode (silent mode).

Charge mode

Charge mode on the utility grid is characterized by the Sunny Island charging the battery or receiving the battery charge.

Energy-saving mode

In energy-saving mode, the Sunny Island is in standby and the utility grid supplies the loads. The Sunny Island switches out of energy-saving mode regularly to charge the battery.

6.5.5   Operating Procedure for Grid Control

Event or state	Result	Internal transfer relay
The grid management service requests the utility grid.	–	Open, the battery-backup grid is not connected to the utility grid.
The grid voltage is within the specified thresholds for voltage and frequency.	In order that the grid management service can detect a valid voltage, the utility grid must be within the thresholds for voltage and frequency for a minimum time.	
	If the grid management detects a valid voltage, the Sunny Island synchronizes the battery-backup grid with the utility grid.	
The battery-backup grid is synchronized.	The Sunny Island connects the battery-backup grid to the utility grid.	Closed, the battery-backup grid is connected to the utility grid.
The battery-backup grid is connected to the utility grid.	The utility grid feeds current into the battery-backup grid.	
The grid management service no longer requests the utility grid.	The Sunny Island disconnects the battery-backup grid from the utility grid and supplies the battery-backup grid.	Open, the battery-backup grid is not connected to the utility grid.

6.5.6 Grid-Connected Systems in Off-Grid Mode

The inverter can be used in off-grid, backup or self-consumption systems. Depending on the system, additional energy sources may be available (e.g. diesel generator, utility grid or others).

Inverters in grid-connected operation mode, are used to increase self-consumption. In off-grid mode, there are such systems that are connected to a diesel generator, the utility grid or both at the same time.

The use of diesel generators in off-grid systems is the classic application of Sunny Island systems. If available, the utility grid can also be used for this application. The grid within a system can be setup in different ways:

- with utility grid as an energy reserve or grid as generator
- with utility grid as the main supplier of loads (with or without PV plant)
- with utility grid as the main supplier of loads with Diesel generator (w/o PV plant)

Larger systems require further components and are more complex. They are not considered here.

6.5.7 Systems with utility grid as an energy reserve for the battery-storage system

The utility grid can be used as an energy reserve instead if a diesel generator. The energy from the utility grid can be requested by the Sunny Island via different settings.

A system structure as shown in the following figure must be implemented to operate in off-grid mode in combination with a utility grid. The Sunny Island can synchronize with the grid at any time and disconnect the grid again when required. It thus retains control over the secure supply of all loads. After successful synchronization, the external source determines the voltage and frequency of the entire system.
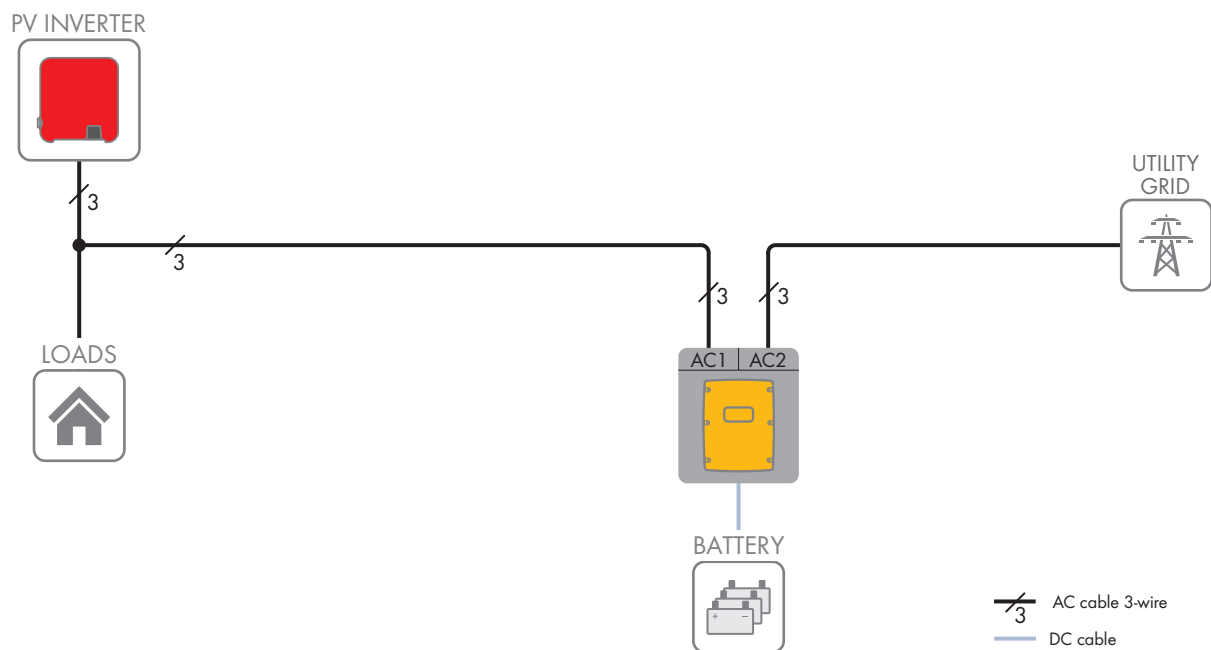

Figure 18: In off-grid mode, loads and PV inverters can be connected to terminal "AC1" and the grid to terminal "AC2".

6.5.8 Systems with utility grid as a main supplier of loads

In countries with a weak utility grid or countries without high grid standards, it is possible to connect a Sunny Island system in series between the grid and loads with the operating state "Off-grid". The utility grid is the main supplier of the loads. If the utility grid fails, the Sunny Island disconnects the network of loads from the utility grid and switches to stand-alone mode (backup system). In standalone mode, the Sunny Island supplies the network of loads with energy from the battery and PV plant (if available).

After the utility grid has been connected with the AC2 terminal of the Sunny Island (see Section 6.5.7, page 47), the system can be set up as a backup system.

The switchover times are available in the document "Technical information: Switchover times for SUNNY ISLAND" at www.SMA-Solar.de.

Using the Sunny Island as a backup system, the batteries are always fully charged and prepared for a possible grid failure. If a PV system is installed at the AC1 terminal, the feed-in of surplus energy can be selected when the grid is connected.

The system with the grid connected to the AC2 terminal of the Sunny Island and PV inverter connected to the AC1 terminal works as follows:

The power generated by the PV modules flows through the PV inverter directly to the loads. If the PV generation at that moment is higher than the load demand, the PV inverter may feed too much generated energy into the utility grid. The following parameter must be selected: **Feedback permitted = Yes**

Figure 19: Parameterization of the feedback (example)

If it is not allowed to feed back the excess of PV power, the parameter **Feedback permitted** should be set to **No**. In this case, the Sunny Island opens its internal relay to separate the loads from the utility grid. Then it starts the FSPC function (frequency shift power control / power curtailment via PV inverter control by varying the frequency) to reduce the output power of the PV inverter and prevent any excess energy from being generated.

The "maximum reverse power" and "maximum reverse power tripping time" can be set in the Sunny Island parameters under **Power monitoring**.

After some minutes, the Sunny Island will reconnect automatically to the utility grid. After the Sunny Island has recognized a valid grid voltage, the frequency and voltage of the Sunny Island grid are synchronized with the utility grid. If the PV generation is still higher than the load, the Sunny Island disconnects the utility grid again. This will happen in a loop as far as the load is similar or higher than the PV generation. The lock time until connection to the external grid after reverse power can be set in the parameter **Cut-off time after shutdown**. To do this, select the menu item **Measurements of external power connection** in the **AC Side** menu.

6.5.9   Systems with utility grid as a main supplier of loads and diesel generator as energy reserve in case of a grid failure

When using the Sunny Islands in a backup system with a diesel generator, the system installer is responsible for setting up the DIGIN (digital input). The DIGIN shows the Sunny Island that there is a diesel generator in case of a grid failure. This allows the Sunny Island to start the diesel generator with a two-wire signal. If the Sunny Island requests the generator via remote start, it provides reverse-current protection at the same time in order to prevent the PV current being fed into the generator again. This function of the Sunny Island gives the installer more flexibility in the design and installation of a backup system.
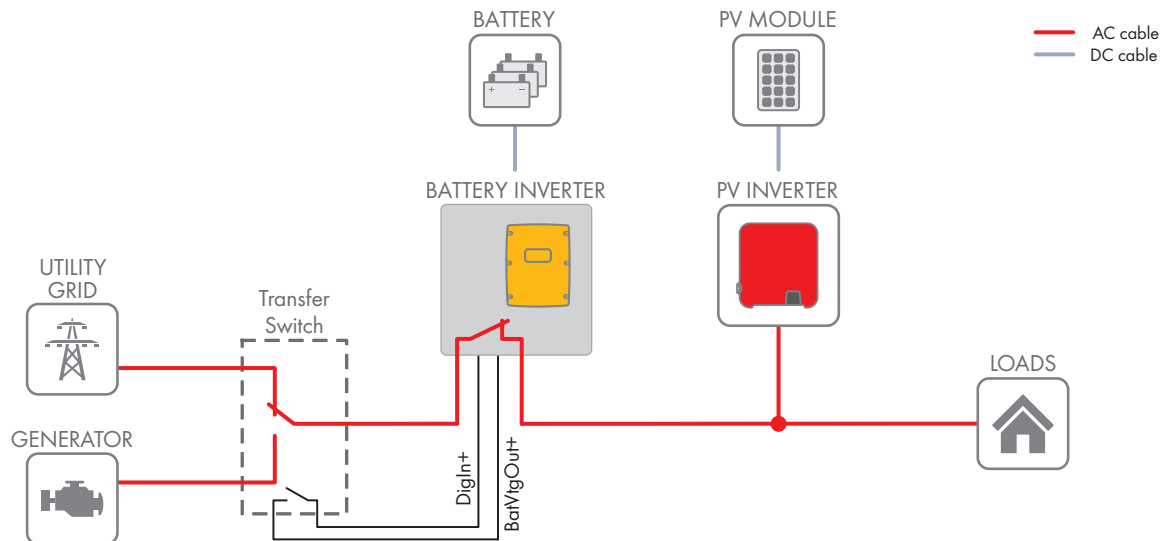
Figure 20: System with utility grid as a main supplier of loads with diesel generator:

The Sunny Island has one AC external source connection labeled AC2 Grid/Generator. The digital input serves to inform the Sunny Island whether a diesel generator or grid is currently connected to the AC2 connection.

When the digital input has an open circuit, the Sunny Island operates under grid parameters and can then feed extra current back to the grid. When the digital input has a closed electric circuit the Sunny Island recognizes that a generator is available. When the generator has been switched on, the Sunny Island will no longer back feed any power through its AC2 connection towards the generator. This will protect the generator by the Generator Reverse Power function of the Sunny Island.

When using a diesel generator and utility grid, the installer must provide a means of switching from grid to generator. This can be performed by utilizing an automatic transfer switch (ATS) or a manual transfer switch.

It is high recommended to use ATS with a neutral transition position. The ATS needs at least 5 seconds to disconnect the Sunny Island from the grid and from the generator.

If a manual switch is installed, leave the switch in OFF position for at least 5 seconds before switching to the new position.

In order to wire the DIGIN circuit, the ATS should be equipped with an auxiliary contact to provide to the DIGIN a logical signal. If this contact is open, it means the grid is connected. If not, it means the generator is connected.

However, if an auxiliary relay is not available, the installer will need to purchase an external relay / contactor with a 230 V coil. The voltage for the coil must be provided from the grid side of the transfer switch. In the event of a grid failure, the voltage will no longer be applied to the coil, and the contact will close.

The DIGIN signal in the Sunny Island occupies 2 auxiliary connections. They are located over the multifunction relay connections inside on the bottom right hand side of the circuit boards in the Sunny Island. The connections that will be utilized are the BatVtg+ and BatVtg- along with the Digin+ and Digin-. The connections that will be utilized are the BatVtg+ and BatVtg- along with the Digin+ and Digin-.

Next, wire the BatVtg+ to the break contact of the external relay/contactor. This is the contactor provided externally, or in your ATS.

Then, wire the Digin+ to the C or common connection on the external relay. Treat this electric circuit as a communication circuit and do not connect it in parallel to AC voltage and current cables. This could lead to signal interference with Sunny Island. No voltage should be present on the relay during a grid failure. For external relays, pull voltage from the grid side of the transfer switch.
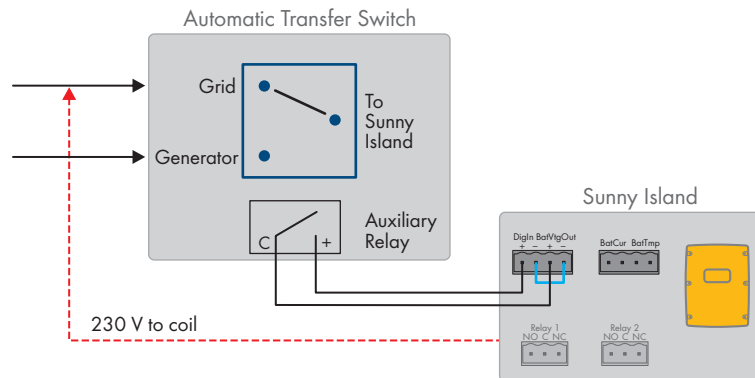

Figure 21: Automatic transfer switching device

6.6 Further Information on Clusters

6.6.1 Mixed multicluster systems

During the operating time of battery-storage systems, it may be necessary to replace or add devices. This section describes compatibilities between different system components within Sunny Island systems. It also provides guidance on how to select and replace devices.

The following device types of battery inverters are considered:

Generation A	SI5048	SI5048	Off-Grid
Generation B0	SI-10	SI6.0H-10 / SI8.0H-10	Off-Grid
Generation B1	SI-11	SI3.0M-11 / SI4.4M-11 / SI6.0H-11 / SI8.0H-11	Off-/On-Grid
Generation B2	SI-12	SI4.4M-12 / SI6.0H-12 / SI8.0H-12	Off-/On-Grid
Generation B3	SI-13	SI4.4M-13 / SI6.0H-13 / SI8.0H-13	Off-/On-Grid

ℹ **SI3.0M-11 / SI4.4M-11 / SI4.4M-13 cannot be used in multicluster systems. US product variants are not considered.**

Individual clusters (3 devices, three-phase connected) may only be combined unmixed (by generation) An exception applies to generation B2 and B3.

Generation A	1 Cluster consisting of 3x SI5048 or
Generation B0	1 Cluster consisting of 3x SI-10 (same type) or
Generation B1	1 Cluster consisting of 3x SI-11 (same type) or
Generation B2/B3	1 cluster each unmixed (of the same type) or consisting of a mix of SI-12 and SI-13 devices (same power classes). In this case, the master device must be an SI-13 device.

Cluster (3 devices, three-phase connected) can be combined as main clusters and extension clusters.

⚟ **The latest device types are downward compatible, the older ones are not upward compatible.**

In mixed multicluster systems, only the functions of the oldest device generation can be used.

The extension clusters must always have the latest firmware installed. You will find the latest firmware versions at http://www.SMA-Solar.com.

The use of special firmware in mixed multicluster systems is not permitted.

The operation of several unmixed clusters of different generations can be carried out on the following Multicluster-Boxes:

- MC-BOX-6.3
- MC-BOX-6.3-11
- MC-BOX-9.3
- MC-BOX-12.3
- MC-BOX-12.3-20
- MC-BOX-36.3
- MC-BOX-36.3-11

The operation of several unmixed extension clusters (e.g. 1x SI-11 cluster and 1x SI-12 cluster) within a multicluster system is permitted.

Under certain firmware constellations, the following event codes may occur when operating mixed multiclusters, but these do not affect the operation of the system:

- "Firmware extension cluster unequal firmware main cluster"
- "Synchronization not successful"

6.6.2   Multicluster Boxes

Multiclusterboxen									
	NA-BOX	GRID-BOX	MCB6	MCB6/11	MCB9	MCB12	MCB12/20	MCB36	MCB36/11
(1) **Main:** SI-5048			✔	✔	✔	✔		✔	✔
(2) **Main:** SI-10			✔	✔	✔	✔		✔	✔
(3) **Main:** SI-11	✔	✔	✔	✔		✔	✔	✔	✔
(4) **Main:** SI-12	✔	✔	✔	✔		✔	✔	✔	✔
(5) **Main:** SI-13	✔	✔	✔	✔		✔	✔	✔	✔

GRID-Box	GRID-BOX-12.3-20	On|Off		
NA-Box	NA-BOX-12.3-20	On|Off	ARN4105	production off
MCB6	MC-BOX-6.3	--|Off	--|G|P|L	production off
MCB6/11	MC-BOX-6.3-11	--|Off	--|G|P|L	
MCB9	MC-BOX-9.3	--|Off	--|G|P|L	production off
MCB12	MC-BOX-12.3	--|Off	--|G|P|L	production off
MCB12/20	MC-BOX-12.3-20	On|Off	N|G|P|L	
MCB36	MC-BOX-36.3	--|Off	--|G|P|L	production off
MCB36/11	MC-BOX-36.3-11	--|Off	--|G|P|L	

✔ Kompatible Kombination / compatible combination

NICHT kompatible Kombination / **NOT** compatible combination

abgekündigt / discontinued

abgekündigt / discontinued

System:	On	On-Grid	Anschlüsse /	N	Netz	
	Off	Off-Grid	Terminals	G	Generator	
				P	Photovoltaik	
				L	Load	

Figure 22: Compatibility matrix of Multicluster-Boxes in mixed multi-cluster systems

6.6.3   Sunny Island battery inverter within mixed multicluster systems

	ExtensionCluster 1 ... 11				
	SI-5048	**SI-10**	**SI-11**	**SI-12**	**SI-13**
(1) **Main:** SI-5048	✓		✓	✓	✓
(2) **Main:** SI-10		✓			
(3) **Main:** SI-11			✓	✓	✓
(4) **Main:** SI-12				✓	✓
(5) **Main:** SI-13				✓	✓

✓ Kompatible Kombination / compatible combination

NICHT kompatible Kombination / NOT compatible combination

✓ abgekündigt / discontinued

abgekündigt / discontinued

Figure 23: Compatibility matrix: Sunny Island in mixed multicluster systems

The figure illustrates possible system constellations in multicluster systems with different Sunny Island generations. Only the resulting possible combinations may be used. SMA recommends the latest firmware version for the device types.

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