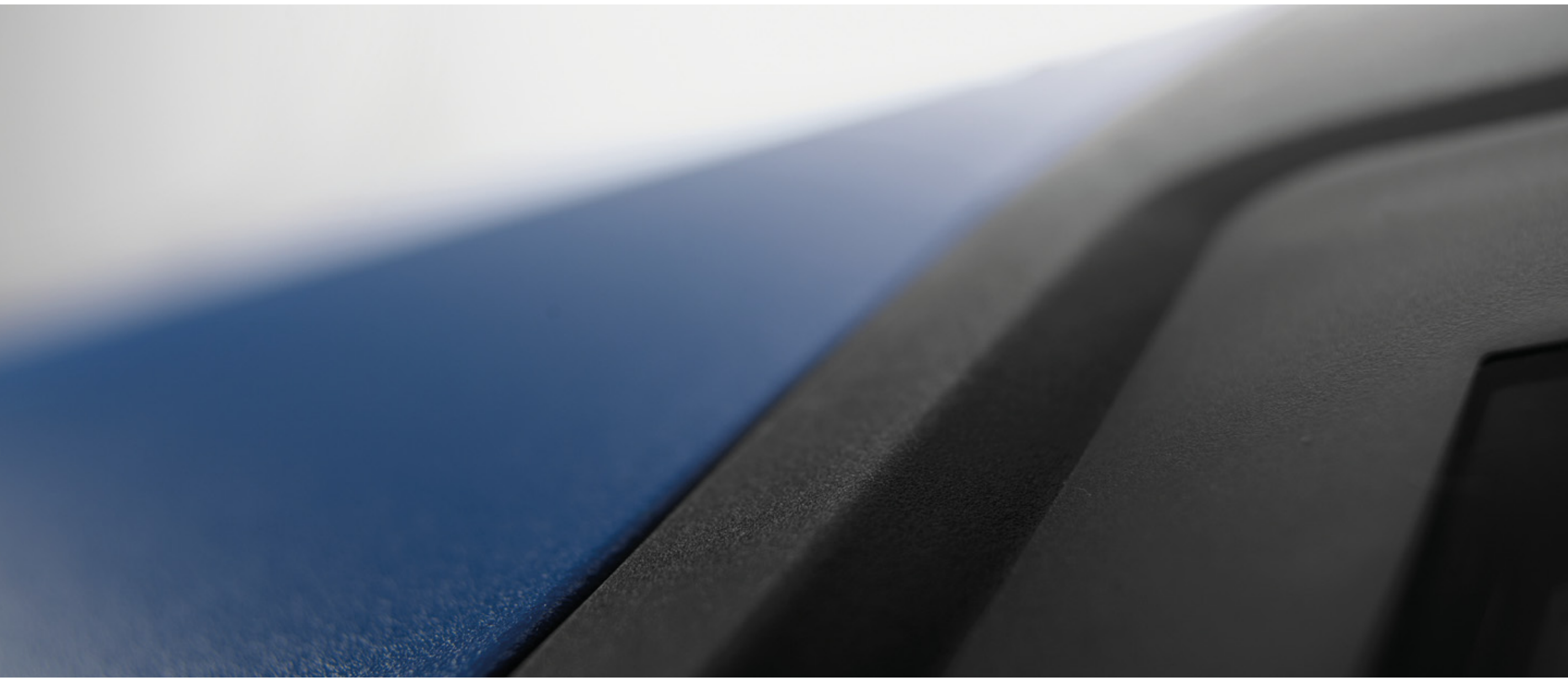
Technical Information

Integrated Plant Control and Q on Demand 24/7
SUNNY TRIPOWER



Reactive power is necessary for the stability of the utility grid. With the functions "Integrated Plant Control" and "Q on Demand 24/7", it is possible that SMA inverters of type Sunny Tripower feed in reactive power during operation and at night. The following table provides an overview of the device types and firmware versions for which the various functions are available.

Device type	Reactive power provision $0_{\text{overexcited}}$ to $0_{\text{underexcited}}$	Q on Demand 24/7	Integrated Plant Control
STP 15000TL-10/ STP 17000TL-10	from firmware version 2.60.02	from firmware version 2.60.02	from firmware version 2.62.04
STP 15000TLEE-10/ STP 20000TLEE-10	from firmware version 2.61.06	from firmware version 2.61.06	from firmware version 2.63.03
STP 20000TL-30/ STP 25000TL-30	from firmware version 2.80.04	from firmware version 2.82.03	from firmware version 2.82.03

Device type	Reactive power provision $0_{\text{overexcited}}$ to $0_{\text{underexcited}}$	Q on Demand 24/7	Integrated Plant Control
STP 12000TL-US-10 / STP 15000TL-US-10 / STP 20000TL-US-10 / STP 24000TL-US-10 / STP 30000TL-US-10	from firmware version 2.80.00	from firmware version 2.80.00	from firmware version 2.80.00

This document provides basic information on reactive power and how to set the inverter in order to feed reactive power into the utility grid in compliance with standards and demand.

1 Definition of Active Power, Reactive Power and Apparent Power

Electrical power is the product of current and voltage. While current and voltage have stable values with direct current, the strength and the direction of both current flow and voltage change regularly in alternating current. In the utility grid, current and voltage have a sinusoidal shape, so that their product, electrical power, is also sinusoidal. In DC systems, the sign of the power indicates the direction in which the electrical energy, in the form of active power, is transported.
In general, this also applies in an AC circuit. However, the power may not always be positive or negative, but rather its sign can fluctuate periodically, causing the power to oscillate back and forth. This oscillating power does not do any work and is therefore referred to as reactive power. The time delay between the current and voltage curve – its so-called phase shift – is a value which is easy to measure and characteristic of the relation between active power and reactive power at the point under consideration in the electric circuit.

1.1 Active Power P

With no phase shift between progression of current i(t) and voltage v(t) over time, both always have the same sign and simultaneously reach their maximum and minimum values. The power oscillates between zero and the positive maximum value. Averaged over time, this results in a positive power value P (unit: W; Watt) and only active power is generated P. This behavior occurs only when ohmic loads are the only loads in the electric circuit. In a real utility grid, however, cable inductance and capacitance ensure that the active power is always accompanied by a small amount of reactive power.

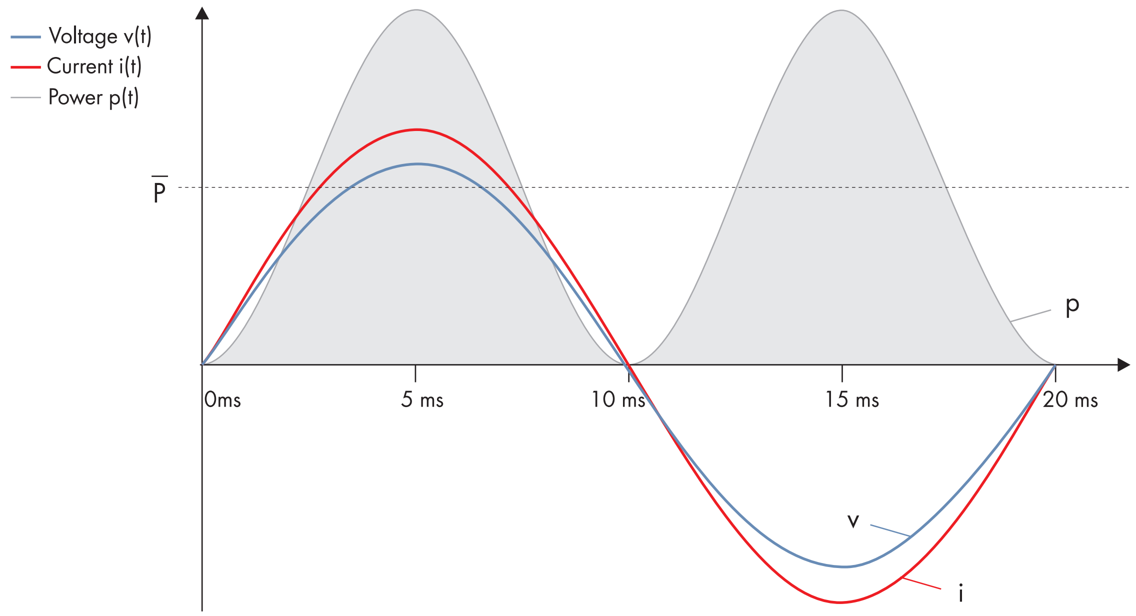


Figure 1: Pure active power: current and voltage are in phase

1.2 Reactive Power Q

With a phase shift phi of 90°, the maximum current occurs precisely when the voltage crosses zero; then the power oscillates between positive and negative values, which is why the average value over time is zero. This is known as pure reactive power Q (unit: Var, from the French volt-ampère-réactif) which moves "back and forth" in the cables.

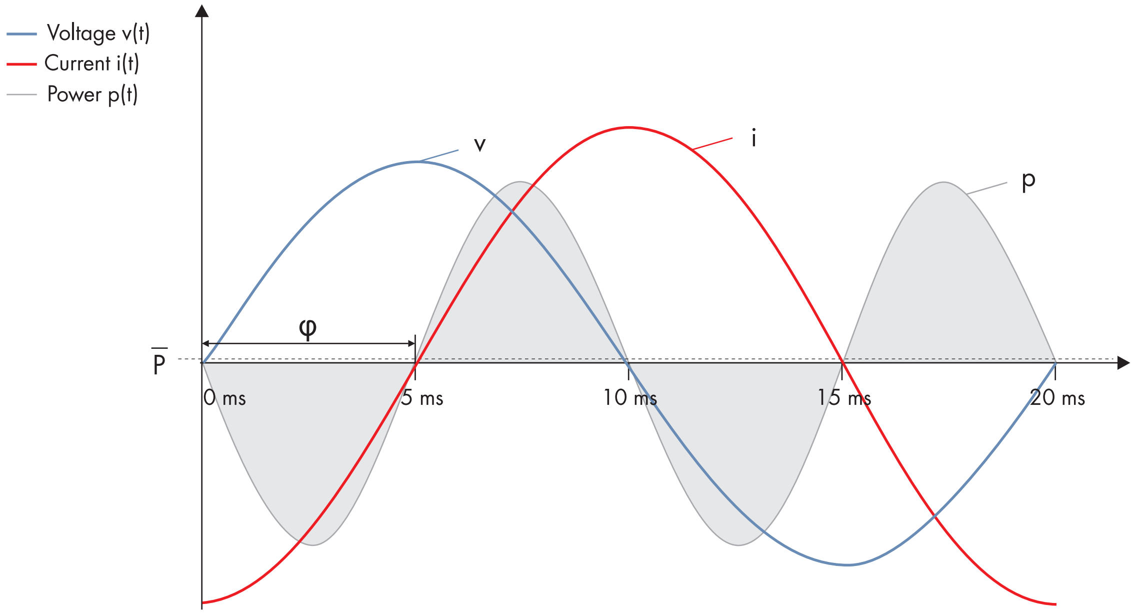


Figure 2: Pure reactive power: current and voltage are phase-shifted by 90°

1.3 Apparent Power S

In real AC circuits, there is a mix of active power and reactive power. This behavior occurs when there are leading or lagging loads in the utility grid. The shift between current and voltage is denoted by the displacement power factor cos φ.

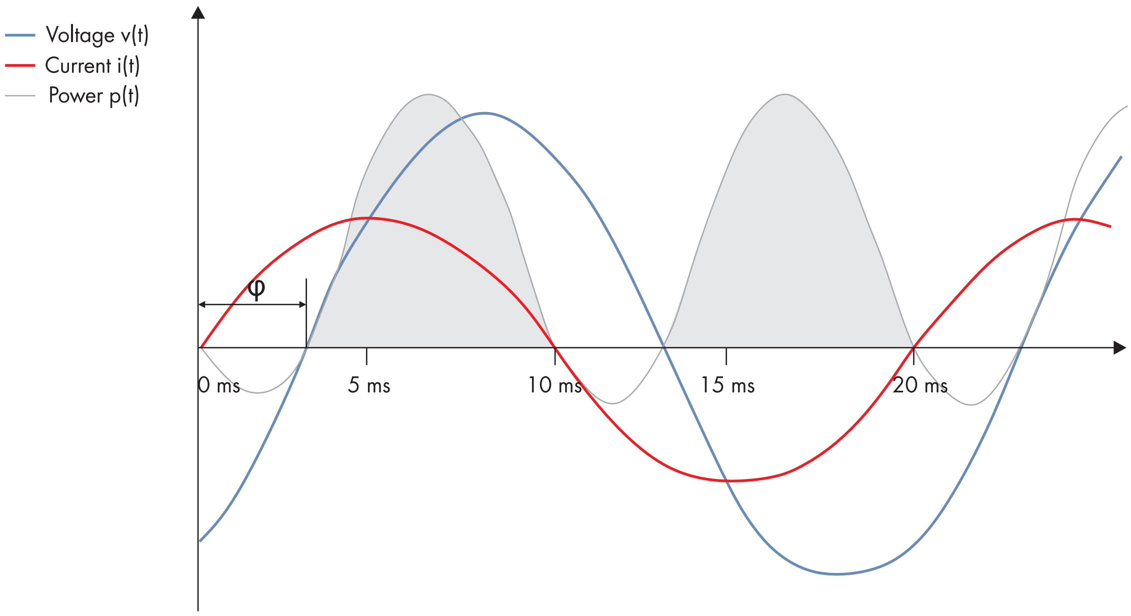


Figure 3: In real AC grids, current and voltage are slightly phase-shifted and reactive power occurs together with active power.

Calculating Apparent Power

The sum of active power and reactive power is the so-called apparent power S (unit: VA; volt-ampère). It should be noted that the units are not simply added arithmetically, but must be represented as vectors: active and reactive power form the sides of a right triangle whose hypotenuse corresponds to the apparent power. The cosine of the angle between the active power and the apparent power is the displacement power factor.

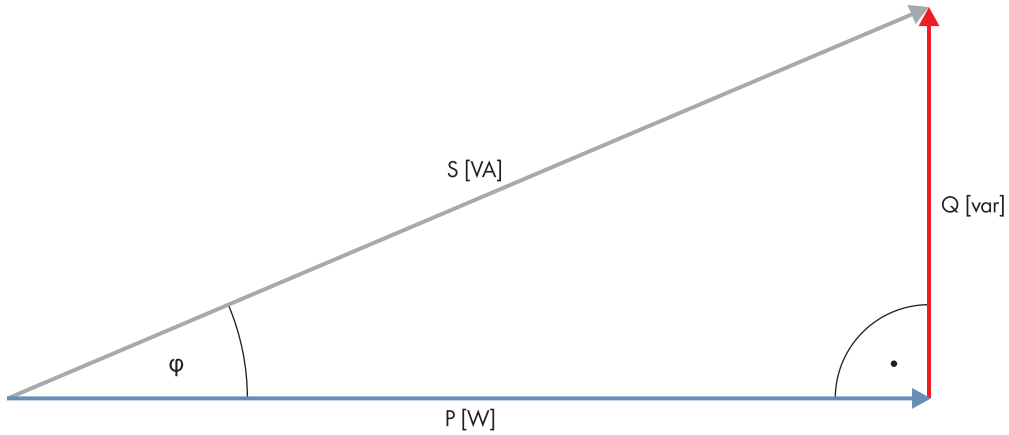


Figure 4: Vector addition of active and reactive power

1.4 Compensating and Controlling Reactive Power with Sunny Tripower

Compensating Reactive Power Demand with Q on Demand 24/7

Leading or lagging loads (e.g. cables, transformers) require reactive power. Transporting reactive power from the power plant to the load places a burden on the utility grid. It therefore makes sense to install a compensation system that provides reactive power at sites with many leading or lagging loads. In order to ensure the stability of the utility grid, grid operators require energy producers to take part in the compensation of reactive power. A PV system can complement or replace such a compensation system.

Due to their design, large PV farms have a certain demand for reactive power which can be compensated with Sunny Tripower inverters. At the same time, Sunny Tripower inverters can feed reactive power into the utility grid. Compensation can take place both in feed-in and non-feed-in operation by using the Q on Demand 24/7 function. Using this function, the Sunny Tripower inverter provides reactive power for the PV farm equipment without placing a burden on the utility grid.

Controlling the Q(V) Characteristic Curve with Integrated Plant Control

The Sunny Tripower inverter can provide reactive power to the utility grid with the Integrated Plant Control function. The grid operator specifies the preferred process by which the inverter should supply reactive power to the utility grid. In many cases, the grid operator will require control in accordance with a Q(V) characteristic curve.

SMA inverters with Integrated Plant Control are capable of representing this Q(V) characteristic curve without performing any measurement at the grid-connection point. The inverter can automatically compensate equipment installed between the inverter and the grid-connection point.

The function "Integrated Plant Control" is not capable of compensating irregular or fluctuating reactive power demands – e.g. from connected machinery – when the machinery is connected between the inverters and the grid-connection point. If the machinery is connected directly at the grid-connection point, it is possible to dynamically determine the reactive power demand of the machines using additional measurement equipment and then to provide this value as an offset to the Q(V) control.

2 Design of PV Farms

2.1 Typical PV Farm with Central PV Farm Control

Decentralized PV farms must be able to control the flow of reactive power. It is not enough for each inverter to comply with the characteristic specified by the grid operator because all of the equipment (cables, transformers, switching equipment, etc.) has an influence on the characteristic curve of the PV power plant as a whole.

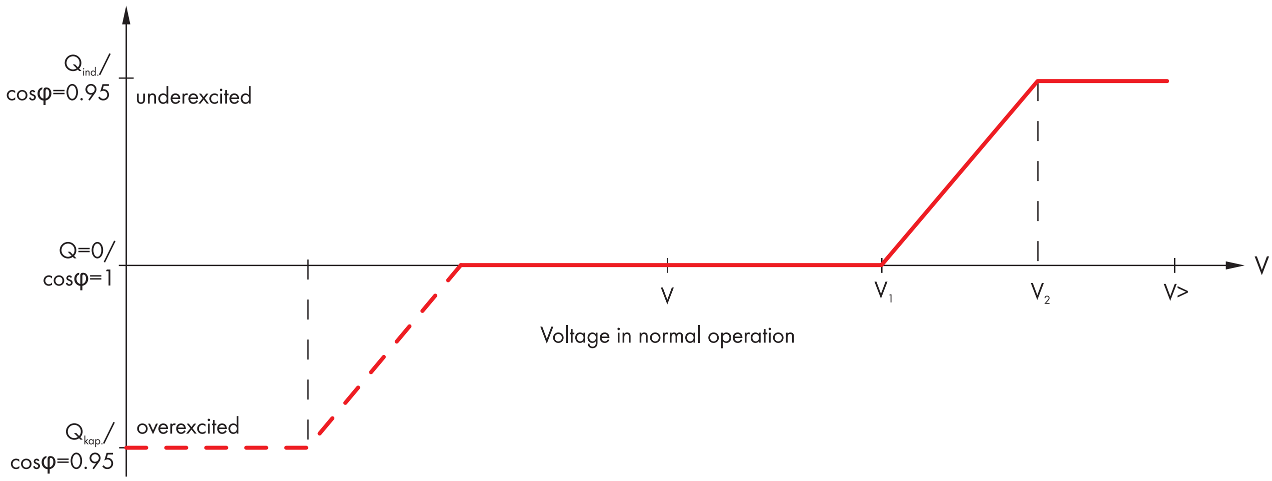


Figure 5: Example of a Q(V) specified by the grid operators

This is why the central PV farm control records the most important grid values at the grid-connection point and compares them with the characteristic curve provided by the grid operator. When deviations occur, a corrected uniform setpoint for reactive power is transmitted to the inverters which then ensures that the required characteristic is achieved.

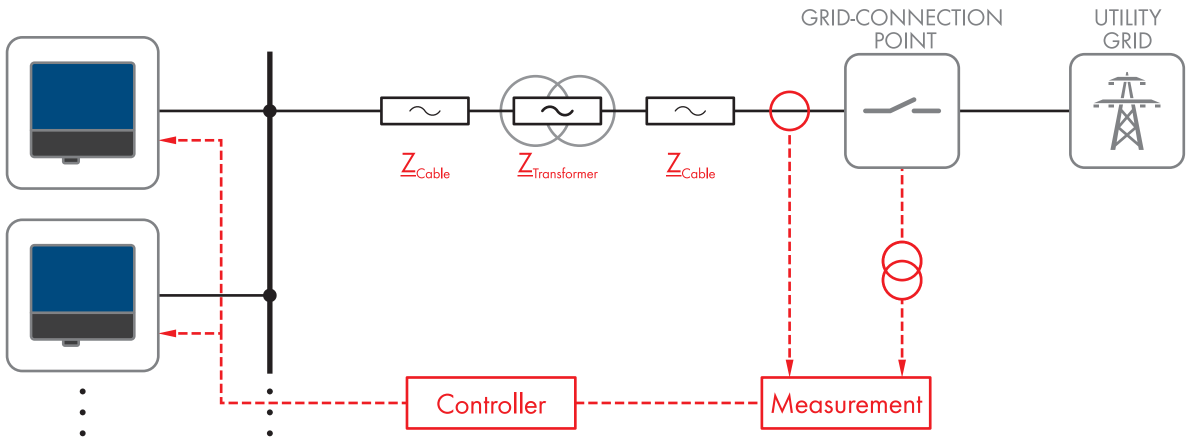


Figure 6: PV farm with central PV farm control

2.2 PV Farm with Integrated Plant Control

The Integrated Plant Control function enables each inverter within a group of inverters to determine its individual contribution in order to ensure that the necessary reactive power is fed into the grid at the grid-connection point. Every inverter in the group compensates for the impedance influences of the cables and the transformer.

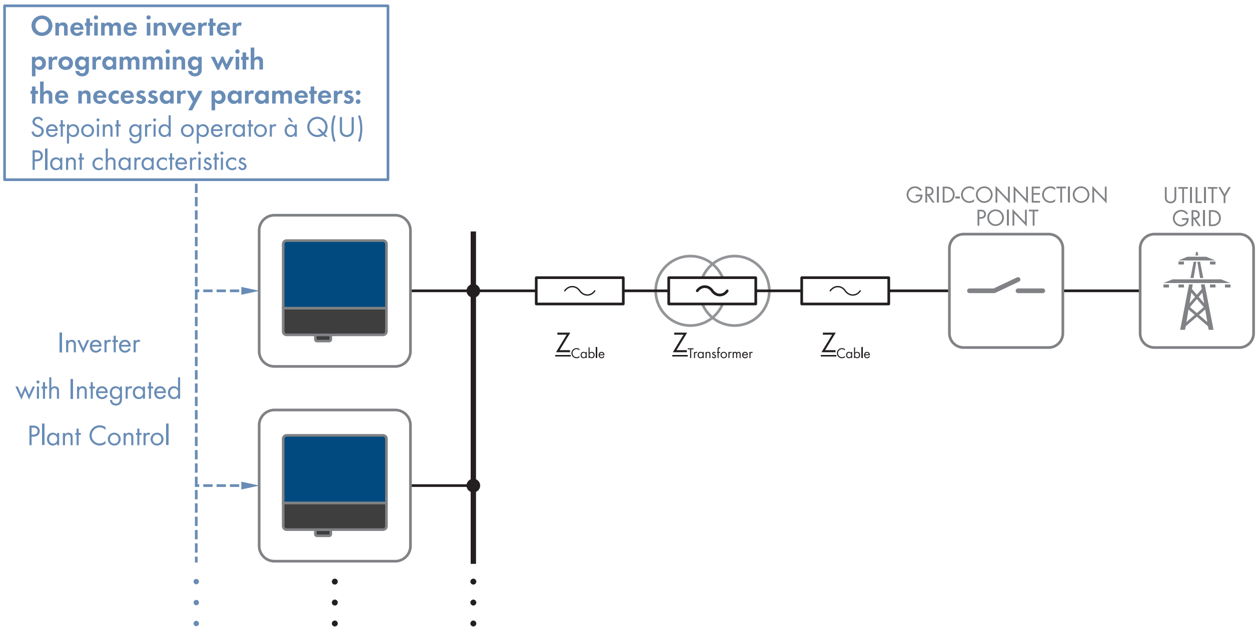


Figure 7: PV farm with Integrated Plant Control

Advantages of Integrated Plant Control

- Economical: no additional costs for central farm control gear, measured value recording at the grid-connection point, fast data transmission, and installation and commissioning
- Grid friendly: adherence to the characteristics desired by the grid operator even in the presence of very rapid changes in grid voltage
- Simple and easy to understand: simplifies system design and maintenance. Inverter parameterization is calculated with the Sunny Design software.
- Secure: redundancy through individual integration and one-time parameterization of each inverter
- Flexible: even small PV systems with two or more inverters can optimize their grid characteristics at low cost. Existing PV systems can be retrofitted via a software update.

Functionality of Integrated Plant Control

Despite the utmost care in the production of the function Integrated Plant Control, SMA Solar Technology AG does not provide any statutory warranty for the functionality of Integrated Plant Control.

3 Configuring Integrated Plant Control

In order to operate PV systems with Integrated Plant Control, the following settings are necessary:

1. The individual design of the PV system with all of its essential equipment must be entered so that each inverter can calculate its individual influence on the grid-connection point.
2. The desired characteristic at the grid-connection point must be set (generally specified by the grid operator).

3.1 Determining the Key Values of the System

In order to determine the parameter settings at the inverter, the equipment between the inverter terminals and the grid-connection point must be characterized. Determine the following key values:

Cables Used

- Conductor material
- Cross section
- Cable length

MV Transformer

- Nominal apparent power (S_N)
- Impedance voltage (v_k)
- Impedance loss in case of short-circuit at nominal power (P_{sc})

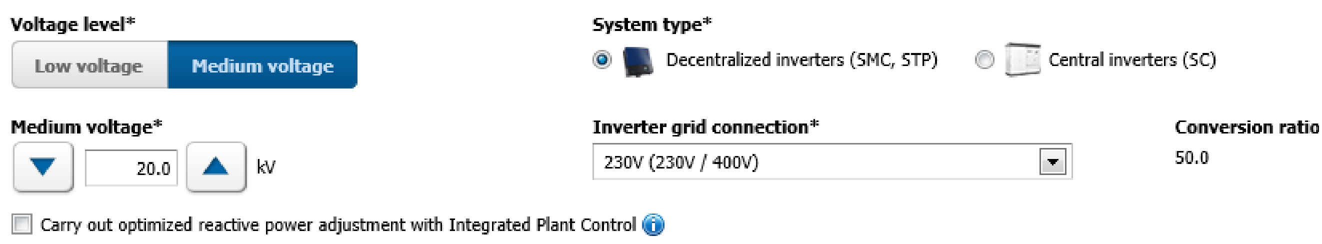
MV transformer data

You can usually find the required data on the MV transformer on the type label or datasheet. If these are not available, contact the manufacturer.

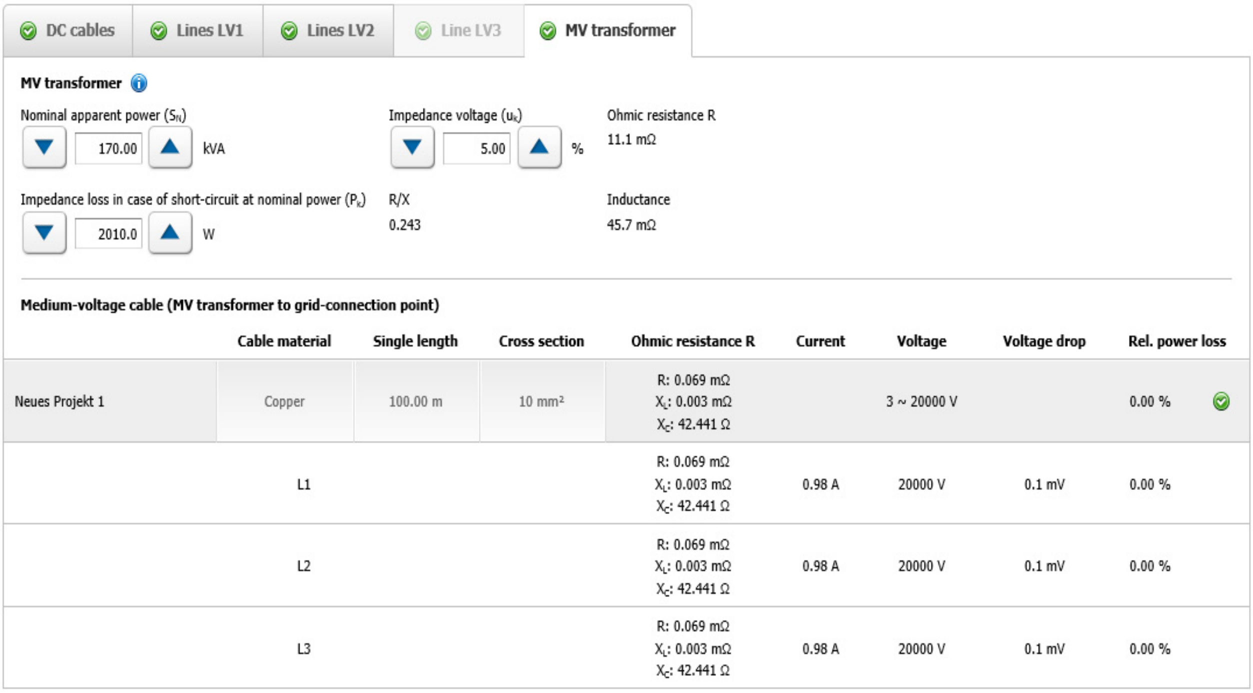
3.2 Entering Key Values in Sunny Design

You can find a detailed manual for Sunny Design at www.SMA-Solar.com. Proceed as follows to enter the key values in Sunny Design:

1. Open Sunny Design and log in as a user.
2. Create a new project.
3. Enter the project data.
4. Under **Project data**, select the option **Carry out optimized reactive power adjustment with Integrated Plant Control**.



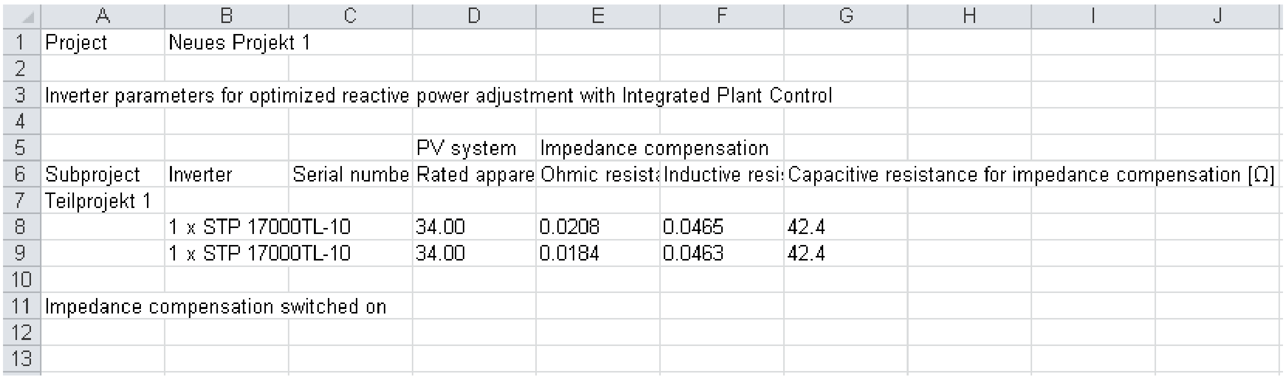
5. Select the button [**Configure the PV system**].
6. Select the PV arrays and inverters used from the menu.
7. Select the button [**Wire Sizing**].
8. If a project sub-distribution (LV3) is available, select the option **Project subdistribution available (LV3)** from the **Overview** window.
9. In the **Overview** window, select the option **Medium-voltage line and MV transformer available (MV)**.



☑ The tabs for entering the information on cables and the MV transformer are activated in the area **Configuration**.

10. Enter the key values for the cables used in the tabs **Lines LV1**, **Lines LV2** and **Lines LV3**.
11. In the tab **MV transformer**, enter the key values for the MV transformer.
12. In the window **Next steps**, select the button **[Download parameters]**.

☑ Sunny Design generates a CSV file containing the parameters that must be entered in the inverter.



	A	B	C	D	E	F	G	H	I	J
1	Project	Neues Projekt 1								
2										
3	Inverter parameters for optimized reactive power adjustment with Integrated Plant Control									
4										
5				PV system	Impedance compensation					
6	Subproject	Inverter	Serial numbe	Rated appare	Ohmic resist	Inductive resi	Capacitive resistance for impedance compensation [Ω]			
7	Teilprojekt 1									
8		1 x STP 17000TL-10		34.00	0.0208	0.0465	42.4			
9		1 x STP 17000TL-10		34.00	0.0184	0.0463	42.4			
10										
11	Impedance compensation switched on									
12										
13										

Parameter Description

Parameter name for BLUETOOTH or Speedwire/Webconnect	Parameter name for RS485	Description
Rated apparent power of all inverters	Plnt.VARtg	Nominal apparent power of all inverters [kVA]
Ohmic resistance for impedance compensation	ImpCpn.OhmRis	Ohmic resistance for impedance compensation [Ω]
Inductive resistance for impedance compensation	ImpCpn.IndRis	Lagging resistance for impedance compensation [Ω]
Capacitive resistance for impedance compensation	ImpCpn.CapacRis	Leading resistance for impedance compensation [Ω]
Impedance compensation switched on	ImpCpn.IsOn	Impedance compensation switched on

3.3 Changing Inverter Operating Parameters

Always change operating parameters as described in this section. Some parameters that have sensitive functions can only be viewed and changed by qualified persons (for further information on changing parameters, refer to the manual of the communication product).

The operating parameters of the inverter are set to certain values by default. To optimize inverter operation, you can change the operating parameters using a communication product.

Requirements:

- ☐ Depending on the type of communication, a computer with a BLUETOOTH or Ethernet interface must be available.
- ☐ A communication product corresponding to the type of communication used must be available.
- ☐ The inverter must be registered in the communication product.
- ☐ The changes to the grid-relevant parameters must be approved by the responsible grid operator.
- ☐ For changing the grid-relevant parameters, the SMA Grid Guard code must be available (see "Application for SMA Grid Guard Code" at www.SMA-Solar.com).

NOTICE

Restricted function of Integrated Plant Control as a result of incorrect settings

If the required parameters for Integrated Plant Control are incorrectly calculated or if the parameters are entered incorrectly in the inverter, the functioning of Integrated Plant Control is restricted. SMA Solar Technology AG does not accept liability for incorrect entries made by customers.

- For error-free functioning of Integrated Plant Control, the system must be modeled correctly using Sunny Design.
- If required, and subject to a fee, SMA Solar Technology AG can provide assistance with the correct calculation of the system parameters and with system parameterization.

Procedure:

1. Call up the user interface of the communication product or software and log in as **Installer** or **User**.
2. If required, enter the SMA Grid Guard code.
3. Select and set the required parameter.
4. Save settings.

Storage of Documentation

The system settings should be properly documented and stored so that they can be easily retrieved.

Example:

Device type and serial number	**PV system**	**Impedance compensation**		
	Nominal apparent power of all inverters [kVA]	Ohmic resistance for impedance compensation [Ω]	Lagging resistance for impedance compensation [Ω]	Leading resistance for impedance compensation [Ω]
STP 17000TL-10 0123456780	580	0.0062	0.012	35.6463
STP 17000TL-10 0123456781	580	0.0062	0.012	35.6463
STP 17000TL-10 0123456782	580	0.0062	0.012	35.6463
STP 10000TL-10 0123456783	580	0.0048	0.0119	35.6463

4 Q on Demand 24/7

The "Q on Demand 24/7" function keeps the inverter on the utility grid over night. It is powered by the grid in order to provide reactive power (III)* . Additionally, in feed-in operation, the inverter can provide up to 100% of its apparent power as reactive power (II) over and above its normal operating range (I).

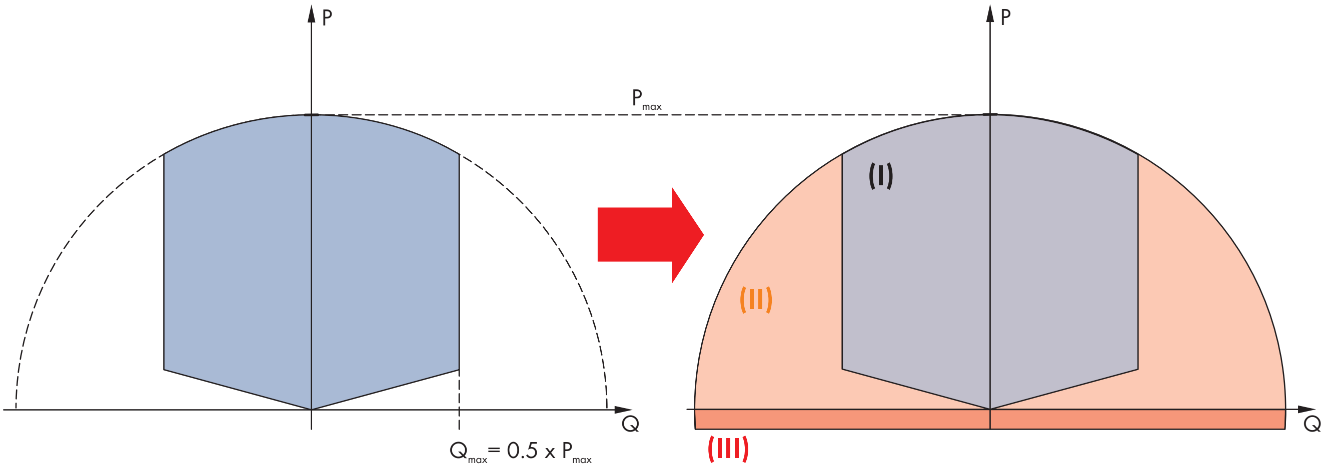


Figure 8: Extension of the operating range and limits of the Sunny Tripower by using the "Q on Demand 24/7" function

Parameters for Q on Demand 24/7

Parameter name	Description
Oper.st.vol.maint.at Q on Dem., st.vol.maint.conf. (Q-VArModDmd)	1 = default setting Limitation of reactive power Q depending on the active power P is switched on. 0 = Limitation of reactive power Q depending on the active power P is switched off. When using the "Q on Demand 24/7" function, set this parameter to 0.

With the parameter **Oper.st.vol.maint.at Q on Dem., st.vol.maint.conf. (Q-VArModDmd)**, you can activate only the function "Q on Demand 24/7".

The general setting of the grid management service (e.g. cos(phi) setpoint or Q(V) characteristic curve) can be set independently of function "Q on Demand 24/7" using the relevant parameters.

* If the inverter is disconnected from the utility grid during the night (e.g. under fault conditions), it cannot connect to the utility grid again until the next morning if there is sufficient PV power. Until then, the function "Q on Demand 24/7" is inactive.