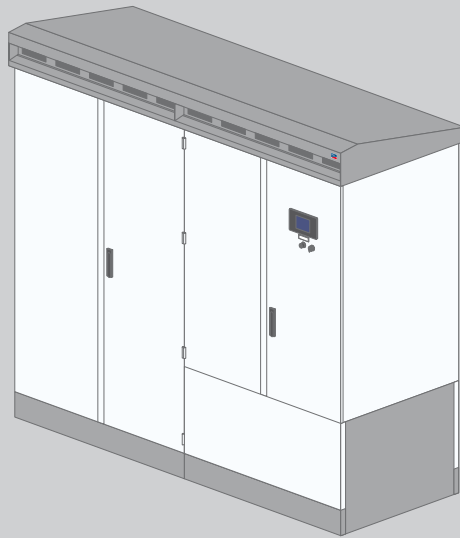


Q at Night

Reactive power outside feed-in operation with the
SUNNY CENTRAL series CP XT, CP-JP and CP-US



Content

The utility grid has a fundamental need for reactive power and in some cases there is also a requirement to prevent instabilities in the utility grid by feeding in reactive power. The inverters in the CP XT, CP-JP and CP-US series with system components from SMA Solar Technology AG or SMA America, LLC can satisfy this requirement and also provide reactive power outside of the feed-in periods.

1 Providing Reactive Power

What are Active Power and Reactive Power?

Electrical power is the product of current and voltage. While current and voltage have stable values for direct current, their relation is more complicated for alternating current: the strength and the direction of both current flow and voltage change periodically. Both take on a sinusoidal shape in the utility grid resulting in the product being a pulsating power.

Whether or not the current and the voltage are phase-shifted is crucial. With no phase shift, i.e. current and voltage achieve their maximum and minimum values simultaneously, the power oscillates between zero and the positive maximum value. Averaged over time, this results in a positive power value and only active power P is generated. Such a behavior only occurs when the utility grid only has linear loads. The active power is the usable portion of the energy that is present in the utility grid.

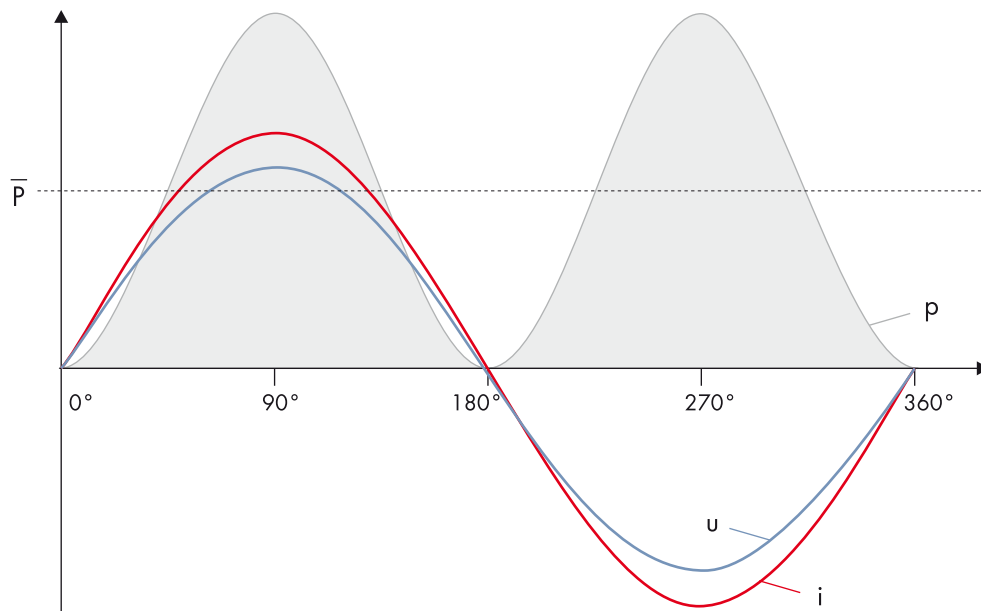


Figure 1: Pure active power: current and voltage are in phase

On the other hand, with a phase shift of 90° the maximum current occurs when the voltage crosses zero; then the power oscillates between positive and negative values and its average value over time is zero. This is known as reactive power Q , which moves "back and forth" in the lines. The reactive power is not consumed and burdens the utility grid.

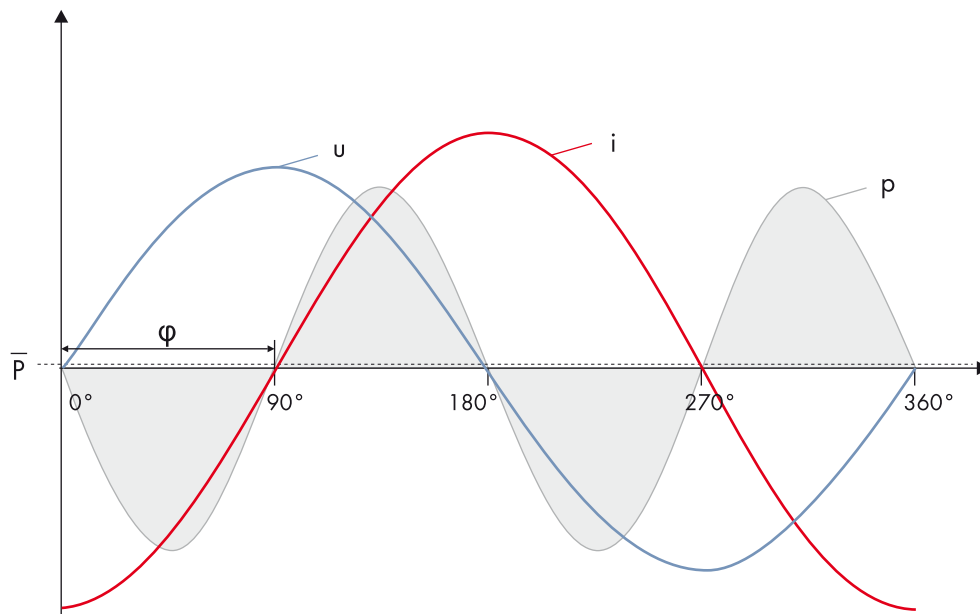


Figure 2: Pure reactive power: current and voltage are phase-shifted by 90° .

Smaller phase shifts result in a mixture of active and reactive power. This behavior occurs when there are lagging or leading loads in the utility grid. The shift between current and voltage is denoted by the displacement power factor $\cos \varphi$.

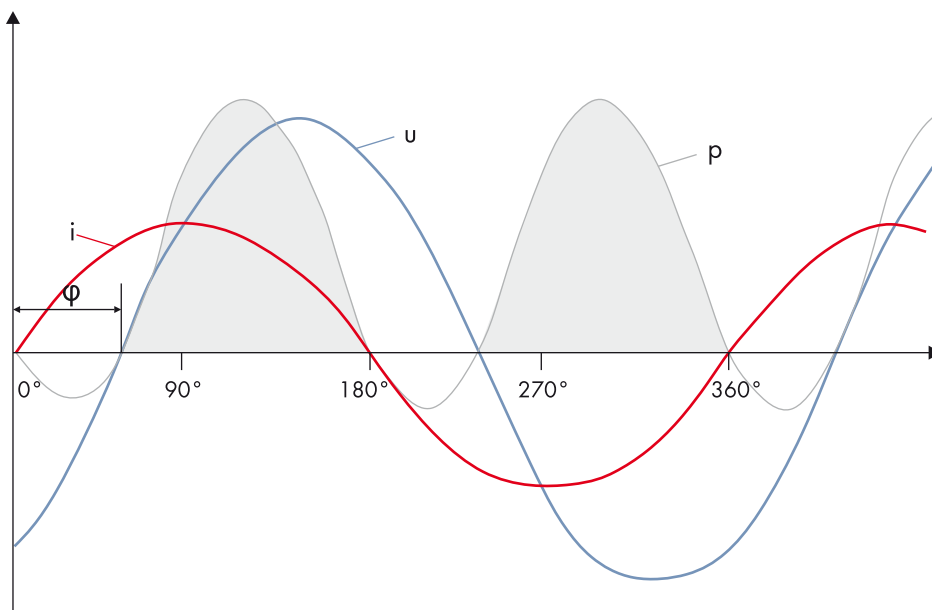


Figure 3: Apparent power: current and voltage are phase-shifted, reducing the active power

The sum of active and reactive power is the so-called apparent power S . Note that they are not added arithmetically, but 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.

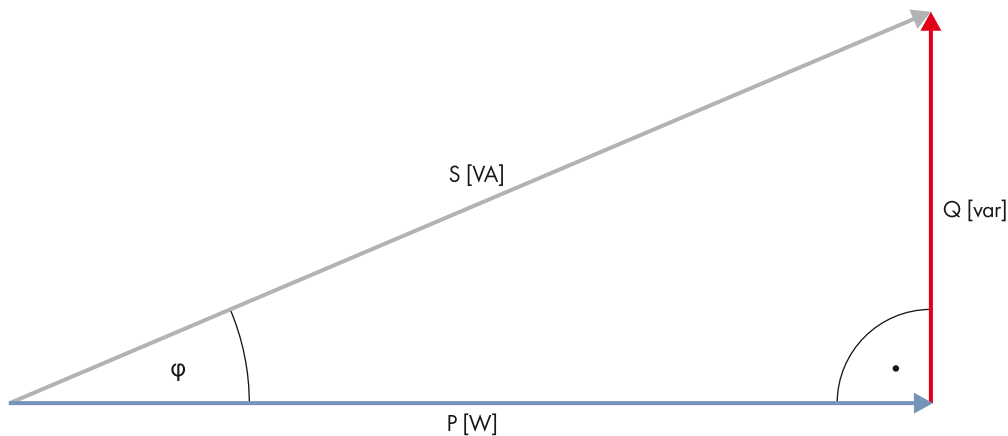


Figure 4: Vector addition of active and reactive power

How Does the Demand for Reactive Power Arise?

Reactive power arises wherever electric current is produced in large power plants. Reactive power burdens the utility grid without contributing to the transport of energy. It is therefore necessary to stabilize the utility grid by compensating for the reactive power.

How Is Reactive Power Compensated?

In order to ensure the stability of the utility grid, grid operators demand that energy producers take part in the compensation of reactive power. This is not a problem during the day as the inverters of the CP XT, CP-JP and CP-US series can generate reactive power during feed-in operation.

If reactive power also has to be compensated outside of feed-in operation, the only solution available in the past was to install cost-intensive compensation plants. These compensation plants make static or dynamic generation of reactive power possible. Static in this case means that the grid operator specifies a reactive power setpoint, which is then implemented in such a plant without taking other requirements into consideration. Need-based reactive power is generated in dynamic compensation plants.

The "Q at Night" option provides an additional solution: the inverters of the CP XT, CP-JP and CP-US series can also provide compensating reactive power at night, feeding pure reactive power into the utility grid. As a result, costs which would arise from external sourcing of reactive power do not apply. In addition, the needs of additional generators can also be addressed by providing extra reactive power, offering an additional source of income.

2 Technical Basics

2.1 Modifications to the PV System

In order for the PV system to also be able to feed in reactive power at night, the inverter must be fitted with the "Q at Night" option. For some MV transformers, the connection between the inverter and the MV transformer must be modified.

"Q at Night" Option in the Inverter

Sunny Central inverters with the "Q at Night" option include additional hardware components that enable feed-in operation even without a DC voltage being present.

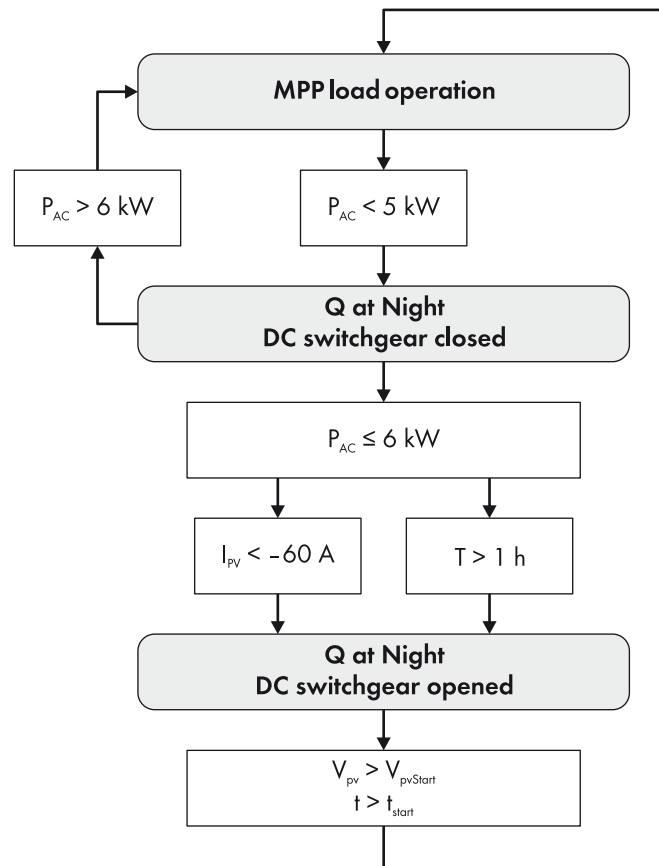
For "Q at Night" operation, the inverter runs through another operating state and uses additional parameters with which the procedure and the limits for reactive power generation can be set. "Q at Night" operation can be activated via a parameter.

Connection between the Inverter and the MV Transformer

Complete systems with Sunny Central and the "Q at Night" option and the MV Power Station can operate with "Q at Night" without further preparations.

"Q at Night" operation results in additional thermal stress. To avoid excessive thermal stress on the cable connection between the inverter and the MV transformer, for some projects it may be necessary to use an extended cable set in the connection between the inverter and the customer transformer. The necessity of using an extended cable set must be confirmed with SMA Solar Technology AG.

2.2 Inverter Behavior



If the AC power generated by the inverter falls below 5 kW, the inverter switches from feed-in operation to "Q at Night" operation. The inverter feeds in reactive power in accordance with the parameter settings. Since this status can also occur during the day, the DC switchgear remains closed at first in order to avoid unnecessary switching cycles of the DC switchgear. If the inverter has been in "Q at Night" operation for one hour or the DC current falls below -60 A, the DC switchgear opens. The inverter continues to feed in reactive power.

If reactive power feed-in is interrupted after a grid fault and the AC contactor is opened while the DC switchgear is open, the DC circuit will first be pre-charged to reduce the stress on the electronic components. This process takes no more than one minute. Once the DC circuit is sufficiently pre-charged, the AC contactor is closed and the inverter monitors the grid limits. If all of the feed-in requirements are met, the inverter will revert to reactive power feed-in within one minute.

While the inverter is feeding in reactive power, the inverter monitors whether the conditions for active power feed-in are met. Once the feed-in requirements are met, the inverter closes the DC switchgear and switches to feed-in operation.

2.3 Reactive Power Setpoints

Analogous to normal feed-in operation, you can set the procedure for reactive power control in "Q at Night" operation via the **QoDQ-VArMod** parameter. The following procedures can be selected:

Procedure	Description
Off	The reactive power setpoint is limited to 0 kVAr.
VArClCom	The reactive power setpoint is received via an external control unit such as the Power Reducer Box or the Power Plant Controller and is transmitted to the inverter.
VArCnst	The reactive power setpoint is specified in kVAr via the parameter Q-VAr . If the reactive power setpoints are to be specified as fixed values via a parameter, different values can be entered for normal feed-in operation and "Q at Night" operation.
VArCnstNom	The reactive power setpoint is specified in % via the parameter Q-VArCnst .
VArCnstNomAnIn	The reactive power setpoint is imported via an analog input. The analog value is converted into a reactive power setpoint.
VArCnstVol	The reactive power setpoint is specified depending on the grid voltage.
VArCnstVolHystDb	The reactive power setpoint is specified depending on the grid voltage via a reactive power characteristic curve or voltage characteristic curve. The same reactive power characteristic curve or voltage characteristic curve is used for both operating states.

The procedures for reactive power regulation can be selected independently for normal feed-in operation and "Q at Night" operation. The following combinations of the procedures are possible:

		Q at Night		
		Qconst_night Input in VAR or % of Pmax	Qexternal Specified via Modbus or analog input	Q(V)_night Input with and without deadband
Feed-in operation	Qconst Input in VAR or % of Pmax	Yes (different specifications possible)	Yes (recommended: always specify via external Q setpoint)	Yes
	Qexternal Specified via Modbus or analog input	Yes	Yes Preferred choice	Yes (recommended: always specify via external Q setpoint)
	Q(V)_night Input with and without deadband	Yes	Yes (recommended: always specify via external Q setpoint)	Yes (same characteristic curve for feed-in operation and "Q at Night" operation)
	Cosp const	Yes	Yes	Yes
	Cosp external Specified via Modbus or analog input	Yes	No (specified via same input)	Yes (recommended: always specify via external Q setpoint)
	Cosp(P)	Yes	Yes (recommended: always specify via external Q setpoint)	Yes

i Reducing electromagnetic interference emissions in large-scale systems

To reduce electromagnetic interference emissions in large-scale PV power plants at the changeover from night to day mode, SMA recommends using Modbus communication to specify setpoints for both day and night mode.

2.4 FRT Limitation

With full dynamic grid support (FRT), during normal feed-in operation the Sunny Central supports the utility grid during a brief grid-voltage dip by feeding in reactive power.

When the Sunny Central is working in "Q at Night" mode, the inverter supports the utility grid during a brief grid-voltage dip with limited dynamic grid support (LVRT). In this case, though the Sunny Central interrupts reactive power feed-in, it does not disconnect from the utility grid; it monitors the grid parameters in order to be able to restart feed-in again after the voltage dip.

2.5 Protection against Reverse Currents

To protect the inverter and the PV array from excessive reverse currents during "Q at Night" operation, you can limit the maximum permissible reverse current via the parameter **QoDInvCurPv**. Recommended: keep the default setting of -60 A to avoid an unnecessary increase in the number of switching cycles of the DC switchgear.

3 Special Cases

When deciding whether the "Q at Night" option is suitable for your project, you should take various aspects into consideration. These topics are described in detail in the following sections.

3.1 Limiting the Reactive Power in "Q at Night" Operation

To protect the MV transformer, the maximum possible reactive power is limited in "Q at Night" operation; 30% of the inverter's nominal power can be fed in. The corresponding limits are permanently set in the parameters. In spite of the reduced power, noise emissions can result during "Q at Night" operation.

3.2 Retrofitting Existing Systems

Sunny Central inverters that are not equipped with the "Optiprotect" option can be retrofitted with the hardware components for the "Q at Night" option under certain conditions. The new parameters are provided in a firmware update.

To avoid excessive thermal stress on the cable connection between the inverter and the MV transformer, for some projects it may be necessary to use an extended cable set for the connection between the inverter and the customer transformer. The necessity of using an extended cable set must be confirmed with SMA Solar Technology AG.

Contact the SMA Service Line with any questions regarding this subject.

3.3 Efficiency of the "Q at Night" Option

The capital expenditures for the "Q at Night" option are significantly lower than the costs for compensation plants. In particular, the savings compared to dynamic compensation plants are considerable.

Additional operating costs must be expected for the overnight internal power supply of the inverter.