# Q at Night

Reactive power outside of feed-in operation with
SUNNY CENTRAL 500CP XT / 630CP XT / 720CP XT /
760CP XT / 800CP XT / 850CP XT / 900CP XT
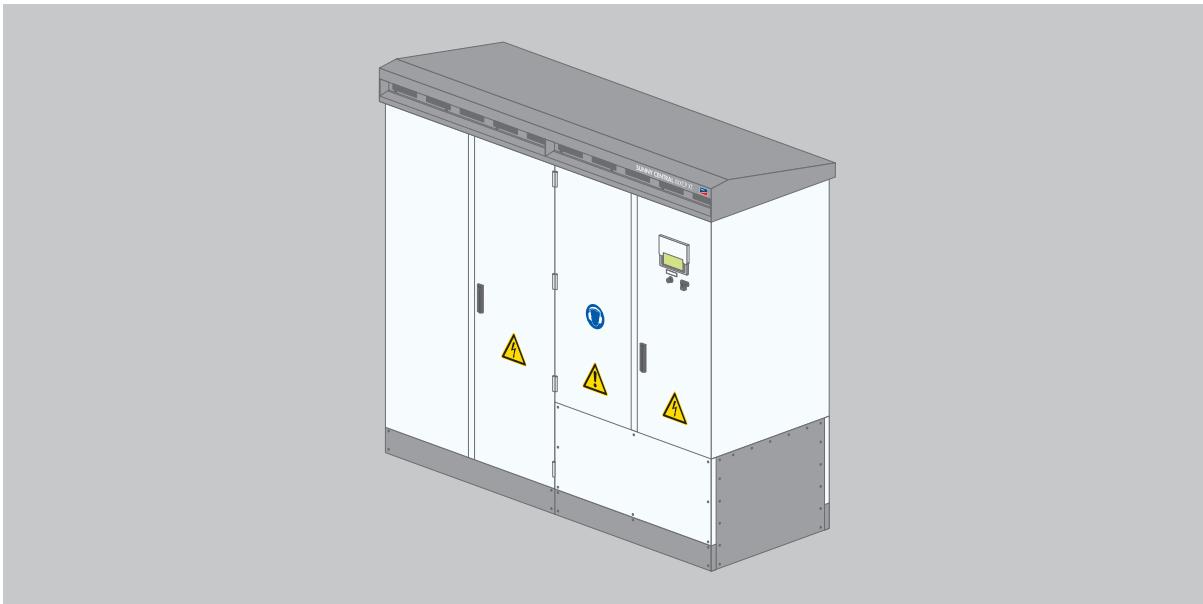
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The electricity grid has a fundamental need for reactive power and, in some cases, the requirement to avoid instabilities via reactive power feed-in. Sunny Central CP XT inverters by SMA Solar Technology AG satisfy this requirement and make reactive power available outside of the feed-in periods.

1 Providing Reactive Power

What is Active Power and Reactive Power?

Electrical power is the product of current and voltage. While direct current has stable current and voltage values, the behavior of alternating current is more complicated: Strengths, direction of the current flow and voltage all change continuously. Both take on a sinusoidal shape in the grid, resulting in pulsating power. At the same time, it is decisive as to whether the current and voltage are phase-shifted or not. Without phase shift (i.e current and voltage achieve their maximum and minimum values at the same time), the power oscillates between zero and the positive maximum value. Over a temporal average period, this results in a positive power value which is exclusively active power. Such a behavior only occurs when the grid only has linear loads. The active power is the usable portion of the energy that is present in the grid.
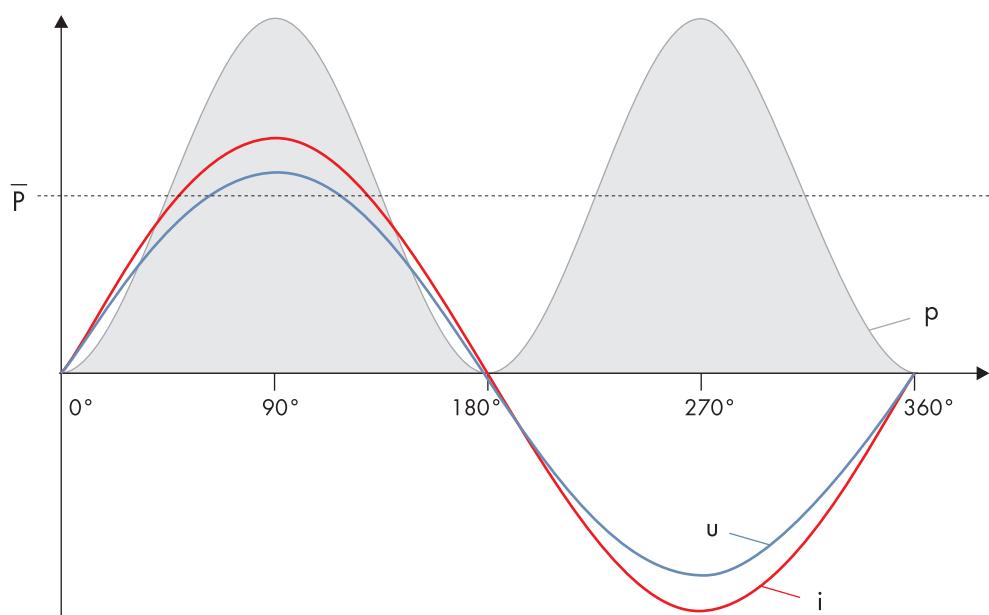

Figure 1: Pure active power: current and voltage are in phase

In contrast, with a phase shift of 90 degrees (i.e. the current maximum occurs at the zero-crossing of the voltage), the power oscillates between negative and positive values. The temporal average is therefore zero. This is known as reactive power Q, which "runs up and down" the lines. The reactive power is not consumed and burdens the grid.
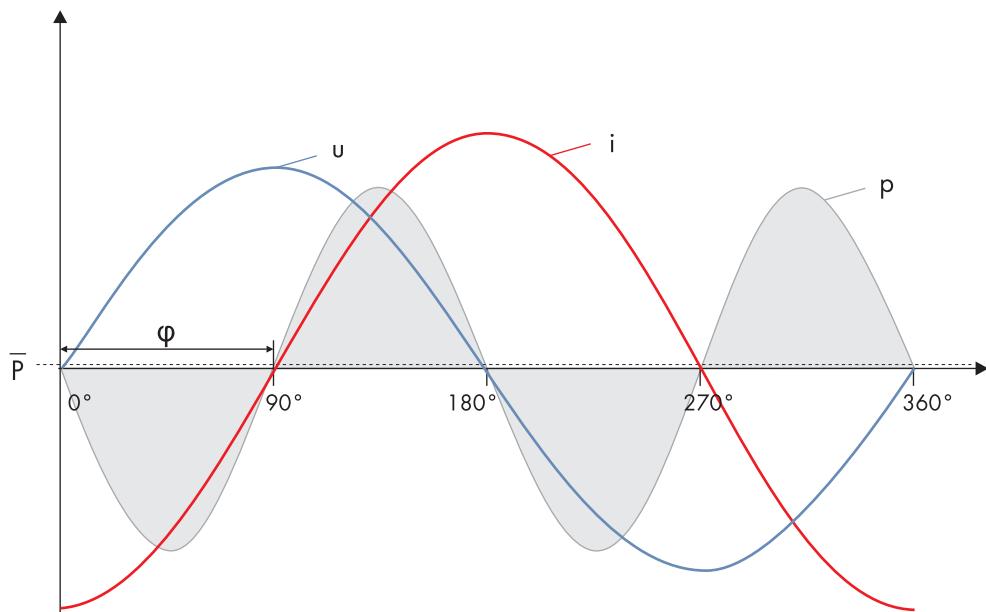
Figure 2: Pure reactive power: current and voltage are 90 degrees phase-shifted.

Smaller phase shifts result in a mixture of active and reactive power. This behavior occurs if there are lagging or leading loads in the grid. The shift between current and voltage is denoted by the displacement power factor cos φ.
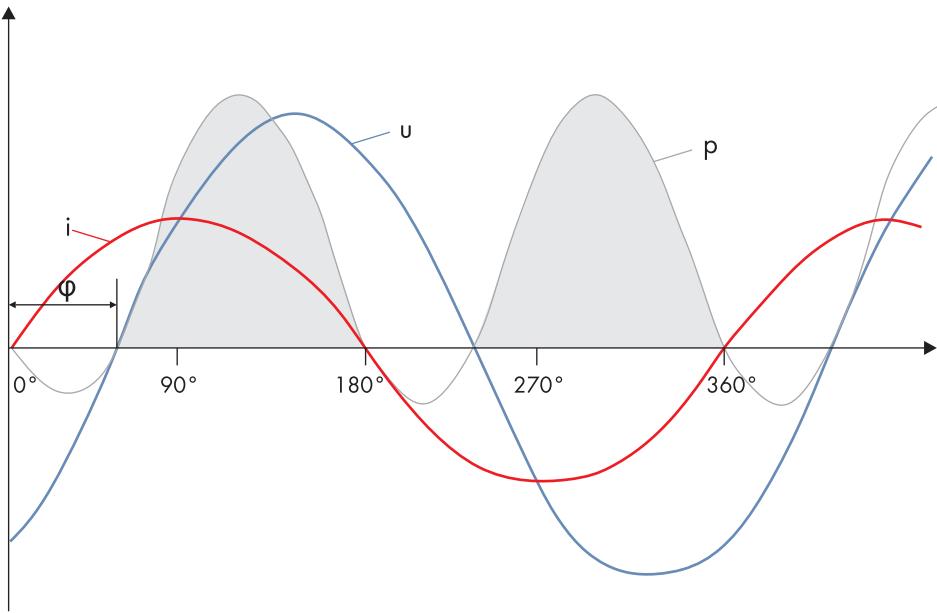
Figure 3: Apparent power: current and voltage are phase-shifted and therefore reduce the active power.

The sum of active and reactive power is apparent power, S. It is to be noted here that they are not added normally, but geometrically: active and reactive power form the legs of a right-angled triangle, the resulting hypotenuse is the apparent power. The cosine of the angle between the active power and apparent power is the displacement power factor.
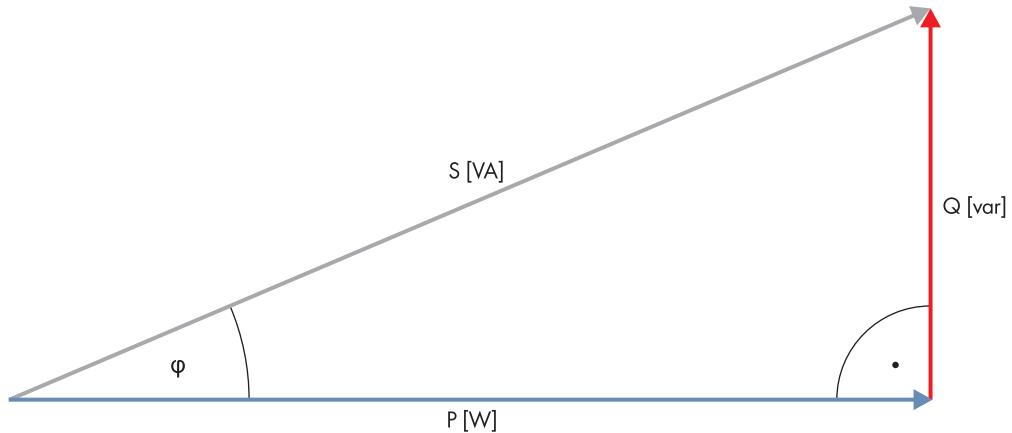
Figure 4: Geometrical addition of active and reactive power

How Does the Demand for Reactive Power Occur?

Reactive power is found wherever electricity is produced in large power plants. Reactive power burdens the grid without contributing to the conduction of energy. It is therefore necessary to stabilize the grid by compensating the reactive power.

How Is Reactive Power Compensated?

In order to ensure a stable grid, producers must take part in the compensation of reactive power. This is not a problem during the day: SMA inverters can generate reactive power during feed-in operation. If reactive power is also to be compensated outside of feed-in operation, the only solution available in the past was to install cost-intensive compensation plants, which make the generation of static or dynamic reactive power possible. Static, in this case, means that the network operator specifies a reactive power target value, which is then implemented in the plant without taking other requirements into consideration. Need-based reactive power is generated in dynamic compensation plants. With the "Q at Night" option, there is an additional solution: Sunny Central CP XT inverters can also make compensating reactive power available at night. In this case, pure reactive power is fed into the grid, resulting in the elimination of costs associated with the external sourcing of reactive power. In addition, it is also possible to compensate the needs of additional generators through the extra reactive power available, offering an additional source of income.

2 Technical Basics

2.1 Adjustments to the PV Plant

In order for the PV plant to also feed in reactive power during the night, the inverter must be fitted with the "Q at Night" option. In some instances, the connection between inverter and MV transformer must be adjusted.

Option "Q at Night" in the Inverter

The Sunny Central CP XT with the "Q at Night" option contains additional hardware components that enable feed-in operation even without 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 of reactive power generation can be set. The "Q at Night" operation can be activated via a parameter.

Connection between the Inverter and the MV Transformer

Complete systems with the Sunny Central CP XT with the "Q at Night" option and the MV Power Station can work in "Q at Night" operation without further preparations. While the inverter is in "Q at Night" operation, an additional thermal stress occurs. In order to keep this to a minimum, an additional cable set must be provided for the connection between the inverter and customer-side transformer.

2.2 Inverter Behavior

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                    ┌──────────────────────────────────┐
                    │      Inverter feed-in operation    │
                    └──────────────────────────────────┘
   ┌───────────────────────┐        ┌───────────────────────┐
   │  $P_{AC} > 6\,kW$     │        │  $P_{AC} < 5\,kW$     │
   └───────────────────────┘        └───────────────────────┘
                    ┌──────────────────────────────────┐
                    │       Q at Night operation,        │
                    │        DC switchgear closed        │
                    └──────────────────────────────────┘

        ┌────────────────────────────────────────┐
        │ $P_{AC} \leq 6\,kW$ and $I_{PV} < 60\,A$ │
        │ or $P_{AC} \leq 6\,kW$ and $t_Q > 1h$     │
        └────────────────────────────────────────┘

                    ┌──────────────────────────────────┐
                    │       Q at Night operation,        │
                    │        DC switchgear opened        │
                    └──────────────────────────────────┘

        ┌────────────────────────────────────────┐
        │ $U_{pv} > U_{pvStart}$ und $T > T_{start}$ │
        └────────────────────────────────────────┘

        ┌────────────────────────────────────────┐
        │         $U_{pv} > PvVtgStrLevMin$        │
        │              $T > PV\ StrT$              │
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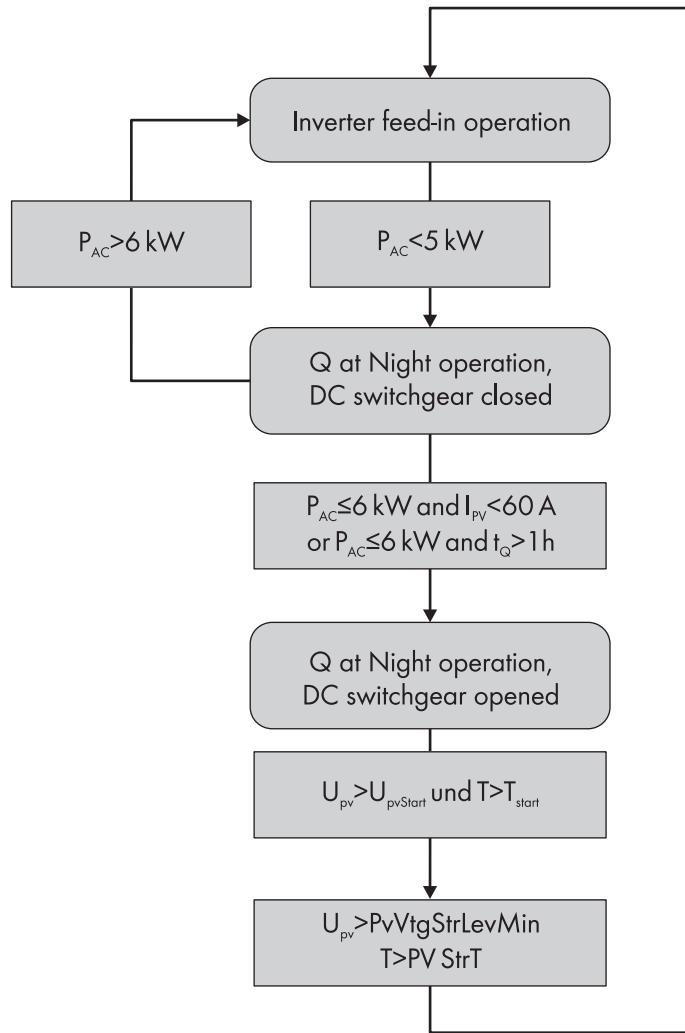
If the AC power generated by the inverter falls below five kilowatts, the inverter switches from feed-in to "Q at night" operation and feeds in reactive power in accordance with the parameters set. Since this status can also occur during the day, the DC switch gear remains closed at first, in order to avoid unnecessary switching of the DC switch gear. If the inverter is in the "Q at Night" mode for one hour or the DC current falls below 60 A, the DC switch gear opens and the inverter continues to feed in reactive power. If reactive power feed-in is interrupted after a grid fault and the AC contactor was opened while the DC switch gear is open, the DC circuit is initially pre-charged, which reduces stress on the electronic components. This procedure takes up to 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 starts reactive power feed-in again within one minute. While the inverter is feeding in reactive power, it simultaneously monitors whether the conditions for active power feed-in have been met. If the feed-in requirements are met, the inverter closes the DC switch gear and changes to feed-in operation.

2.3 Reactive Power Setpoints

Similar to normal feed-in operation, reactive power control in the "Q at Night" operation can be set via the parameter **QoDQ-VArMod**. The following procedures are available for selection:

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

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

		Q at Night		
		Qfest_nacht Entry in VAr or % of Pmax	**Qextern** Specification via Modbus or analogue input	**Q(U)_nacht** Entry with and without neutral zone
Feed-in operation	**Qfest** Entry in VAr or % of Pmax	Yes (different specifications possible)	Yes (recommendation: specification always via external Q setpoint)	Yes
	Qextern Specification via Modbus or analogue input	Yes	Yes Preferred option	Yes (recommendation: specification always via external Q setpoint)
	Q(U)_nacht Entry with and without dead band	Yes	Yes (recommendation: specification always via external Q setpoint)	Yes (same characteristic curve for feed-in operation and "Q at Night" operation)
	Cosφ fest	Yes	Yes	Yes
	Cosφ extern Specification via Modbus or analogue input	Yes	No (specification via the same input)	Yes (recommendation: specification always via external Q setpoint)
	Cosφ(P)	Yes	Yes (recommendation: specification always via external Q setpoint)	Yes

2.4 FRT Limitation
With full dynamic grid support (FRT), the Sunny Central CP XT supports the grid in normal feed-in operation during a brief grid voltage dip by feeding in reactive power. If it is operating in "Q at Night" mode, the inverter supports the grid during the voltage dip with limited dynamic grid support (LVRT). In this case, the Sunny Central CP XT interrupts reactive power feed-in, while remaining connected to the grid, and monitors the grid parameters in order to be able to restart feed-in again after the voltage dip.

2.5 Protection against Reverse Currents
In order to protect the inverter and the PV array from excessive reverse currents during the "Q at Night" operation, maximum permissible reverse current can be limited via the parameter **QoDInvCurPv**. SMA recommends that the default setting of 60 A is kept. The number of switching cycles of the DC switch gear is thus not increased unnecessarily and the replacement interval is not reduced.

3 Special Features

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

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

The maximum possible reactive power is limited in the "Q at Night" operation for the protection of the MV transformer. Thirty percent of the nominal power of the inverter can be fed in and the respective limits are set permanently in the parameters.

3.2 Retrofitting of Existing Plants

Sunny Central CP XT inverters from fabrication version B4 can be retrofitted with the hardware components for the "Q at Night" option. The new parameters will be made available via a firmware update. An extra AC cable must be laid between inverter and customer-side MV transformer in addition to the adjustments to the inverter. Contact the SMA Service Line with any questions regarding this subject.

3.3 Economic Viability of the Option "Q at Night"

The investment costs of the option "Q at Night" are significantly lower in comparison to the costs for compensation plants. In particular, the savings are considerable compared to dynamic compensation plants. Additional operating costs must be considered for the overnight internal power supply of the inverter.

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