



Description of the Operating Parameters

SUNNY TRIPOWER 60
SUNNY HIGHPOWER PEAK1

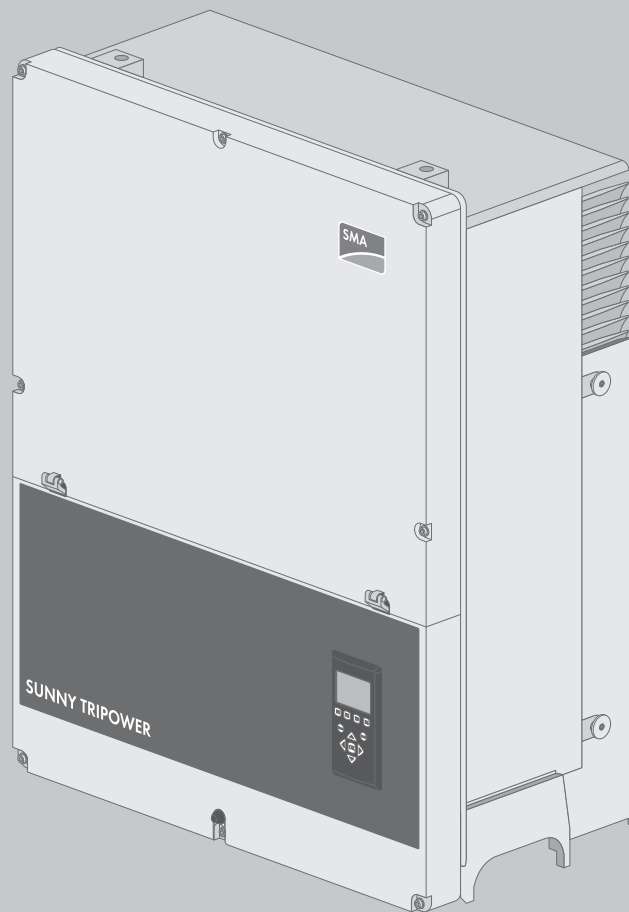


Table of Contents

1	Information on this Document	5
2	Grid Protection Settings	5
2.1	Nominal Voltage	5
2.2	Nominal Frequency	5
2.3	Voltage-Dependant Disconnection	5
2.3.1	Disconnection due to Undervoltage	5
2.3.2	10-Minute Average Value	6
2.3.3	Disconnection due to Overvoltage	6
2.4	Manual Restart	6
2.4.1	Activating Manual Restart	6
2.4.2	Events causing grid faults	6
2.5	Frequency-Dependent Disconnection	7
2.5.1	Disconnection due to Underfrequency	7
2.5.2	Disconnection due to Overfrequency	7
2.6	Connection, Reconnection and Disconnection	7
2.6.1	Connection Time	7
2.6.2	Reconnection Time	8
2.6.3	Short Interruption Time	8
2.6.4	Time to Alarm	8
2.6.5	Voltage and Frequency Connection Limits	8
2.6.6	Ramp-In	8
3	Grid Failure	9
3.1	Active Frequency Shift	9
3.2	Phase Failure Detection	9
3.3	Rate of Change of Frequency	9
4	Settings of Grid Management Services: Fault Ride-Through (FRT)	10
5	Settings of Grid Management Services	14
5.1	Basic Settings	15
5.1.1	Selecting the Control Mode for Reactive Power Provision	15
5.1.2	Night Mode	15
5.1.3	Active Power Limitation for Reactive Power Feed-In	15
5.1.4	Nominal Apparent Power at Point of Common Coupling (PCC)	16
5.1.5	Voltage Differences Between the Point of Common Coupling (PCC) and the PV System	16
5.1.6	Nominal Voltage	16
5.2	Direct Control	16
5.2.1	Start Signal	16
5.2.2	Connection/Reconnection Ramp Rate	17
5.2.3	Time Delay for Shutdown	17
5.2.4	Reactive Power Ramp Rates	17
5.2.5	Active Power Ramp Rates	17
5.2.6	Setting the Maximum Active Power	17
5.2.7	Setting the Reactive Power	17
5.2.8	Setting the Power Factor (PF)	18

5.2.9	Setting the Apparent Power	18
5.3	Control Modes	18
5.3.1	Q(U) - Reactive Power as a Function of Grid Voltage	19
5.3.2	Q(P) - Reactive Power as a Function of Active Power	19
5.3.3	Q(S) - Reactive Power as a Function of Apparent Power	19
5.3.4	Q(ext) - Reactive Power as a Function of an External Setpoint	19
5.3.5	PF(P) - Power Factor as a Function of Active Power	20
5.3.6	PF(U) - Power Factor as a Function of Grid Voltage	20
5.3.7	PF(ext) - Power Factor as a Function of an External Setpoint	20
5.3.8	P(U) - Active Power as a Function of Grid Voltage	21
5.3.9	P(f) - Reactive Power as a Function of Frequency	21

1 Information on this Document

This document is valid for the following device types:

- STP 60-10 (Sunny Tripower 60) from software version 1.80
- SHP 75-10 (Sunny Highpower Peak1) from software version 1.90

This document is intended to help the user get a better understanding of the functionality of the inverter. The descriptions refer to the parameter IDs which can also be found in the "Settings report".

The value ranges indicated in the following sections do not necessarily refer to the permissible ranges in accordance with the applied standards, but are to reflect the performance of the inverter. All adjustable parameters have the same indicated ranges and increments. Since not all parameters are used by all standards, the parameters that are not used will be deactivated in the file "Inverter settings".

2 Grid Protection Settings

The following parameters for grid connection settings are saved in the inverter and only used here. The settings are divided into groups. The groups reflect the various grid management services.

All requirements for grid protection settings are set at the inverter connection point.

2.1 Nominal Voltage

This parameter refers to the nominal grid voltage of a country. In most countries, only one official grid voltage is valid. For countries with several official grid voltages, additional grid codes are provided so that the user is able to set the grid voltage requested by the grid operator.

Parameter Name	Adjustment range
UNOM	220 Vac to 277 Vac (L-N)

2.2 Nominal Frequency

The nominal frequency can either be 50 Hz or 60 Hz, and for the most part only one of the two is used. For countries where both frequency values are used, additional grid codes are provided so that the user is able to set the nominal frequency requested by the grid operator.

Parameter Name	Adjustment range
FNOM	50 Hz or 60 Hz

2.3 Voltage-Dependant Disconnection

2.3.1 Disconnection due to Undervoltage

The undervoltage disconnection capability has two parameters in a set, the first parameter is the magnitude, which is given in voltage, the second is the trip time, which is given in seconds. Undervoltage disconnection works in the way that in case of grid failure below the value stated in **UMIN**, the inverter stays connected to the grid for the time period stated in **T_UMIN**. After this time has elapsed, the inverter must disconnect from the utility grid. Depending on the applied standard, these two values can either be a maximum, minimum or mean value. Refer to the relevant standard to see which of the three key values is used in your file.

Parameter Name	Adjustment range	Increment
UMIN	23 Vac (L-N) to UNOM	0.1 Vac (L-N)
T_UMIN	0.05 s to 90.0 s	0.01 s

2.3.2 10-Minute Average Value

The ten-minute average value is defined in the standard EN 50160 as maximum threshold for a continuous high voltage in the grid. If this value is exceeded, the inverter is disconnected from the utility grid.

Parameter Name	Adjustment range	Increment
U10M_AVG	UNOM to 350 Vac (L-N)	0.1 Vac (L-N)
T_U10M_AVG	0.05 s to 90.0 s	0.01 s

2.3.3 Disconnection due to Overvoltage

The overvoltage disconnection function has two related values: the first value indicates the voltage level in volt, the second value indicates the tripping time in seconds. Overvoltage disconnection works in the way that if the grid voltage exceeds the value stated in **UMAX**, the inverter stays connected to the grid for the time period stated in **T_UMAX**. After this time has elapsed, the inverter must disconnect from the utility grid. Depending on the applied standard, these two values can either be a maximum, minimum or mean value. Refer to the relevant standard to see which of the three key values is used in your file.

Parameter Name	Adjustment range	Increment
UMAX	UNOM to 350 Vac (L-N)	0.1 Vac (L-N)
T_UMAX	0.05 s to 90.0 s	0.01 s

2.4 Manual Restart

With the function Manual Restart, you can configure whether the inverter is to revert to feed-in operation automatically after the fault has occurred, or whether feed-in operation should remain interrupted until it is manually reactivated.

2.4.1 Activating Manual Restart

The parameter **RST_MOD** activates the manual restart. A value of 1 causes that the user must start the inverter after a grid fault. A value of 0 causes that the inverter reverts to feed-in operation automatically after the grid fault has been rectified.

Parameter Name	Setting Options
RST_MOD	on (1), off (0)

2.4.2 Events causing grid faults

The following events cause the inverter to interrupt feed-in operation and that the feed-in operation must be activated through manual restart.

- Overvoltage
- Undervoltage
- Active islanding detection
- Passive islanding detection
- Overfrequency
- Underfrequency

If one of the parameters is set to value 1 and a corresponding grid fault occurs, a specific event is generated and the inverter interrupts the feed-in operation until it is restarted manually.

Parameter Name	Setting Options
MAN_RST_OV_VTG	on (1), off (0)

Parameter Name	Setting Options
MAN_RST_UN_VTG	on (1), off (0)
MAN_RST_OV_FREQ	on (1), off (0)
MAN_RST_UN_FREQ	on (1), off (0)
MAN_RST_PID	on (1), off (0)
MAN_RST_AID	on (1), off (0)

2.5 Frequency-Dependent Disconnection

2.5.1 Disconnection due to Underfrequency

The underfrequency disconnection function has two related values: the first value indicates the frequency level in Hertz, the second value indicates the tripping time in seconds. Underfrequency disconnection works in the way that if the grid frequency drops below the value stated in **FMIN**, the inverter stays connected to the grid for the time period stated in **T_FMIN**. After this time has elapsed, the inverter must disconnect from the utility grid. Depending on the applied standard, these two values can either be a maximum, minimum or mean value. Refer to the relevant standard to see which of the three key values is used in your file.

Parameter Name	Adjustment range	Increment
FMIN	45 Hz to FNOM	0,01 Hz
T_FMIN	0.05 s to 90.0 s	0.01 s

2.5.2 Disconnection due to Overfrequency

The overfrequency disconnection function has two related values: the first value indicates the frequency level in Hertz, the second value indicates the tripping time in seconds. Overfrequency disconnection works in the way that if the power frequency exceeds the value stated in **FMAX**, the inverter stays connected to the grid for the time period stated in **T_FMAX**. After this time has elapsed, the inverter must disconnect from the utility grid. Depending on the applied standard, these two values can either be a maximum, minimum or mean value. Refer to the relevant standard to see which of the three key values is used in your file.

Parameter Name	Adjustment range	Increment
FMAX	FNOM to 66 Hz	0,01 Hz
T_FMAX	0.05 s to 90.0 s	0.01 s

2.6 Connection, Reconnection and Disconnection

2.6.1 Connection Time

The connection time is the time period of grid monitoring between start of the inverter and start of grid feed-in.

Parameter Name	Adjustment range	Increment
T_CON	0 s to 1800 s	0.01 s

2.6.2 Reconnection Time

If a fault on the grid makes the inverter disconnect and the grid then afterwards stabilizes within the allowed voltage and frequency ranges, then the inverter is allowed to reconnect to the grid with this time delay. The reconnection time is usually shorter than the connection time, but it can also be the same time or longer than the connection time.

Parameter Name	Adjustment range	Increment
T_RECON	0 s to 1800 s	0.01 s

2.6.3 Short Interruption Time

The short interruption time is the permissible time period after which the inverter must start the complete reconnection procedure. If the grid fault is remedied in a shorter time period, the inverter can reconnect to the utility grid after the reconnection time **T_RECON**.

Parameter Name	Adjustment range	Increment
T_SHT_INT	0 s to 1800 s	0.01 s

2.6.4 Time to Alarm

Time to alarm is the period which the inverter must wait before generating an alarm event. This is to prevent the inverter from generating alarm events all the time.

Parameter Name	Adjustment range	Increment
T_ALARM	0 s to 1800 s	0.01 s

2.6.5 Voltage and Frequency Connection Limits

The minimum and maximum connection limits for voltage and frequency define the value range in which the inverter can connect to the utility grid.

Parameter Name	Adjustment range	Increment
UMIN_CON	UMIN1 to UNOM	0.1 V
UMAX_CON	UNOM to UMAX1	0.1 V
FMIN_CON	FMIN1 to FNOM	0.01 Hz
FMAX_CON	FNOM to FMAX1	0.01 Hz

2.6.6 Ramp-In

The ramp-in factor describes the ramp for the power up of the inverter. More details can be found in the settings for grid management services under parameter **Connection/reconnection ramp rate**.

3 Grid Failure

3.1 Active Frequency Shift

The active frequency shift works in the way that if the grid becomes unstable for any reason, this function then helps to push the grid even more of balance so that the inverter disconnects due to RoCoF or one of the regular disconnection parameters.

Parameter Name	Setting Options
LOM_F_SHF_K0/_K1	on (1) off (0)

3.2 Phase Failure Detection

The phase failure detection is used to determine the failure of one or more line conductors of the utility grid. In case of a grid failure, the grid relays open.

Parameter Name	Setting Options
OPEN_PH_DETECT	on (1) off (0)

3.3 Rate of Change of Frequency

The parameter **RoCoF** or **Rate of Change of Frequency** measures the change in frequency. If the change in frequency exceeds the stated maximum limit for a longer period of time, the inverter disconnects from the utility grid. The frequency can change very rapidly if one or several line conductors fail.

Parameter Name	Adjustment range	Increment
LOM_ROC	0 Hz/s to 10 Hz/s	0.01 Hz/s
LOM_ROC	0 Hz/s to 10 Hz/s	0.01 Hz/s
T_LOM_ROC	0 s to 1800 s	0.01 s
LOM_ROC_THR	0 Hz to 5.0 Hz	0.01 Hz

4 Settings of Grid Management Services: Fault Ride-Through (FRT)

The inverter is equipped with the Fault Ride-Through function for both undervoltage (LVRT) and overvoltage (HVRT/OVRT) situations. Although the FRT function belongs to grid management services, it is stored in the inverter. The FRT function is set to cope with voltage dips down to 0% UNOM without time limit. This is confirmed in the FRT performance test which was manually stopped after 60 seconds (see figure 1).

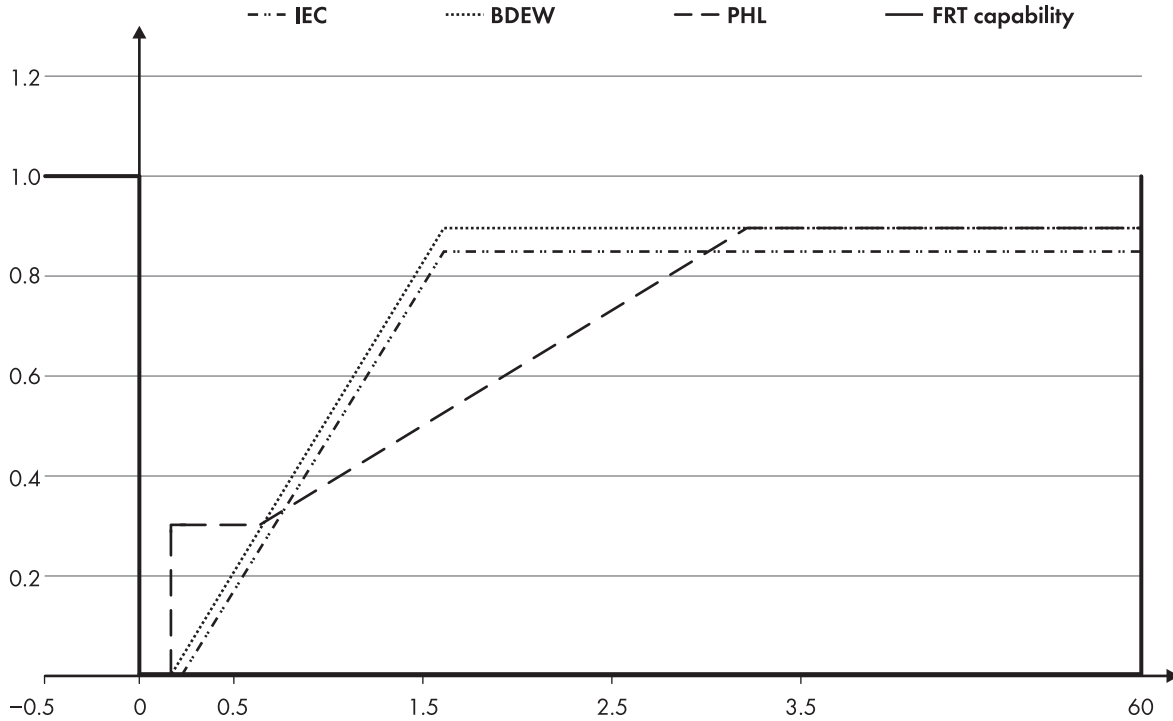


Figure 1: The FRT function of the inverter has been tested at 60 kW and three-phase voltage dips down to 80% UNOM, 50% UNOM, 20% UNOM, 5% UNOM. The performance test was manually stopped after 60 seconds.

The parameter **FRT_MODE** is used to set the FRT operating mode for current feed-in. There are six selectable operating modes.

For reactive power feed-in, the positive and negative sequence components are considered separately. The half-cycle root-mean-square values of the positive and negative sequence components of the grid voltage during the grid fault are compared with the average root-mean-square values before the fault. The relevant time frame for the average voltage before the grid fault can be set via the parameter **FRT_T_U_AVG** (default 10 minutes). Figure 2 shows the functionality of the parameter **FRT_T_U_AVG**.

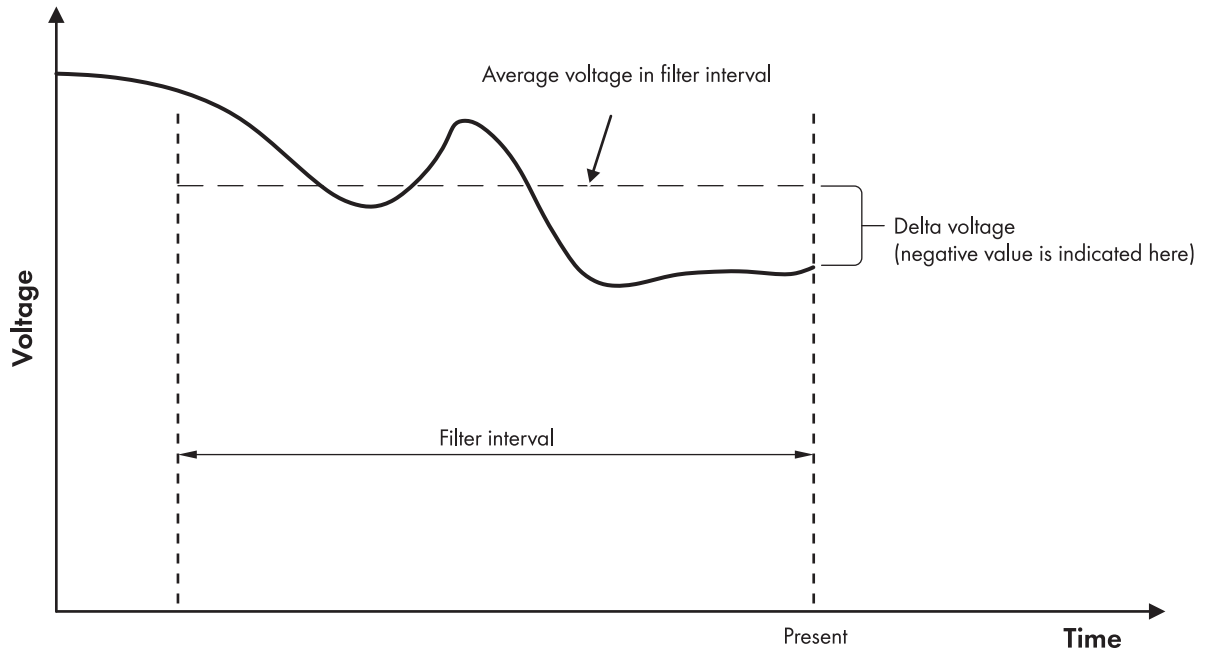


Figure 2: FRT voltage average as a function of time (IEC 61850-90-7)

The voltage differences (**DeltaU_pos** and **DeltaU_neg**) are passed through one of the following Iq(V) characteristic curves. The choice of the characteristic curve depends on parameter **FRT_IQ_MODE** (default: 0).

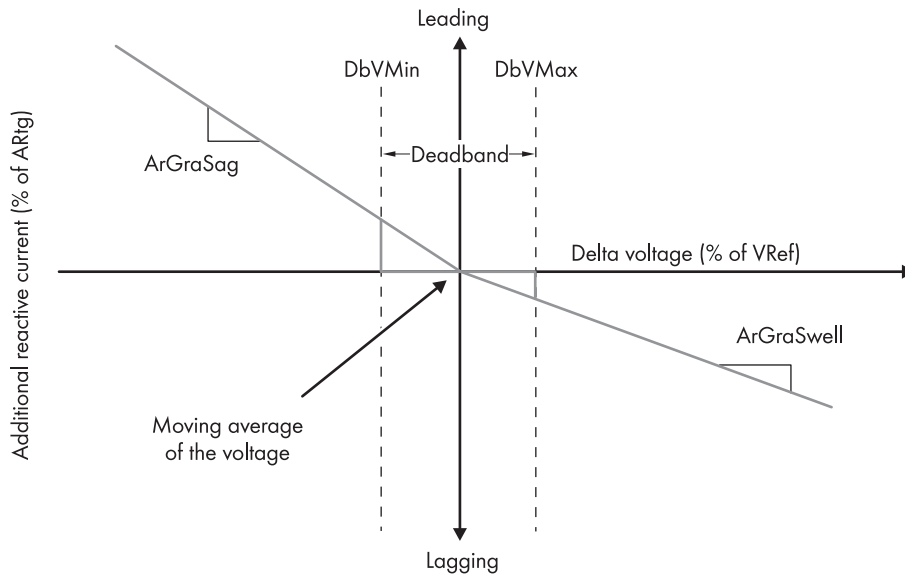


Figure 3: **FRT_IQ_MODE** = 0: as per BDEW (IEC 62850-90-7)

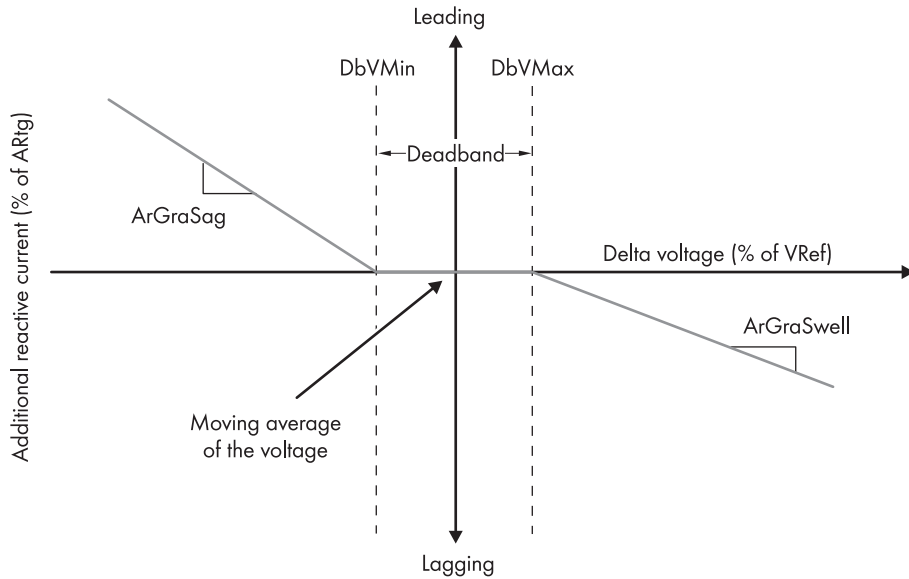


Figure 4: **FRT_IQ_MODE = 1**: as per SDLWind (IEC 62850-90-7)

In both operating modes, there is a common set of parameters which have to be set for the FRT functionality to work properly:

1. The deadband is defined by two thresholds: the lower threshold **FRT_ULOW** and the upper threshold **FRT_UUP**.
2. For the positive sequence component, the gradient K for the slope of voltage dips is defined by **FRT_DIDU_POS_LVRT** and for the slope of voltage increase by **FRT_DIDU_POS_HVRT**.
3. For the negative sequence component, the gradient K for the slope of voltage dips is defined by **FRT_DIDU_NEG_HVRT** and for the slope of voltage increase by **FRT_DIDU_NEG_HVRT**.

The additional reactive current is added to the pre-fault reactive current value.

The positive sequence components have priority over the negative sequence components. Thus, first the negative sequence component is limited if the current limitation is reached. In case that I_d has higher priority than I_q , the reactive currents will be limited in such way as the total current does not exceed the limit.

After fault clearance, reactive current feed-in stays active for a certain transition period. This period can be set with the grid code parameter **FRT_T_TRANS**.

Active current is fed in under the following conditions:

1. Active current feed-in is activated in accordance with the selection made in **FRT_MODE** (operating modes 3, 4, and 5).
2. The current reactive power value allows additional active current without the total current being greater than the nominal current.
3. There is enough primary input power.

Restriction: active power feed-in during fault is upwards limited to the pre-fault active power, even if higher primary input power is (or becomes) available during the fault.

After the fault, the active power returns to its initial level with first order dynamic. The recovery time can be set via the parameter **FRT_T_P_RECOV**.

If required, it is possible to set up a so-called blocking zone during the grid fault: if the voltage falls below a configurable limit **FRT_U_BLK**, power generation is ceased after a configurable time **FRT_T_BLK**. Over the blocking zone **FRT_U_BLK** there is the hysteresis band determined by **FRT_U_BLK_HYS**. Once voltage exceeds this hysteresis band again, power generation is continued.

Parameter Name	Setting range/setting option	Increment/explanation
FRT_ULOW	10 % to 100 %	1 %
FRT_UUP	100 % to 130 %	1 %
FRT_MODE	0: Frt_Off	The FRT function is deactivated.
	1: Frt_ZeroCurrent	No current feed-in
	2: Frt_ReactiveOnly	Reactive current is fed in, but no active current.
	3: Frt_ActiveOnly	Active current is fed in, but no reactive current.
	4: Frt_Full_IqPriority	The reactive current is fed in. If PV power is available, the total current is supplied with active current until current limitation is reached.
	5: Frt_Full_IdPriority	The maximum possible active current is fed in. Starting from the grid code characteristic curve, the total current is supplied with reactive current until the current limitation is reached.
FRT_DIDU_POS_LVRT	1 to 10	0.1
FRT_DIDU_POS_HVRT	1 to 10	0.1
FRT_DIDU_NEG_LVRT	1 to 10	0.1
FRT_DIDU_NEG_HVRT	1 to 10	0.1
FRT_IQ_MODE	0 or 1	-
FRT_T_BLK	0 s to 10 s	0.01 s
FRT_T_TRANS	0 s to 10 s	0.01 s
FRT_T_U_AVG	0 s to 1800 s	1 s
FRT_U_BLK	0 % to 100 %	1 %
FRT_U_BLK_HYS	0 % to 100 %	1 %

5 Settings of Grid Management Services

The following parameters for grid management services are loaded to the SMA Inverter Manager (IM) and only used here. The settings are divided into groups. The groups reflect the various grid management services (control modes).

The value ranges indicated in the following sections do not necessarily describe the permissible ranges in accordance with the grid code, but are to reflect the performance of the inverter. Since not all parameters are used by all standards, the parameters that are not used will be deactivated in the file "Grid Code".

Regarding the signs for reactive power and power factor (PF), plus means overexcited reactive power (grid voltage is increased) and minus means underexcited reactive power (grid voltage is reduced).

All requirements for grid management services are given for the point of common coupling (PCC).

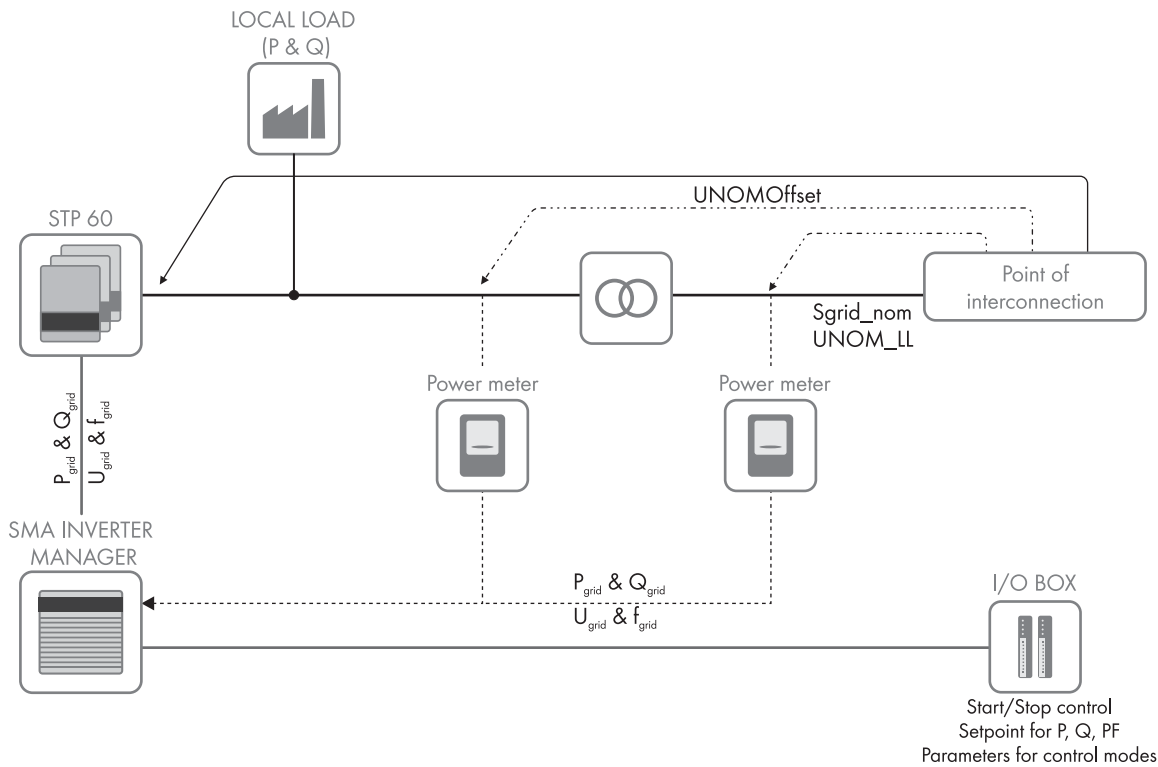


Figure 5: Overview of a system with inverters, SMA Inverter Manager, local load, power meter and definition of Point of Common Coupling (PCC).

5.1 Basic Settings

5.1.1 Selecting the Control Mode for Reactive Power Provision

Reactive power references can either be given as a direct reference for reactive power (Q) or as an indirect reference via the power factor (PF). The references are based on the following control modes (setting options), can be set with the number 1 to 9 in the parameter **ModeSelect**.

Parameter Name	Setting option	Explanation
ModeSelect	1	Q(U) - Reactive Power as a Function of Grid Voltage
	2	Q(P) - Reactive Power as a Function of Active Power
	3	Q(S) - Reactive power as a function of apparent power
	4	Control mode is in implementation phase
	5	Q(ext) - Reactive power as a function of an external setpoint (default)
	6	PF(U) - Power Factor as a Function of Grid Voltage
	7	PF(P) - Power Factor as a Function of Active Power
	8	Control mode is in implementation phase
	9	PF(ext) - Power factor as a function of an external setpoint

5.1.2 Night Mode

The system with an inverter provides reactive power also in night mode. Therefore, the inverters are not switched off after sunset. Information: If no primary energy source is available, only the control modes 1 to 5 can be used for reactive power provision.*

Parameter Name	Setting option	Explanation
NightMode	0	Deactivated (Default)
	1	Activated

5.1.3 Active Power Limitation for Reactive Power Feed-In

Some grid codes require that the PV system can also be operated during feed-in of nominal reactive power at nominal active power. Example: A PV system is required to have a controllable power factor (PF) between ± 0.9 and 1.0 without affecting the generation of active power. Thus, the nominal active power is no longer 100% but rather 90% so that the parameter **P_LIM_IF_Q** should be set to 90%.

Parameter Name	Setting option
P_LIM_IF_Q	80% to 100% (default: 100%)

* In the inverter, no switch-on circuit is installed. Thus, the inverter cannot start-up / reconnect to the grid after a voltage dip when no DC-voltage is present. The voltage of the DC busbar is directly connected to the PV arrays at night. Thus, current can flow in the arrays. This can only be prevented via one of the following measures: using string diodes in the DC String-Combiner or using a controllable switch in the DC String-Combiner.

5.1.4 Nominal Apparent Power at Point of Common Coupling (PCC)

All grid management services in the inverter are based on the nominal apparent power at the point of common coupling. Example: At an active power limitation to 50%, the active power at the point of common coupling is limited to 50% by **Sgrid_nom**. The default value is "blank" meaning that the PV system uses the sum of apparent power from the commissioned inverters. In some cases the installed power of the PV system is higher than agreed upon with the distribution grid operator. Thus, the **Sgrid_nom** parameter should be set according to the contract clauses. In cases where the PV system is installed to supply local loads (this requires an external power meter) and no active power is allowed to be fed into the grid, the **Sgrid_nom** parameter should be left "blank" and the parameter **P_ref** should be set to 0%.

Parameter Name	Setting option
Sgrid_nom	blank, 0 kVA to 4000 kVA (default: blank)

5.1.5 Voltage Differences Between the Point of Common Coupling (PCC) and the PV System

This parameter serves to compensate for possible voltage differences on the cables between the inverters and the PCC and is called up in the case where voltage-based control modes are used, i.e. Q(U), PF(U) and P(U). Thus, only a single characteristic curve is required for different PV systems and only the parameter **UNOMOffset** (line to line voltage) needs to be set for each PV system.

Parameter Name	Setting option
UNOMOffset	0, generally between ± 10 V for low-voltage grids and ± 1000 V for medium-voltage grids (default: 0)

5.1.6 Nominal Voltage

This parameter refers to the nominal grid voltage at the point of common coupling. The parameter is used to scale the grid voltage for the control modes where the grid voltage is the independent variable, i.e. for Q(U), PF(U) and P(U). If no external energy meter is used, this parameter should have the same value as **UNOM** in the protection part of the grid code file. This also applies if an external energy meter is switched on the low-voltage (LV) side of the transformer. If an external power meter is connected to the medium-voltage (MV) side of the transformer, the corresponding nominal values for the grid voltage must be set, e.g. 33 kV.

Parameter Name	Setting option
UNOM_LL	200 V to 480 V (default: 398 V) for low-voltage grids 3300 V to 33000 V for medium-voltage grids

5.2 Direct Control

5.2.1 Start Signal

The PV system can be disconnected immediately from the grid or it can be set that it connects to the grid once the grid parameters (voltage level and frequency) are within the permissible range for connection (see Section 2 "Grid Protection Settings", page 5).

Parameter Name	Setting option	Explanation
ReleaseToStart	0	Immediate disconnection
	1	Connection when grid parameter is in the permissible range (default)

5.2.2 Connection/Reconnection Ramp Rate

The active power is ramped according to this setting whenever the inverter is connected / reconnected to the grid, i.e. when starting up in the morning, when starting up after the parameter **ReleaseToStart** is set to 1 and after disconnection due to overvoltage or undervoltage, overfrequency or underfrequency etc.

Parameter Name	Adjustment range	Increment
RmpIncTmm_ONLINE	0.6%/min to 1200%/min (default: 10%/min)	0.1 %

5.2.3 Time Delay for Shutdown

Controlled disconnection over the defined time period, this means the power will be ramped down in a controlled manner over the delay period.

Parameter Name	Adjustment range	Increment
T_DELAY_SHUTDOWN	0 s to 600 s (default: 2 s)	0.2 s

5.2.4 Reactive Power Ramp Rates

The reactive power is ramped according to this setting whenever the setpoint for reactive power is changed (both for external setpoints and for other control modes, e.g. Q(U) or PF(P)). Note that two parameters are available: one for decreasing and one for increasing setpoints.

Parameter Name	Adjustment range	Increment
RmpDecTmm_Q	-0.6%/min to -1200%/min (default)	0.1 %
RmpIncTmm_Q	0.6%/min to 1200%/min (default)	0.1 %

5.2.5 Active Power Ramp Rates

The active power is ramped according to these setting whenever the external setpoint for active power is changed. Note that two parameters are available: one for decreasing and one for increasing setpoints.

Parameter Name	Adjustment range	Increment
RmpDecTmm_EXT	-0.6%/min to -1200%/min (default)	0.1 %
RmpIncTmm_EXT	0.6%/min to 1200%/min (default)	0.1 %

5.2.6 Setting the Maximum Active Power

The active power is limited according to this parameter.

Parameter Name	Adjustment range	Increment
P_ref	0% to 100% (default)	0.1 %

5.2.7 Setting the Reactive Power

This parameter indicates the reactive power setpoint (only available if control mode 5 has been selected in the parameter **ModeSelect**).

Parameter Name	Adjustment range	Increment
Q_ref	0% to $\pm 100\%$ (default: 0%)	0.1 %

5.2.8 Setting the Power Factor (PF)

This parameter indicates the setpoint for the power factor (PF) (only available if control mode 9 has been selected in the parameter **ModeSelect**).

Parameter Name	Adjustment range	Increment
PF_ref	0.8 to 1.0 for overexcitation -0.8 to -1.0 for underexcitation (default)	0.01

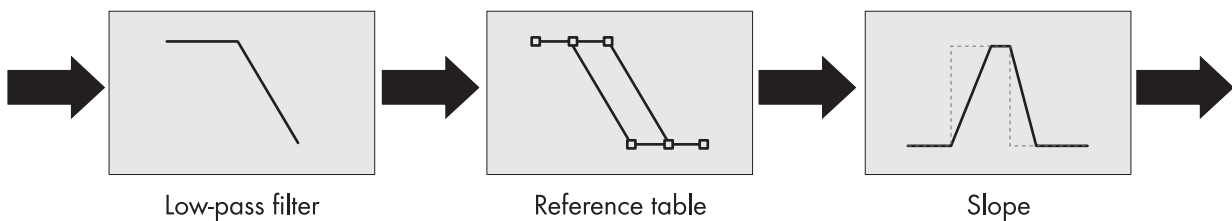
5.2.9 Setting the Apparent Power

Some grid codes require that the PV system always generates a certain amount of apparent power, i.e. the system operates within a unit circle in the PQ diagram. If the parameter **S_ref** is set to 60%, the PV system does not generate reactive power until the active power is above 60%. However, if the active power is lower than 60%, the PV system starts to generate reactive power to keep the apparent power at 60%. If the sign is positive, the PV system will exchange overexcited reactive power. If the sign is negative, the system will exchange underexcited reactive power. This type of control mode should not be used when a local load is connected, since it could cause the PV system to lower the production of active power (only available if control mode 3 has been selected in the parameter **ModeSelect**).

Parameter Name	Adjustment range	Increment
S_ref	0% to $\pm 100\%$ (default: 0%)	0.1 %

5.3 Control Modes

The general approach for the control modes is based on the structure in the technical report of the standard IEC 61850-90-7 (see the figure below).



Up to five parameters are used to program the local modes depicted above. The parameter **RmpTmsPT1** is the rise time from 0% to 95% (equal to 3τ) for the low-pass filter applied on the independent variable (e.g. grid voltage). The reference table is made of two characteristic curves each containing up to ten break-points. One characteristic curve is used when the independent variable is increasing and the other when decreasing. In this way, hysteresis can be included in the reference table. Finally, the parameters **RmpIncTmm** and **RmpDecTmm** are the ramp rates for increasing and decreasing output values (dependent variable) from the reference table.

Independent ramp rates are only available for control modes for active power, whereas for reactive power the ramp rates are always given by the parameters **RmpDecTmm_Q** and **RmpIncTmm_Q**. If the input value (independent variable) of the reference table exceeds the values defining the characteristic curves, the output value (dependent variable) of the reference table is given as the first or last value in the characteristic curve respectively.

5.3.1 Q(U) - Reactive Power as a Function of Grid Voltage

This control mode uses the grid voltage to generate a reference value for the reactive power so that the grid voltage can be controlled at the point of common coupling. The control mode contains two additional parameters for activation. The mode is activated when the active power is above the set threshold and deactivated again when the active power is below the set threshold. The threshold for activation must be larger than or equal to the threshold for deactivation. If this control mode shall always be available, set **lock_in_UQ** = **lock_out_UQ** = 0% (only available if control mode 1 has been selected in the parameter **ModeSelect**).

Parameter Name	Adjustment range	Increment
RmpTmsPT1_UQ	0,6 s to 3600 s	0.01 s
lock_in_UQ	0% to 100% of active power	0.1 %
lock_out_UQ	0% to 100% of active power (must be smaller than lock_in_UQ)	0.1 %
Q_of_U	U: Grid voltage (independent values) from 80% to 120% of nominal voltage Q: Reactive power (dependent values) from -100% to 100% of nominal power	-

5.3.2 Q(P) - Reactive Power as a Function of Active Power

This control mode uses the active power to generate a reference value for the reactive power so that the grid voltage can be controlled at the point of common coupling. The independent variable (grid power) can be negative if an external energy meter is installed and the PV system must compensate for a local load (only available if control mode 2 has been selected in the parameter **ModeSelect**).

Parameter Name	Adjustment range	Increment
RmpTmsPT1_PQ	0,6 s to 3600 s	0.01 s
Q_of_P	P: Active power (independent values) from -100% to 100% of nominal power Q: Reactive power (dependent values) from -100% to 100% of nominal power	-

5.3.3 Q(S) - Reactive Power as a Function of Apparent Power

See above, Section "Maximum apparent power" (only available if control mode 3 has been selected in the parameter **ModeSelect**).

5.3.4 Q(ext) - Reactive Power as a Function of an External Setpoint

See above, Section "Maximum reactive power" (only available if control mode 5 has been selected in the parameter **ModeSelect**).

5.3.5 PF(P) - Power Factor as a Function of Active Power

This control mode uses the nominal active power to generate a reference value for the power factor (PF) so that the grid voltage can be controlled at the point of common coupling. The control mode contains two additional parameters for activation. The control mode is activated when the grid voltage is above the lock-in threshold and deactivated when the grid voltage is below the lock-out threshold. The threshold for activation must be larger than or equal to the threshold for deactivation. If this control mode shall always be available, set **lock_in_PPF = lock_out_PPF = 90%** (only available if control mode 6 has been selected in the parameter **ModeSelect**).

Parameter Name	Adjustment range	Increment
RmpTmsPT1_PPF	0,6 s to 3600 s	0.01 s
lock_in_PPF	80% to 120% of grid voltage	0.1 %
lock_out_PPF	80% to 120% of grid voltage (must be smaller than lock_in_PPF)	0.1 %
PF_of_P	P: Grid active power (independent values) from -100% to 100% of nominal apparent power	-
	PF: Power factor (dependent values) from ± 0.8 to 1.0	-

5.3.6 PF(U) - Power Factor as a Function of Grid Voltage

This control mode uses the grid voltage to generate a reference value for the power factor (PF) so that the grid voltage can be controlled at the point of common coupling (only available if control mode 7 has been selected in the parameter **ModeSelect**).

Parameter Name	Adjustment range	Increment
RmpTmsPT1_UPF	0,6 s to 3600 s	0.01 s
PF_of_U	U: Grid voltage (independent values) from 80% to 120% of nominal voltage	-
	PF: Power factor (dependent values) from ± 0.8 to 1.0	-

5.3.7 PF(ext) - Power Factor as a Function of an External Setpoint

See above, paragraph "Maximum power factor" (only available if control mode 9 has been selected in the parameter **ModeSelect**).

5.3.8 P(U) - Active Power as a Function of Grid Voltage

This control mode uses the grid voltage to generate a threshold for the active power so that the grid voltage can be controlled at the point of common coupling. The P(V) characteristic curve must be coordinated with the Q(U) or PF(U) control modes.

Parameter Name	Adjustment range	Increment
RmpTmsPT1_UP	0,6 s to 3600 s	0.01 s
RmpDecTmm_UP	-0.6%/min to -1200%/min (default)	0.1 %
RmplncTmm_UP	0.6%/min to 1200%/min (default)	0.1 %
P_of_U	U: Grid voltage (independent values) from 80% to 120% of nominal voltage	-
	P: Active power (dependent values) from -100% to 100% of nominal power	-

5.3.9 P(f) - Reactive Power as a Function of Frequency

This is the common type of primary frequency control applied, e.g. as per the BDEW technical guideline, with some extensions, see the figure below. By using the parameter **tdelay_on**, it is possible to add a delay between the point in time where the frequency reaches its threshold (e.g. 50.2 Hz) and the point in time where the active power starts to decrease. The purpose of this time delay is to reach a lower sensitivity in terms of transient frequency changes and higher reliability when detecting grid failures. The amount of generated active power is still sampled and hold at the instant where the frequency exceeds the threshold. Some grid codes, e.g. CEI 0-16, requires that the generation of active power is kept low in a certain duration after the frequency has returned back to its normal range. This can be set via the parameter **tdelay_off**. Once the frequency is back to its normal range, the active power is ramped up again with a certain ramp rate. This is done via the parameter **RmplncTmm_FPReg**. Some grid codes, e.g. CEI 0-16, require that the ramp rate is variable. This can be programmed with the parameter variable.

Hysteresis can be added in the P(f) curve, e.g. as per BDEW, by programming two P(f) characteristic curves with the same values. Note: Active power will not start to increase again before the output value from the reference table is equal to 100%.

Parameter Name	Adjustment range	Increment
tdelay_on	0 s to 2 s (default: 0)	0.01 s
tdelay_off	0 s to 600 s (default: 0)	0.01 s
RmplncTmm_FPReg	0.6%/min to 1200%/min	0.1 %
Variable (e.g. as per CEI 0-16)	0 for constant rate limitation and 1 for variable rate limitation	-
FP_of_f	FP: Power frequency (independent values) from 45 Hz to 65 Hz	-
	f: Active power (dependent values) from 0% to 100% of the nominal power	-

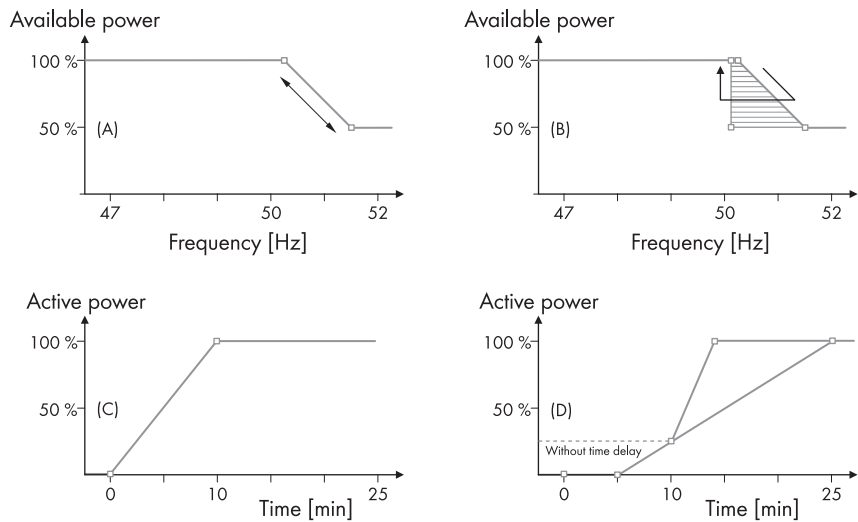


Figure 6: Parameterization of frequency control

Position	Explanation
A	Typical programming of the FP_of_f characteristic curve when hysteresis is not required, e.g. as per VDE AR-N 4105. Thus, the two characteristic curves in the reference table contain equal co-ordinates (x, y).
B	Example of programming the FP_of_f characteristic curve when hysteresis is required, e.g. as per BDEW. Thus, the two characteristic curves contain different co-ordinates (x, y).
C	Output power of the PV system after the frequency transient has ended (at time = 0) when constant rate limit and no delay is applied, e.g. as per BDEW.
D	Output power of the PV system after the frequency transient has ended (at time = 0) when variable rate limit and delay is applied, e.g. as per CEI 0-16.

SMA Solar Technology

www.SMA-Solar.com

