Technical Information

Short-Circuit Currents
Information on short-circuit currents in SMA PV inverters

Sunny Tripower, Sunny Highpower, Sunny Tripower Storage

1 Content

During voltage dips, especially complete grid failures, all PV and battery inverters connected to the grid may generate currents that are slightly above the maximum current in normal operating conditions. Such currents are relevant for the correct dimensioning of the wiring and the protective devices, both at the system level and the grid level.

Grid operators frequently ask manufacturers of PV and battery inverters to provide maximum values of short-circuit currents. In other cases, the manufacturers are asked to provide characteristic values such as I_k and i_p or further electrical values at defined times during a grid failure.

This technical information

- provides characteristic values for the short-circuit currents of individual PV and battery inverters from SMA that result from testing according to international standards.
- provides information on the difference between the short-circuit current contribution by a conventional power generator and a PV inverter or battery inverter.

2 Response to Voltage Dips

PV and battery inverters are not equivalent to conventional electrical generators in terms of their behavior during voltage dips.

The following figure shows a comparison with the ideal response to voltage dips by electrical generators:

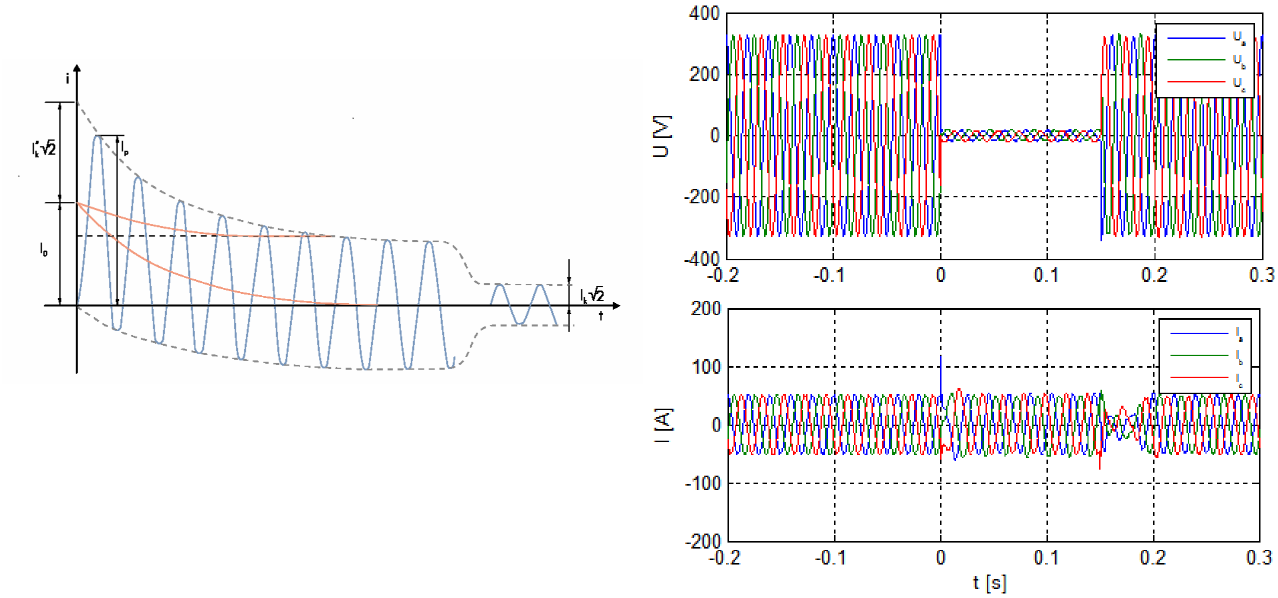


Figure 1: Ideal response to voltage dips (fault ride-through, FRT) by an electrical generator (left) and real response to voltage dips by an inverter in the FRT "full" operating mode (right).

As the figure above shows, the voltage dip causes an immediate response of the inverter with a short-lived current peak caused by its grid filter. Afterwards, the inverter limits the current to its nominal current as fast as possible in order to prevent a thermal overload of the power electronics.

Such behavior is not comparable to the ideal response by an electrical generator. Instead, this behavior can be characterized by means of one static and two dynamic time periods, as shown in the following figure:

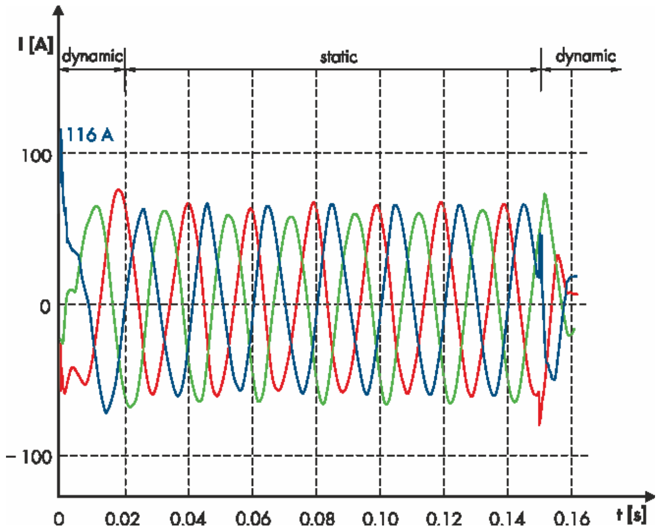


Figure 2: Temporal distribution of the response to voltage dips (PV)

The dynamic time periods in the range of t = 0 s to t = 0.03 s and starting at t = 0.15 s contain both the maximum and minimum values of the current during a short period of time. In the static period, the current remains within a certain tolerable range.

Almost every response of an inverter to various curves of voltage dips can be described by successive dynamic and static time periods. This approach resembles the model validation process used in TR4 certification.

3 Operating Modes During Voltage Dips

3.1 Information on operating modes

The short-circuit current contribution during a voltage dip depends largely on the operation mode of the inverter. The following operation modes can occur and influence the uninterrupted short-circuit current I_k.
Note that both operating modes are equally available for riding through overvoltage events (high-voltage ride-through, HVRT).

3.2 Operation Mode Fault Ride-Through "full"

FRT "full" means fault ride-through including voltage support by a reactive power supply. The inverter remains connected to the utility grid and feeds in reactive current according to a certain parameterizable characteristic curve. The resulting short-circuit current I_k depends on the residual voltage and the pre-fault reactive power supply.

The following table shows the maximum values that are comparable to values for the short-circuit surge current i_p, the initial symmetrical short-circuit current I_k'' and the uninterrupted short-circuit current I_k of conventional generators.

i_p	I_k''	I_k
up to 5 x i_{max}	up to 1.4 x i_{max}	1 x i_{max}

Note that the i_p value is given as an amplitude, whereas the values for I_k'' and I_k are root-mean-square (RMS) values. To see the exact value for each selected SMA inverter, refer to the table hereafter Short-Circuit Current Contributions of Individual SMA Inverters.

The short-circuit surge current i_p is a current peak with a duration of max. 40 μs with no significant area under the characteristic curve of the current. It thus provides much less energy than a conventional generator.

The initial symmetrical short-circuit current I_k'' will not last longer than 50 ms.

The value for the uninterrupted short-circuit current I_k will be reached after 50 ms, at the latest, and will be maintained during the entire duration of the voltage dip.

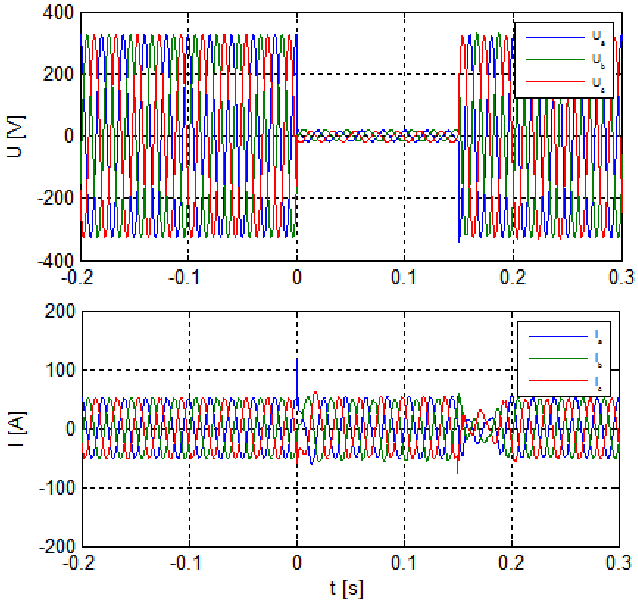


Figure 3: Real response to a 5% Vn voltage dip by the PV inverter STP 25000TL-30 in the FRT "full" operation mode.

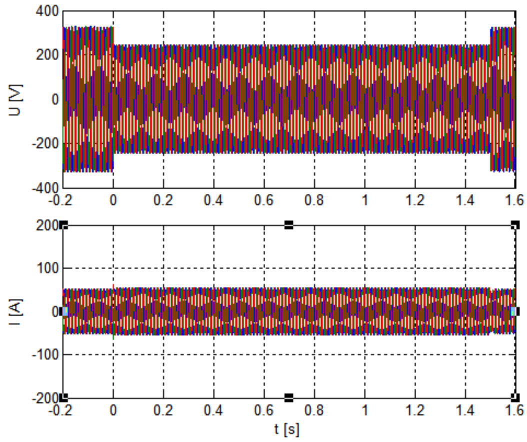
3.3 Operation Mode Fault Ride-Through "partial"

FRT "partial" means a fault ride-through without supplying current during the dip.

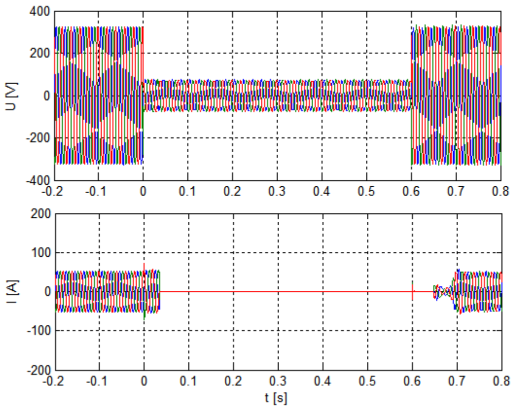
The inverter stops feeding in current (both active and reactive) as soon as the grid voltage falls below a certain threshold.
However, the inverter does not disconnect. It remains ready for operation and continues to feed in current immediately after fault clearance.

Depending on the depth of the voltage dip, two cases can be distinguished during the voltage dip if the inverter operation mode is set to FRT "partial":

1. If the voltage is higher than the FRT threshold, the inverter rides through such dips as long as the maximum current is not reached. The figure on the right shows the actual response of a PV inverter STP 25000TL-30 to a 75% Vn voltage dip with the FRT threshold set to 70% Vn.



2. If the voltage threshold is reached, the inverter immediately stops feeding in current. The I_k will be zero. Since the electric current of the grid filter cannot be controlled by the inverter, an i_p value may occur according to the table hereafter Short-Circuit Current Contributions of Individual SMA Inverters. Please note that no significant energy is stored in the grid filter. The figure on the right shows the actual response of a PV inverter STP 25000TL-30 to a 30% Vn voltage dip with the FRT threshold set to 70% Vn.



SMA inverters of the Sunny Tripower, Sunny Tripower Storage and Sunny Highpower families can operate in both of the above-mentioned operating modes, including high-voltage ride-through (HVRT).

SMA inverters of the Sunny Boy family can operate only in the FRT "partial" operating mode.

4 Short-Circuit Current Contributions of Individual SMA Inverters

At an international level, the IEC 61400-21 standard describes testing procedures for wind farms that can be easily applied to PV inverters. In some countries, such as Germany (TR3, Technical Guidelines for Power Generating Units, Part 3, FGW e.V.) and Italy (CEI 0-21 and CEI 0-16), there are specific standard requirements for testing the capability of “riding through” grid-voltage dips.

The instantaneous values of alternating currents and alternating voltages are recorded synchronously with 50 kHz (20 µs). Basic frequencies of the co-system based on measurement of instantaneous voltages and currents are calculated according to IEC 61400-21. All results are measured as half-period RMS values.

The following table shows the test results for the following SMA PV and battery inverters of type Sunny Tripower, Sunny Highpower and Sunny Tripower Storage:

Inverter type	Short-circuit surge current i_p (A)	Symmetrical initial short-circuit current I_k'' (A)	Uninterrupted short-circuit current I_k (A)		Maximum current I_{max} (A)
			FRT "full"	FRT "partial"	
Sunny Highpower					
SHP 75-10	301.20	128.40	111.3	0	109.0
SHP 100-20 / SHP100-21	318.67	166.39	151.0	0	144.3
SHP 125-US-20 / SHP125-US-21	324.16	173.72	151.0	0	150.4
SHP 150-20 / SHP 150-US-20 / SHP150-21 / SHP150-US-21	318.28	170.34	151.0	0	144.3
SHP165-US-21	329.75	175.56	151	0	151
SHP172-21 / SHP172-US-21	328.66	174.97	151	0	150.5

Inverter type	Short-circuit surge current i_p (A)	Symmetrical initial short-circuit current I_k'' (A)	Uninterrupted short-circuit current I_k (A)		Maximum current I_{max} (A)
			FRT "full"	FRT "partial"	
SHP180-21	328.88	175.09	151	0	150.6
Sunny Island					
SI30-20	151.1	61.0	45.6	0	45.6
SI50-20	179.6	90.2	75.5	0	75.5
SI27-US208-20	161.9	92.7	75.5	0	75.5
SI60-US480-20	190.0	95.4	75.5	0	75.5
Sunny Tripower					
STP3.0-3AV-40	46.37	7.55	4.6	0	4.6
STP4.0-3AV-40	46.91	9.06	6.1	0	6.1
STP5.0-3AV-40	46.53	10.41	7.6	0	7.6
STP6.0-3AV-40	46.46	11.47	9.1	0	9.1
STP8.0-3AV-40	65.47	11.90	11.6	0	11.6
STP10.0-3AV-40	82.87	14.83	14.5	0	14.5
STP 15000TL-30	84.29	30.45	29	0	21.7
STP 20000TL-30	98.58	31.07	29	0	29
STP 25000TL-30	116.37	40.06	36.2	0	36.2
STP 50-40 / STP 50-41	185.56	85.91	72.5	0	72.5
STP 50-US-40	154.69	75.02	64.0	0	60.2
STP 33-US-41	144.61	48.95	40.0	0	39.7
STP 50-US-41	170.17	74.21	64.0	0	60.2
STP 62-US-40	193.47	89.54	79.95	0	75.3
STP 110-60	300.00	175.00	158.8	0	158.8
STP 12-50	106.84	38.3	36.6	0	36.6
STP 15-50	101.42	42.53	36.6	0	36.6
STP 20-50	95.68	43.06	36.6	0	36.6
STP 25-50	100.01	42.73	36.6	0	36.6
Sunny Tripower Storage					

Inverter type	Short-circuit surge current i_p (A)	Symmetrical initial short-circuit current I_k'' (A)	Uninterrupted short-circuit current I_k (A)		Maximum current I_{max} (A)
			FRT "full"	FRT "partial"	
STPS30-20	151.1	61.0	45.6	0	45.6
STPS50-20	179.6	90.2	75.5	0	75.5

Note that the i_p values are given as an amplitude, whereas the values for I_k'' and I_k are RMS values.

The values for I_k'' and i_p were measured during the certification process (TR3, CEI 0-16) by an accredited test institute and are comparable to the characteristic values defined in DIN EN 60909. These values represent the maximum values of all tests.

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