

Technical Information

Short-Circuit Currents

Information on short-circuit currents of SMA PV inverters



Content

During grid failures as for example voltage dips, all PV inverters 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 protective devices, both at PV power plant and grid level. Grid operators frequently ask manufacturers of PV inverters to provide maximum values of short-circuit currents. In other cases, they are asked to provide characteristic values (as for example I_k'' and i_p) or currents at defined times during failures.

This technical information is intended to provide characteristic values of the short-circuit currents of each SMA PV inverter resulting from testing activities in accordance with international standards, and to indicate the difference between the short-circuit contribution by a conventional electrical generator and a PV inverter.

1 Response to Voltage Dips

PV inverters are not equivalent to conventional electrical generators in terms of their behavior during voltage dips. A comparison with the ideal response to voltage dips by electrical generators is shown in the following figure:

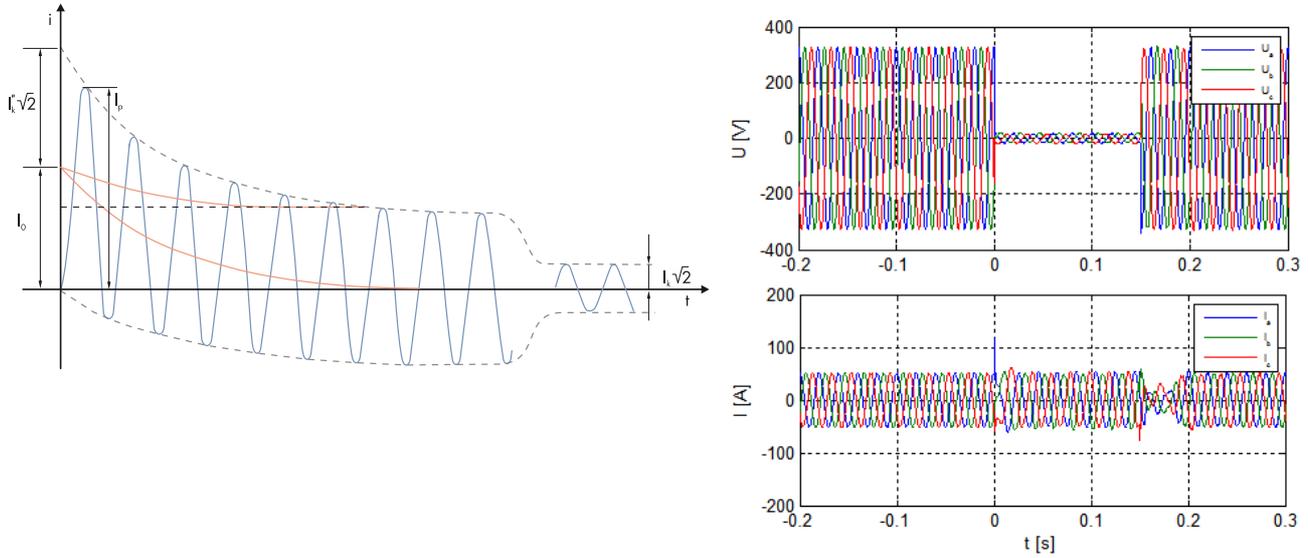


Figure 1: Ideal response to voltage dips by an electrical generator (left) and real response to voltage dips by a PV inverter in the fault ride through (FRT) "full" operating mode (right)

As it can be seen in the figure below, the voltage dip causes an immediate reaction of the PV inverter with a current peak of short duration which is caused by the output filter. Afterwards, the inverter controls the current as fast as possible to prevent the inverter from thermal overload. Such behavior is not comparable to the ideal response by an electrical generator. Therefore it can be said that this behavior contains one static and two dynamic parts, as shown in the following figure.

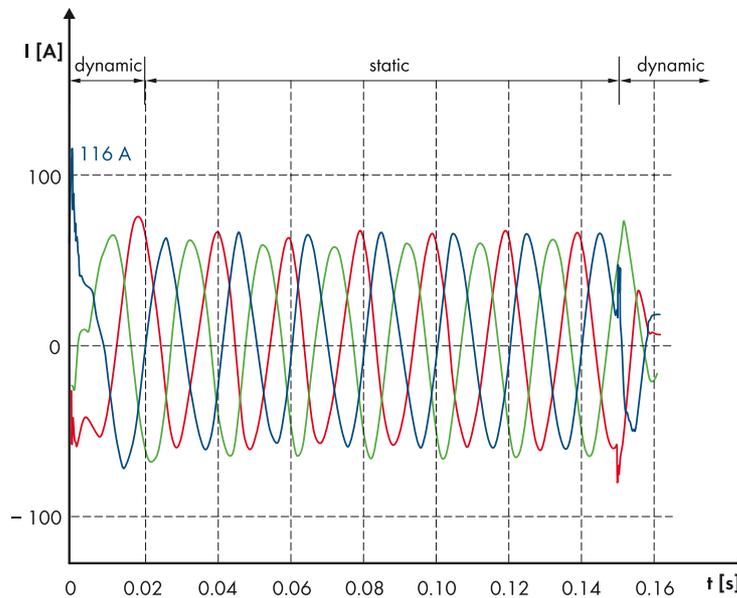


Figure 2: Distribution of the response to voltage dips (PV)

The dynamic parts contain both the maximum and minimum values of the current during a short period of time, whereas in the static part the current remains within a certain tolerable range.

Almost every current response can be described by consecutive dynamic and static areas.

This approach is similar to the process of model validation by the BDEW certification.

2 Operation Modes During Voltage Dips

The short-circuit contribution depends on the operation mode of the inverter. The following operation modes can occur and influence the uninterrupted short-circuit current I_k .

2.1 Operation Mode 1: Fault Ride Through “Full”

FRT “full” means fault ride through including voltage support by reactive current feed-in. The inverter remains connected to the utility grid and feeds in reactive current according to a certain characteristic. 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. 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). Check the table on page 5 for the exact value for the chosen inverter.

i_p	I_k''	I_k
up to $5 \times i_{max}$	up to $1.4 \times I_{max}$	$1.0 \times I_{max}$

Table: 1 Maximum values for short-circuit surge current i_p , initial symmetrical short-circuit current I_k'' and uninterrupted short-circuit current I_k

The short-circuit surge current i_p is just a peak of max. $40 \mu s$ with no significant area under the characteristic curve of the current and thus it represents much less energy than a conventional generator.

The initial symmetrical short-circuit current I_k'' will not last longer than 30 ms.

The value for the uninterrupted short circuit current I_k will be reached after 30 ms and will be maintained during the entire duration of the voltage dip.

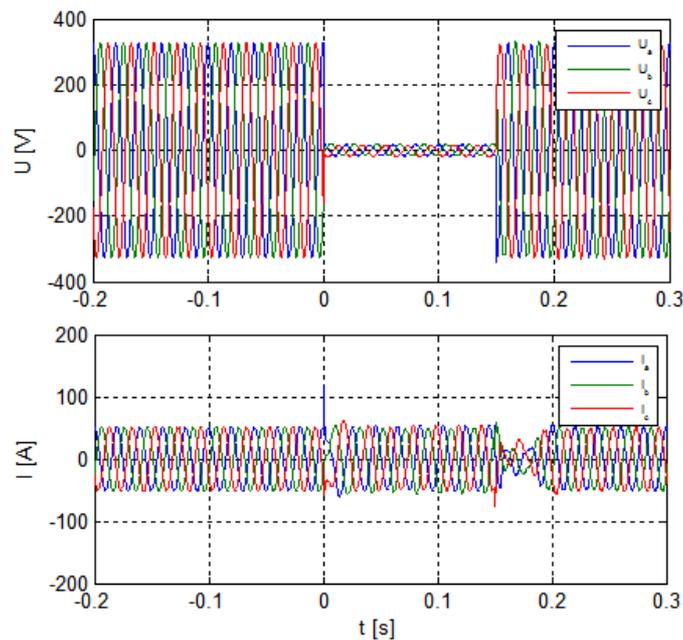


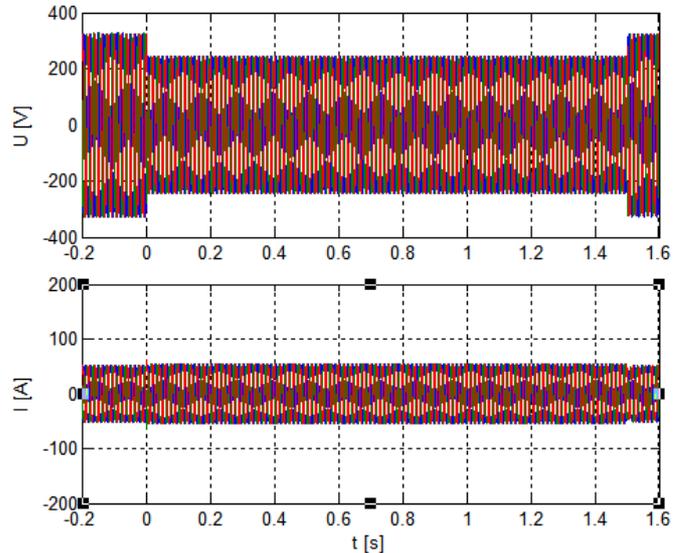
Figure 3: Real response to a 5% V_n voltage dip by the PV inverter STP 25000TL-30 in the FRT “full” operation mode

2.2 Operation Mode 2: Fault Ride Through “Partial”

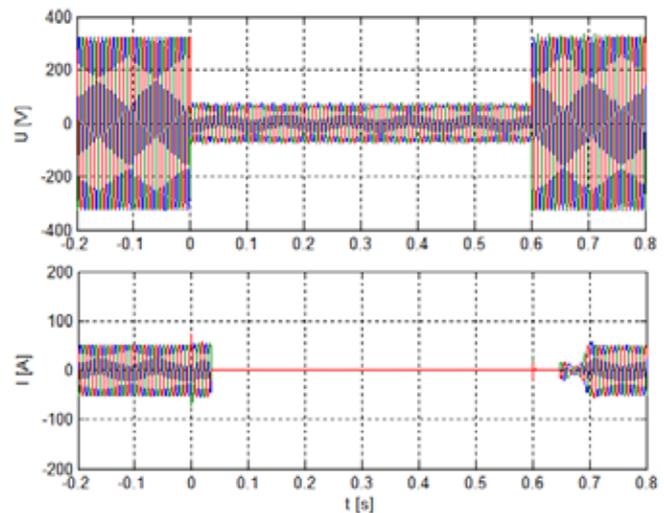
FRT “partial” means fault ride through without supplying current during the dip. The inverter stops feeding in current (both active and reactive) when the grid voltage falls below a certain threshold. But the inverter does not disconnect (remains ready for operation) and continues to feed in power immediately 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. In case 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 real response to a 75% V_n voltage dip by the PV inverter STP 25000TL-30 with an FRT threshold set to 70% V_n .



2. In case the voltage threshold is reached, the inverter immediately stops feeding in current. I_k will be zero. Since the current from the output filter cannot be controlled by the inverter, i_p may occur according to the table on page 3. Please note that there is no significant energy stored in the output filter. The figure on the right shows the real response to a 30% V_n voltage dip by the PV inverter STP 25000TL-30 with a FRT threshold set to 70% V_n .



SMA inverters of the Sunny Tripower family can operate in both of the aforementioned operation modes.

SMA inverters of the Sunny Boy family can operate only in the second operation mode.

3 Short-Circuit Contribution for SMA Sunny Tripower Inverters

At an international level, the standard IEC 61400-21 describes testing procedures for wind farms that can be easily applied to PV inverters. In some countries like Germany (TR3, Technische Richtlinien für Erzeugungseinheiten Teil 3, FGW e.V., 2013) 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 AC currents and AC voltages are recorded synchronously with 50 kHz (20 μ s). Positive sequence fundamentals based on measurement of instantaneous voltages and currents are calculated according to IEC 61400-21 (2008). All results are measured as half periods RMS values.

The following table shows the test results for each SMA inverter. Note that the i_p values are given as an amplitude, whereas the values for I_k'' and I_k are RMS.

Inverter type	Short-circuit surge current i_p (A)	Initial symmetrical short-circuit current I_k'' (A)	Uninterrupted short-circuit current I_k (A)		Maximal current I_{max} (A)
			Mode 1	Mode 2	
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	49.46	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 5000TL-20	56.56	9.71	7.3	0	7.3
STP 6000TL-20	59.39	9.79	8.7	0	8.7
STP 7000TL-20	64.76	14.07	10.2	0	10.2
STP 8000TL-20	67.65	14.19	11.6	0	11.6
STP 9000TL-20	71.52	14.40	13.1	0	13.1
STP 10000TL-20	77.65	15.98	14.5	0	14.5
STP 12000TL-20	76.36	19.14	17.4	0	17.4
STP 10000TL-10	72.99	20.60	16.0	0	14.5
STP 12000TL-10	76.03	20.89	19.2	0	17.4
STP 15000TL-10	92.85	26.45	24.0	0	21.7
STP 17000TL-10	98.94	26.88	24.6	0	24.6
STP 15000TLEE-10	94.94	25.85	24.0	0	21.7
STP 20000TLEE-10	106.84	31.14	29	0	29
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 12000TL-US-10	81.30	17.27	14.4	0	14.4
STP 15000TL-US-10	89.29	20.57	18	0	18
STP 20000TL-US-10	101.44	26.46	24	0	24
STP 24000TL-US-10	111.92	30.91	29	0	29
STP 30000TL-US-10	181	50.68	36.2	0	36.2
STP 50-40	185.56	85.91	72.5	0	72.5
STP 50-US-40	154.69	75.02	64	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-41	193.47	89.54	79.5	0	75.3
STP 60-10 /	201.2	106.6	87	0	87
STP 60-US-10					
SHP 75-10	301.2	128.4	111.3	0	109
SHP 100-20	318.67	166.39	151	0	144.3
SHP 125-US-20	324.16	173.72	151	0	150.4
SHP 150-20 /	318.28	170.34	151	0	144.3
SHP 150-US-20					

Table 2 Short circuit contribution for SMA Sunny Tripower.

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