

Technical Requirements for Connecting Small Scale PV (ssPV) Systems to Low Voltage Distribution Networks

This document specifies the technical requirement for connecting ssPV to the low voltage distribution network. It applies to ssPV installed at three-phase connections while ensuring compliance of the utility interface with the requirements documented in this specification.

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Contents

1.	Terms and Definitions	3
2.	Requirements	4
2.1.	Utility compatibility	4
2.2.	System Parameteres	4
2.2.1.	Voltage Range of Operation	5
2.2.2.	Frequency operating range	5
2.2.3.	Flicker	5
2.2.4.	Harmonics and waveform distortion	5
2.2.5.	Power factor	5
2.2.6.	DC injection	6
2.2.7.	Synchronization	6
2.3.	Safety and protection	6
2.3.1.	Safety disconnect from utility network	6
2.3.2.	Disconnection switching unit	6
2.3.3.	Oversoltage, undervoltage and frequency	6
2.3.4.	Prevention of islanding	7
2.3.5.	Response to utility recovery	7
2.3.6.	Isolation	7
2.3.7.	Earthing	8
2.3.8.	Short-circuit protection	8
2.4.	Metering	8
2.4.1.	Metering schemes	8
2.4.2.	Types of meter	9

This document entitled “**Technical Requirements for Connecting ssPV Systems to low voltage Distribution Networks**” is all complementary documents that entail obligatory provisions for Customers seeking ssPV installations.

1. Terms and Definitions

a- The following words and phrases, wherever they appear in this document shall have the same meanings assigned to them hereunder unless the context provides otherwise.

Bi-directional meter

Meter that measures the active energy flow in both directions (import and export) and either displays the balance of the imported and exported energy in a single register meter (net metering) or displays both imported and exported energy in separate registers

Customer network

Electrical installation downstream of the electricity consumption meter, usually on the customer premises. This network can be backed up and operate as an island provided that it complies with the safety and protection requirements of this specification.

Disconnection switching unit

Switching unit that disconnects the ssPV operating in parallel with the utility network from the network in response to an abnormal condition

Island

State in which a portion of the utility’s or customer’s network, containing load and generation, continues to operate isolated from the rest of the grid.

Loss-of-grid

Condition in which supply from the utility network is interrupted for whatever reason

Point of Common Coupling (PCC)

Interconnection between the ssPV and the utility distribution network, referring to the node on the utility network electrically closest to a particular ssPV’s installation

Prevention of islanding

ssPV inverter’s ability to detect loss-of-grid and prevent the condition of unintended islanding

Safety disconnect

Independent control system that monitors the utility network conditions and disconnects the a.c. output of the ssPV from the network for abnormal conditions

Simple separation

Galvanic separation between circuits or between a circuit and earth by means of basic insulation

Small-scale PV (ssPV)

An energy generation source(s) which includes the energy conversion device(s), the static power converter(s), if applicable, and the control and protection gear within a customer’s network that operates in synchronism with the utility’s low voltage supply

Static power converter

power electronic device that converts variable d.c. or a.c. to grid compatible a.c. either synchronously (able to operate in stand-alone mode) or asynchronously (requires utility interconnection)

Total harmonic distortion (THD)

ratio of the r.m.s. value of the harmonics to the r.m.s. value of the fundamental and is defined as:

$$THD_i = \frac{\sqrt{\sum_{n=2}^{\infty} x_n^2}}{x_1}$$

where

x_n is the r.m.s. harmonic voltage or current of the order n ;

x_1 is the r.m.s. fundamental voltage or current.

Uni-directional meter

Meter that measures the active energy flow in one direction only and ignores the active energy flow in the reverse direction

Utility-interconnected inverter

Asynchronous static power converter

b. For the purposes of this document, words and phrases undefined above shall bear the same meanings assigned in the “Distribution Code”.

2. Requirements**2.1. Utility compatibility**

2.1.1. The quality of power provided by the ssPV systems is governed by practices and standards on voltage, flicker, frequency, harmonics and power factor at the PCC.

2.1.2. The ssPV shall be type approved.

2.1.3. Based that the system is operating with voltage variation in the range of $\pm 10\%$ of the nominal voltage without PV; then the maximum size of the ssPV is limited to:

- the rating of the CB at the supply point on the premises, and
- the voltage at the LV side of the MV/LV transformer does not exceed +10% of the nominal voltage at minimum load, and
- the voltage at the farthest point of the feeder does not exceed +10% of the nominal voltage at maximum load.

2.1.4. The ssPV shall be designed and connected as balanced three-phase generation

2.2. System Parameters

- Voltage range of operation
- Frequency range of operation
- Flicker
- Harmonics
- Power factor
- DC Injection
- Synchronization

2.2.1. Voltage Range of Operation

In accordance to the Distribution Code 4-1-1, an ssPV that operates in parallel with the utility system shall operate within the limits of the voltage variation in the range of $\pm 10\%$ ¹ of the nominal voltage.

2.2.2. Frequency operating range

In accordance to the Distribution Code 4-1-3, an ssPV that operates in parallel with the utility system shall operate within the frequency trip limits (48.5 Hz -51 Hz)².

2.2.3. Flicker

In accordance to Distribution Code 4-1-2, the operation of the ssPV, in conjunction with other existing and future loads at the same point of connection, shall not cause flicker levels to increase beyond the levels specified Table 1.

Table 1 Flicker Intensity Allowed for Low and Medium Voltages

Flicker Intensity	Level required for low and medium voltages
Flicker for a short period Pst*	1
Flicker for a long period Plt**	0.8

* short period for measuring is 10 minutes

** long period for measuring is 2 hours

2.2.4. Harmonics and waveform distortion

Total harmonic current distortion shall be less than 5 % at rated generator output in accordance with IEC 61727:2004. Each individual harmonic shall be limited to the percentages listed in Table 2 (IEC 61727:2004).

Table 2 Current Distortion Limit as a Function of Harmonics

Odd harmonics	Distortion limits
3 rd through 9 th	< 4.0 %
11 th through 15 th	< 2.0 %
17 th through 21 st	< 1.5 %
23 rd through 33 rd	< 0.6 %
Even harmonics	Distortion limits
2 nd through 8 th	< 1.0 %
10 th through 32 nd	< 0.5 %

2.2.5. Power factor

In accordance to Distribution Code 4-1-10, the ssPV shall not inject reactive power into the utility network, while the drain of reactive power shall be limited to a power factor of 0.9. This limit applies unless otherwise agreed upon with the utility.

¹ This value is under change in the Distribution Code.

² This range will be added to the Distribution Code.

2.2.6. DC injection

In accordance to Distribution Code 4-6-A, the static power converter of the ssPV shall not inject d.c. current exceeding 0.5 % of the rated a.c. output current into the utility at PCC under any operating condition. Inverter must disconnect within 500 ms if this threshold is exceeded.

2.2.7. Synchronization

- The ssPV shall synchronize with the utility network before the parallel connection is made.
- The inverter shall be the only method of automatic synchronization.
- The limits for the synchronizing parameters for each phase are:
 - frequency difference: 0.3 Hz,
 - voltage difference: 5 % = 11.5 V per phase, and
 - phase angle difference: 20°.

2.3. Safety and protection

2.3.1. Safety disconnect from utility network

The ssPV shall automatically and safely disconnect from the grid in the event of abnormal conditions which include:

- Network voltage or frequency out-of-bounds conditions.
- Loss-of-grid conditions, and d.c. current injection threshold exceeded.

2.3.2. Disconnection switching unit

- The ssPV shall be equipped with a disconnection switching unit which separates the ssPV from the grid due to abnormal conditions. The disconnection unit may be integrated into one of the components of the ssPV (the PV utility-interconnected inverter) or an independent device installed between the ssPV and the utility interface.
- The disconnection switching unit shall be able to operate under all operating conditions of the utility network.
- A failure within the disconnection switching unit shall lead to disconnection and indication of the failure condition.
- A single failure within the disconnection switching unit shall not lead to failure to disconnect. Failures with one common cause shall be taken into account and addressed through adequate redundancy.
- The disconnection switching unit shall disconnect from the network by means of two series switches. Each switch shall be separately rated to the ssPV's nominal power output. At least one of the switches shall be an electromechanical switch while the second switch may be part of the existing solid state switching circuits of a utility-interconnected static power converter. The electromechanical switch shall disconnect the ssPV on the neutral and the live wire(s).

2.3.3. Overvoltage, undervoltage, and frequency

Abnormal conditions can arise on the utility system and requires a response from the connected ssPV. This response is to ensure the safety of utility maintenance personnel and the general public, and to avoid damage to connected equipment. The abnormal utility conditions of concern are voltage and frequency excursions above or below the values stated in this clause. The ssPV shall disconnect if these conditions occur.

Over-voltage and under-voltage

The ssPV shall cease to energize the utility distribution system when the network voltage deviate outside the conditions specified in Table 3 in accordance to IEC 61727:2004. This applies to any phase of a multiphase system. The ssPV system shall sense abnormal voltage and respond. The following conditions shall be met, with voltages in r.m.s. referred to the nominal voltage and measured at the PCC.

Table 3 Voltage Ranges at PCC and their Maximum Trip Times

Voltage range at PCC	Maximum trip time (s)
$V < 50 \%$	0.2
$50 \% \leq V < 85 \%$	2
$85 \% \leq V \leq 110 \%$	Continuous operation
$110 \% < V < 120 \%$	2
$120 \% \leq V$	0.16

The purpose of the allowed time delay is to ride through short-term disturbances to avoid excessive unnecessary tripping. The ssPV does not have to cease to energize if the voltage returns to the normal utility continuous operating condition within the specified trip time.

Over-frequency and under-frequency

When the utility frequency is outside the range of 48.5 Hz and 51 Hz, the ssPV system shall cease to energize the utility line within 500ms. The purpose of the allowed range and time delay is to allow continued operation for short-term disturbances and to avoid excessive unnecessary tripping in weak utility system conditions. The plant does not have to cease to energize if the frequency returns to the normal utility continuous operating condition within the specified trip time.

2.3.4. Prevention of islanding

- If the load and ssPV within an isolated network be closely matched, then the voltage and frequency limits may not be triggered. This would result in an unintentional island that could continue beyond the allowed time limits.
- In order to detect an islanding condition, the ssPV shall make use of at least one active islanding detection method. An active islanding detection method intentionally varies an output parameter and monitors the response or it attempts to cause an abnormal condition at the utility interface to trigger an out-of-bounds condition. If the utility supply is available, the attempt to vary an output parameter or cause an abnormal condition will fail and no response will be detected. However, if the utility supply network is de-energized, there will be a response to the change which can be detected.
- Islanding condition shall cause the ssPV to cease to energize the utility network within 2 s. The ssPV shall comply with the requirements of IEC 62116.

2.3.5. Response to utility recovery

After a voltage or frequency out-of-range condition that has caused the ssPV to cease energizing the utility network, the ssPV shall not re-energize the utility network for 1 min after the utility service voltage and frequency have recovered to within the specified ranges.

2.3.6. Isolation

The ssPV shall provide a means of isolating from the utility interface in order to allow for safe maintenance.

2.3.7. Earthing

- The electrical installation shall be earthed in accordance with IEC 60364-7-712.
- The ssPV shall be protected by an earth leakage unit. The ssPV shall not be connected to any of the customer network earth leakage protection units.
- Utility-interconnected inverters without simple separation shall make use of earth leakage circuit-breakers which are able to respond to d.c. fault currents including smooth d.c. fault currents (without zero crossings) unless the inverter can exclude the occurrence of d.c. leakage currents through its circuit design).

2.3.8. Short-circuit protection

The ssPV shall have short-circuit protection in accordance with IEC 60364-7-712.

2.4. Metering

All meters shall be the property of the utility even when the meters are located on the premises of the customer. Meters that are embedded in the customer's network shall be accessible to the utility on request.

2.4.1. Metering schemes

Figures 1 and 2 show different metering schemes in an ssPV system without a storage.

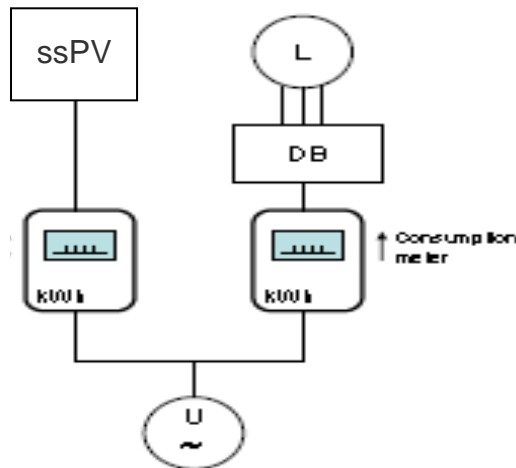


Figure 1 — Unidirectional meters

Where;

DB: distribution board, ssPV: overall generation, L: overall consumption, and U: utility network.

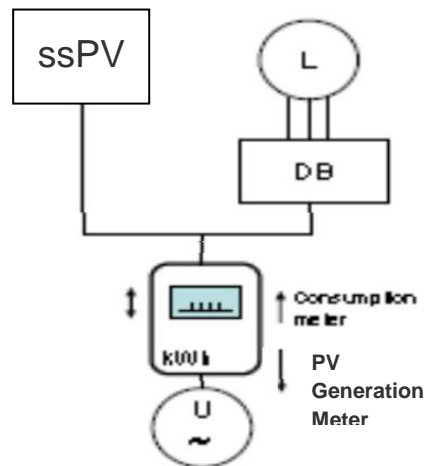


Figure 2 — Bi-directional meter

2.4.2. Types of meter

- Energy meters used in conjunction with ssPV shall record active energy. The meters shall be conventional electronic, bi-directional type meters. The meters can either be of the single or the separate register type.
- Pre-payment meters require separate registers in order to record import and export of power separately. Single register prepayment meters deduct credit when load is drawn by the customer. However, when customer exports energy to the utility network, credit is still decremented from the register or, alternatively, the meter goes into tamper alert. This is a revenue protection feature that renders single register prepayment meters unsuitable for ssPV.