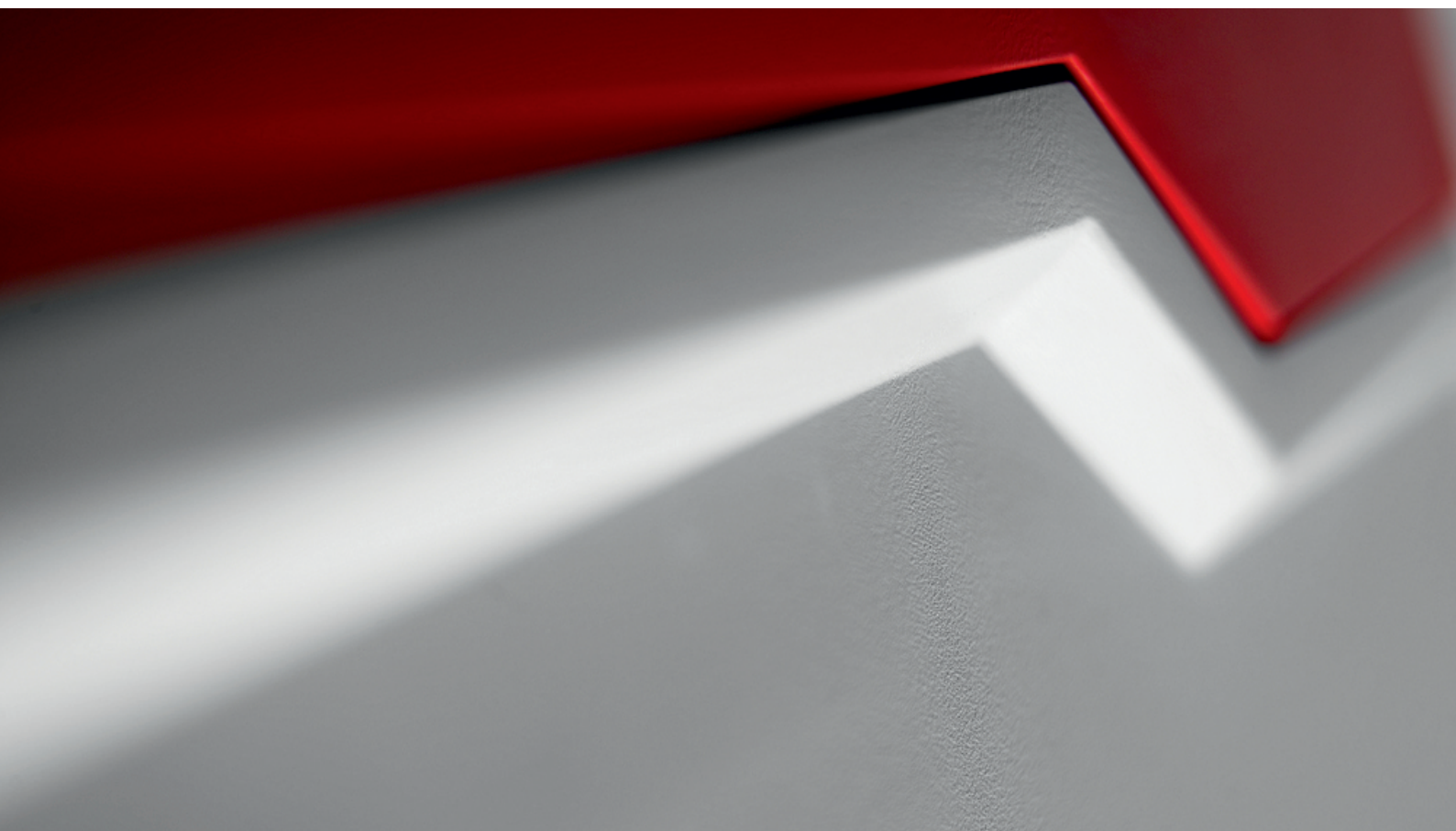




## **Important Requirements for Medium-Voltage Transformers SUNNY HIGHPOWER PEAK3**

## 1 Introduction

This document describes technical requirements for transformers and related considerations regarding the system design for Sunny Highpower PEAK3 devices and informs about necessary guidelines and specifications by considering compatible winding configurations and allowable impedance levels.

## 2 Compatibility List

All information granted in this document is regarded towards the system design in combination with the following SMA inverters:

- SHP 100-21 (Sunny Highpower PEAK3)
- SHP 150-21 (Sunny Highpower PEAK3)
- SHP 172-21 (Sunny Highpower PEAK3)
- SHP 180-21 (Sunny Highpower PEAK3)
- SHP 125-US-21 (Sunny Highpower PEAK3)
- SHP 150-US-21 (Sunny Highpower PEAK3)
- SHP 165-US-21 (Sunny Highpower PEAK3)
- SHP 172-US-21 (Sunny Highpower PEAK3)
- SHP FLEX-US-21 (Sunny Highpower PEAK3)
- SHP 100-JP-21 (Sunny Highpower PEAK3)
- SHP 143-JP-21 (Sunny Highpower PEAK3)

## 3 General Technical Properties

The following guidelines are necessary when specifying or evaluating transformers for use with Sunny Highpower inverters:

- Multiple Sunny Highpower inverters connected in parallel can be interconnected to a single transformer.
- Standard distribution or service transformers are acceptable for interconnection to medium-voltage distribution systems.
- Sunny Highpower inverters do not require electrostatic shielding between primary and secondary windings of transformers.
- The nominal voltage at the inverter electrical connection point (ECP) must match the nominal output voltage of the inverter.
- The rated kVA capacity of a transformer must be equal to or greater than the total nominal output power of all inverters connected to the transformer.
- The winding configuration of transformers to which the inverters are connected must be compatible with the inverter. Compatible winding configurations for use with Sunny Highpower inverters are defined in this document (see Section 4, page 3).
- The total impedance between the inverters and the point of common coupling (PCC) with the grid must not exceed the values as specified in this document. (see Section 5, page 3)
- Transformers must be rated for the nominal frequency of the grid voltage at the grid connection point and the tolerances to be expected.
- The expected load (generation) profile and ambient temperature conditions of the PV system and the transformer must be considered when specifying transformer rated kVA capacity, temperature rise, and insulation class.
- SMA recommends specifying transformers with multiple connection taps to enable adaption to the local system voltage.
- Transformers should comply with all applicable standards based on the installation location.

## 4 Compatible Transformer Winding Configurations (Vector Groups)

Sunny Highpower inverters require connection to a grounded Wye transformer winding. A neutral conductor connection is not required between the inverter and the transformer's grounded neutral point. The phase displacement of transformers does not affect the operation of Sunny Highpower inverters. Transformers with compatible winding configurations can be specified with any available phase displacement.

| Compatible Transformer Winding Configurations <sup>1)</sup> at Inverter ECP |                             |                                        | Inverter Type                       |
|-----------------------------------------------------------------------------|-----------------------------|----------------------------------------|-------------------------------------|
| YNyn<br>Wye-grounded : wye-grounded                                         | Dyn<br>Delta : wye-grounded | YNd<br>Wye-grounded : delta            |                                     |
| Yes                                                                         | Yes                         | Yes                                    | SHP 100-21<br>SHP 100-JP-21 (400 V) |
| Yes                                                                         | Yes                         | No                                     | SHP 125-US-21 (480 V)               |
| Yes                                                                         | Yes                         | No                                     | SHP 143-JP-21 (550 V)               |
| Yes                                                                         | Yes                         | No                                     | SHP 150-21<br>SHP 150-US-21 (600 V) |
| Yes                                                                         | Yes                         | No                                     | SHP 165-US-21                       |
| Yes                                                                         | Yes                         | No                                     | SHP 172-21<br>SHP 172-US-21         |
| Yes                                                                         | Yes                         | No                                     | SHP 180-21                          |
| Yes                                                                         | Yes                         | Yes, up to 435Vac nominal, 500Vac max) | SHP FLEX-US-21                      |

Connecting inverters to transformers that do not comply with these guidelines can result in unstable inverter operation, excessive nuisance tripping, and disruption or damage to the inverters or other connected equipment.

## 5 Allowable Impedance Levels

Impedance (especially resistances of conductors and transformers) between the PV system and the grid cause an increase in voltage measured at the inverter terminals. In order to avoid over-voltage tripping of the inverters and excessive energy losses, AC conductors should be sized to limit the voltage drop between the inverters and the point of common coupling (PCC) to a maximum of 1% of nominal voltage. In addition, the stability of the inverter control system is affected by the level of impedance (especially inductances of transformers) between the inverters and the point of common coupling (PCC) with the grid. The maximum allowable impedance level for each Sunny Highpower inverter model is given in the table below.

| Inverter Type              | Maximum allowable impedance (Z <sub>max</sub> ) |
|----------------------------|-------------------------------------------------|
| SHP 100-21 / SHP 100-JP-21 | 50%                                             |
| SHP 125-US-21              | 50%                                             |
| SHP 143-JP-21              | 50%                                             |
| SHP 150-21 / SHP 150-US-21 | 50%                                             |
| SHP 165-US-21              | 50%                                             |

<sup>1)</sup> The second part of the transformer's vector-group notation gives the inverter-side winding configuration. For example, Dyn is a transformer with a Delta configuration on the grid connection side and a Wye-grounded configuration on the inverter connection side.

| Inverter Type              | Maximum allowable impedance (Z <sub>max</sub> ) |
|----------------------------|-------------------------------------------------|
| SHP 172-21 / SHP 172-US-21 | 50%                                             |
| SHP 180-21                 | 50%                                             |
| SHP FLEX-US-21             | 50%                                             |

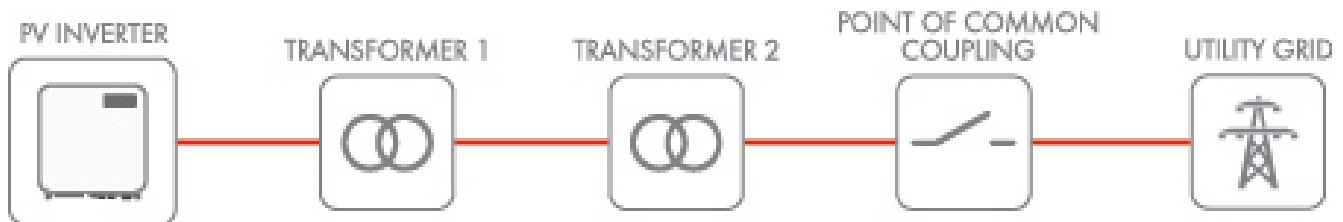


Figure 1: PV system connected to the grid via multiple transformers

## 6 Calculation for Allowable Impedance Levels

The total system impedance for a given inverter in a PV system can be calculated using the equation below:

$$Z_{\text{total}} = \sum_{n=1}^t \left( \frac{S_{\text{PVn}}}{S_{\text{TRn}}} * Z_{\text{TRn}} \right) + Z_{\text{PCC}}$$

- $Z_{\text{PCC}}$  is the short-circuit impedance based on the short-circuit power available at the PCC:
  - Where the total PV system kVA capacity is insignificant relative to the grid capacity at the PCC, grid impedance will be negligibly small and can be excluded from the calculation.
  - When needed, this value is typically provided by the interconnection utility.
- $n$  is one of one or more transformers connected in series between the inverter and the PCC.
- $S_{\text{PVn}}$  is the total nominal output power (in kVA) of all inverters connected to transformer  $n$ .
- $S_{\text{TRn}}$  is the rated kVA of transformer  $n$ .
- $Z_{\text{TRn}}$  is the short-circuit impedance of transformer  $n$ .

Conductor impedance is assumed to be 2 % and has been deducted from inverter maximum allowable impedance levels.

## 7 Use-Case Example 1: Connected PV Systems Through Single Distribution Transformers

Distribution transformers typically have short-circuit impedances between 4 % and 6 % - well below the lowest maximum allowable impedance of Sunny Highpower inverters. Therefore assuming the transformer kVA rating is equal to or greater than the total nominal output power of all connected inverters (as specified in Section 1 General Technical Properties of this document), system impedance should not be a concern in PV systems connected through a single distribution transformer to the PCC with the grid.

## 8 Use-Case Example 2: Connected Large Utility-Scale PV Systems to HV Transmission Systems

In this example, a large utility-scale PV system is planned to be interconnected to the high voltage transmission network. The output of the inverters will be stepped up to medium voltage within the PV plant, and then stepped up to high voltage for interconnection.

PV system: 400 x SHP 150-US-21

- $S_{PV\_total} = 60 \text{ MVA}$
- $Z_{max} = 50 \%$

$$Z_{PCC} = 60 \text{ MVA} / 1000 \text{ MVA} = 6 \%$$

- Where 1000 MVA = short-circuit power available at PCC (provided by utility or transmission system operator)

1. MV step-up transformers: 10 inverter per transformer

- $S_{PV1} = 1.5 \text{ MVA}$
- $S_1 = 1.5 \text{ MVA}$
- $Z_1 = 5.75 \%$

2. HV step-up transformer

- $S_{PV2} = 60 \text{ MVA}$
- $S_2 = 60 \text{ MVA}$
- $Z_2 = 10 \%$

Total system impedance to the inverters would be calculated as below:

$$Z_{total} = (1.5/1.5) * 5.75 \% + (60/60) * 10 \% + 6 \% = 21.75 \%$$

In this example total impedance is less than the 50 % maximum allowable impedance for SHP 150-US-21 inverters. The specified system design is within the impedance limits for the selected Sunny Highpower inverters.