Technical Information

Important Requirements for Medium-Voltage Transformers SUNNY TRIPOWER

Content

This document describes transformer technical requirements and related system design considerations for the following SMA inverters:

- Sunny Tripower 12000TL-US / 15000TL-US / 20000TL-US / 24000TL-US / 30000TL-US
- Sunny Tripower CORE1 (STP 33-US-41 / STP 50-US-40 / STP 50-US-41 / STP 62-US-41)

1 General Technical Properties

The following guidelines must be considered when specifying or evaluating transformers for use with Sunny Tripower inverters:

- Multiple Sunny Tripower 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.
- General purpose distribution transformers and auto-transformers are acceptable for interconnection to low-voltage services where the service voltage or winding configuration is not compatible with the inverter.
- Sunny Tripower 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 Tripower inverters are defined in Section 2 Compatible Transformer Winding Configurations (Vector Groups) of this document.
- The total impedance between the inverters and the point of common coupling (PCC) with the grid must not exceed the values specified in Section 3 Allowable Impedance Levels of this document.
- 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.
- For PV systems interconnected to a medium-voltage distribution system, 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.

2 Compatible Transformer Winding Configurations (Vector Groups)

Sunny Tripower 12000TL-US, 15000TL-US, 20000TL-US, 24000TL-US inverters require connection to a grounded Wye transformer winding. A neutral conductor connection is required between the inverter and the transformer's grounded neutral point.

Sunny Tripower 30000TL-US inverters may be connected to either a grounded Wye or ungrounded Delta transformer winding. When connected to a grounded Wye transformer winding, a neutral conductor connection is required between the inverter and the transformer's grounded neutral point. When connected to an ungrounded Delta transformer winding, the inverter does not require a neutral conductor connection.

Sunny Tripower CORE1 (STP 50-US-40) inverters require connection to a grounded Wye transformer winding. A neutral conductor connection to the transformer's grounded neutral point is optional. Sunny Tripower CORE1 inverters are delivered with a factory installed neutral-to-ground jumper, which should remain in place for interconnection without a neutral conductor connection.

The phase displacement of transformers does not affect the operation of Sunny Tripower inverters. Transformers with compatible winding configurations can be specified with any available phase displacement.

	Compatible Transformer Winding Configurations* at Inverter ECP			Inverter type
	YNyn Wye-grounded : wye-grounded	Dyn Delta : wye-grounded	YNd Wye-grounded : delta	
GRID	Yes	Yes	No	STP 12000TL-US-10, STP 15000TL-US-10, STP 20000TL-US-10, STP 24000TL-US-10
	Yes	Yes	Yes**	STP 30000TL-US-10
	Yes	Yes	No	STP 33-US-41, STP 50-US-40, STP 50-US-41, STP 62-US-41

* The second part of the transformer's vector-group notation gives the inverter-side winding configuration. For example, YNd is a transformer with a Wye-grounded configuration on the grid connection side and a Delta configuration on the inverter connection side.

** For connection to 480 V Delta commercial services where co-located loads may result in recurring and persistent line-to-ground faults (effectively resulting in a corner grounded Delta grid configuration), Sunny Tripower inverters must be protected from excessive line-to-ground voltages by isolating the PV system from the source(s) of the fault(s).

If the voltage or winding configuration of an existing service transformer is not compatible for interconnection with the inverters, an intermediate low voltage transformer or auto-transformer can be installed in series between the inverters and the service transformer to provide a compatible electrical connection point (ECP) for the inverters. Auto-transformers must have a Wye winding configuration (YNa0) and must provide a neutral connection terminal for connection to the Sunny Tripower inverter(s), where rquired. When connecting inverters through intermediate low voltage transformers or auto-transformers, the total impedance to the grid must not exceed the values specified in Section 3 Allowable Impedance Levels of this document.

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.

3 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 Tripower inverter model is given in the table below.

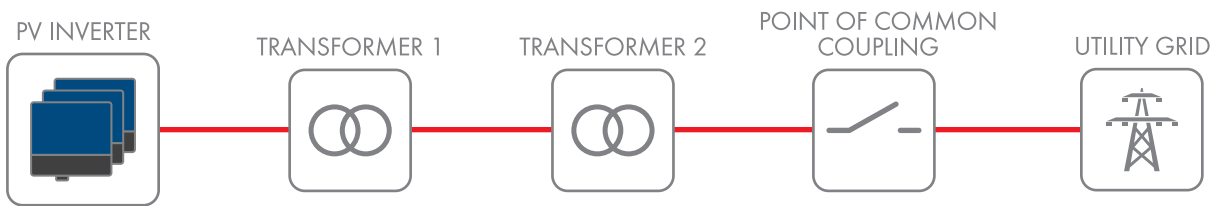| Inverter type	Maximum allowable impedance (Zmax)
STP 33-US-41, STP 50-US-40, STP 50-US-41, STP 62-US-41	33 %
STP 30000TL-US-10	25 %
STP 24000TL-US-10	18 %
STP 20000TL-US-10	14 %
STP 15000TL-US-10	10 %
STP 12000TL-US-10	8 %

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

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

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

- Z_{PCC} is the short-circuit impedance based on the short-circuit power available at the PCC
  - For most commercial PV systems the size of the PV system is insignificant relative to the grid capacity at the PCC - therefore, 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_{PVn} is the total nominal output power (in kVA) of all inverters connected to transformer n.
- S_{TRn} is the rated kVA of transformer n.
- Z_{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.

Use-case example 1: PV system connected through a single distribution transformer

Distribution transformers typically have short-circuit impedances between 4 % and 6 % - well below the lowest maximum allowable impedance of Sunny Tripower 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.

Use-case example 2: PV system connected through multiple transformers in series

Where a PV system is connected to the grid through multiple transformers in series (such as to provide a compatible voltage or winding configuration at the inverter EPC), it is possible for the total system impedance of multiple transformers to exceed the maximum allowable impedance of the inverters.

In this example a PV system is planned to be connected to an existing 120 V / 208 V general purpose transformer that is located closer to the PV system than the 277 V / 480 V main service. An additional PV system transformer will be required to provide compatible connection voltage for the inverters.

PV system: 6 x STP 15000TL-US-10

- S_{PV} = 90 kVA
- Z_{max} = 10 %

Z_{PCC} = negligible, excluded from calculation

1. Utility main service transformer (existing): 12.47 kV : 277 V / 480 V

    - S_1 = 500 kVA
    - Z_1 = 6 %

2. Customer general purpose transformer (existing): 480 V : 120 V / 208 V

    - S_2 = 112.5 kVA
    - Z_2 = 6 %

3. PV system transformer (new): 208 V : 277 V / 480 V

    - S_3 = 112.5 kVA
    - Z_3 = 6 %

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

$$Z_{total} = (90/500)*6\,\% + (90/112.5)*6\,\% + (90/112.5)*6\,\% = 10.7\,\%$$

In this example total impedance exceeds the 10 % maximum allowable impedance for STP 15000TL-US-10 inverters. To avoid unstable inverter operation SMA would recommend that this system design be revised to either reduce the impedance between the inverters and the PCC or utilizing an inverter with a higher maximum allowable grid impedance.

Adapting system designs with excessive system impedance

For system designs where the calculated system impedance exceeds the maximum allowable impedance of the inverters, the system design can be adjusted through one or a combination of the following engineering changes:

- specify a transformer with lower impedance
- specify a transformer with a higher kVA rating, thus reducing the relative impedance to the inverters
- revise the design to eliminate intermediate transformers connected in series between the inverters and the PCC with the grid
- revise the design to utilize Sunny Tripower models with higher maximum allowable impedance levels

In the preceding example, the system impedance could be reduced below the 10 % maximum allowable impedance for STP 15000TL-US-10 inverters by increasing the kVA rating of the PV system transformer to 150 kVA or 225 kVA or by utilizing a transformer of sufficiently low impedance. Depending on the site conditions, it may also be possible to revise the design to connect the PV system directly to the 277 V / 480 V main service - thereby eliminating the impedance of the two 208 V transformers.

Alternatively, the maximum allowable impedance could be increased to 25 % by re-designing the system to utilize three STP 30000TL-US-10 inverters instead of six STP 15000TL-US-10 inverters.

Use-case example 3: Large utility-scale PV system connected to HV transmission system

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: 2000 x STP 30000TL-US-10

- S_{PV_total} = 60 MVA
- Z_{max} = 25 %

Z_{PPC} = 60 MVA / 1000 MVA = 6 %

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

1. MV step-up transformers: 50 inverter per transformer
   - S_{PV1} = 1.5 MVA
   - S_1 = 1.5 MVA
   - Z_1 = 5.75 %

2. HV step-up transformer
   - S_{PV2} = 60 MVA
   - S_2 = 60 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 25 % maximum allowable impedance for STP 30000TL-US-10 inverters. The specified system design is within the impedance limits for the selected Sunny Tripower inverters.