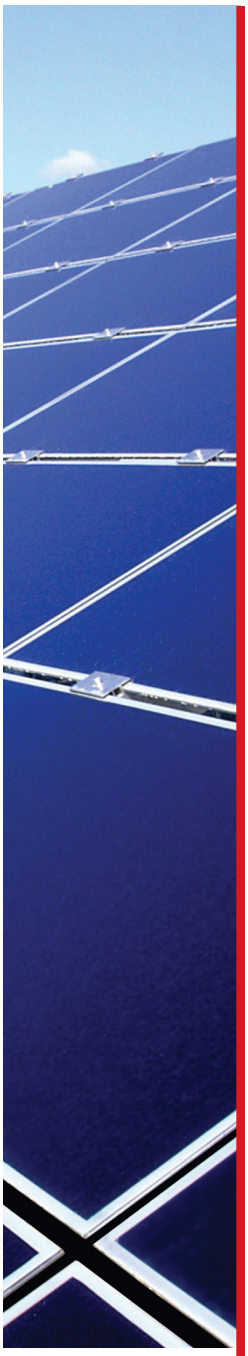

Application Note
FS Series PV Modules: Inverters with Demonstrated Compatibility

This document provides information about the compatibility of First Solar FS Series PV Modules with existing inverter technologies to aid in the selection of inverters during the system design process. This document provides a general overview of the key characteristics that should be considered when evaluating inverter options for use with FS Series Modules. The appendix of this document provides a list of inverters that are compatible and approved for use with FS Series Modules based on evaluation of demonstrated actual inverter performance with FS Series 2 Modules. Due to the electrical similarity of the FS Series 3 Modules, First Solar also supports the use of these inverters for FS Series 3 Modules. This document does not provide performance evaluations or comparisons between inverters and does not recommend a specific inverter manufacturer.

Inverter Types

First Solar FS Series PV Modules are compatible with a range of string, central, and transformer less inverters. String and central inverters which employ a transformer to galvanically separate the DC circuit from the AC grid are generally compatible with the FS Series Modules so long as the PV array is not positive grounded. FS Series PV Module compatibility with selected transformer less inverters has been validated through extensive testing. First Solar has studied the phenomenon of transparent conductive oxide (TCO) corrosion in thin film PV modules operated at negative bias with respect to ground, and concluded that a combination of multiple physical construction and environmental conditions must be present during negative bias conditions for the failure mode to occur. FS Series Modules are designed to be robust against these specific physical and environmental conditions. First Solar's testing has concluded that approved transformer less inverters will not subject the FS Series PV Modules to conditions which could lead to TCO corrosion. First Solar has extended its inverter compatibility and approval to include several transformer less inverters. First Solar will continue to test existing and new transformer less inverters to ensure reliability and performance expectations are achieved. Please refer to First Solar application note PD-5-429 for additional information regarding transformer less inverters.

Bias Conditions

When selecting an inverter, system bias conditions and grounding should also be considered. FS Series PV Modules can be used in negative-grounded or ungrounded installations. FS Series PV Modules should not be used in positive-grounded or bi-polar systems. Local installation codes and cost impact should be considered when choosing between negative-grounded and ungrounded system configuration.

Power Rating

The system design of series and parallel combinations of the FS Series Modules should be optimized for an inverter's maximum power rating. For a given string or array of modules, the expected output power from the modules should not continuously exceed the maximum power rating of an inverter for typical operating conditions. FS Series module output can be influenced

by several physical and ambient conditions including irradiance level, temperature, tilt angle, and geographic location. These factors must be considered when configuring the PV array relative to the inverter maximum power rating. Refer to First Solar Module Characterization documents[1] for additional information.

Maximum System Voltage FS Series 2 Modules

The maximum voltage of a series connected string of FS Series 2 Modules must be considered for compatibility with specific inverter device limitations. First Solar application note PD-5-428 should be referenced when determining the site specific maximum open-circuit system voltage ($\mathbf{V}_{oc}$) seen by the inverter. For applications in North America which may be governed by the National Electrical Code, please refer to First Solar application note PD-5-435 NA for additional guidance in determination of maximum system voltage.

Maximum Power Point Tracking

The Maximum Power Point (MPP) voltage of the array must be considered for compatibility with the specified MPP window of the inverter. Similar to the maximum open-circuit voltage, the MPP voltage of the array is dependent on ambient conditions, and the system must be designed to ensure that the MPP voltage of the array remains within the MPP window for all expected operating conditions. Operating voltage can also impact the conversion efficiency of the inverter, and should be considered for optimal system design.

First Solar has tested the operation and MPP Tracking function of multiple inverter types (string, central, and transformer less). Each compatible inverter listed in the appendix was verified to exhibit fault free operation under normal operating conditions. Additionally, each listed inverter was tested to ensure its MPP Tracking algorithms track system MPP in all expected climate conditions.

Summary

When selecting an inverter to use with First Solar FS Series Modules, the Bias Conditions, module Power Rating, Maximum System Voltage, and inverter MPP Tracking must be evaluated to ensure system design component compatibility. First Solar has evaluated and tested several commercially available inverters for compatibility with the FS Series Modules. The inverters that have demonstrated compatibility with First Solar FS Series 2 Modules are listed in the appendix.

First Solar provides additional application notes and reference materials to optimize and aid in the system design process. In addition, First Solar requires all system designs be submitted for review and approval via its System Design & Application (SDA) process. The SDA process ensures that the expectations of system owners and stakeholders are realized through the application of approved design practices.

[1] First Solar Documents: PD-5-420, PD-5-421, PD-5-422, PD-5-425

APPENDIX – List of Compatible Inverters

The following inverters have been tested by First Solar to ensure functional compatibility and reliable performance of First Solar FS Series 2 Modules over their lifetime. Each inverter has varying specifications and performance characteristics that need to be considered for each individual application. Except as noted below, absence from the list does not indicate that there is an incompatibility with an inverter; only that First Solar or its partners have not completed performance verification of the component.

Compatible Inverters for First Solar FS Series Modules:

Conergy AG

- IPG Series — IPG40, IPG60, IPG80, IPG100, IPG280
- Sun Profi Series — SP1300, SP2500, SP3100, SP3400

Fronius International GmbH

- IG Series — IG 15/20/30/40/60HV (Europe)
  IG 300/390/400/500 (Europe)
  IG 2000/3000/2500LV/4000/4500LV/5100 (USA)
- IG Plus Series — IG Plus 35/50/70/100/120/150 (International)
  IG Plus 3.0-1_{UNI} to 3.8-1_{UNI}, 5.0-1_{UNI} to 7.5-1_{UNI}, 10.0-1_{UNI} to 11.4-1_{UNI}, 11.4-3_{Delta} and 12.0-3_{WYE277}

Kaco Gerätetechnik GmbH

- xi-Series — Powador 1501/3501/4501 xi

Mastervolt

- QS Series — Sunmaster QS1200/2000/3200/6400

Power One

- PVI Central — 50/100/150/200/250/300

SatCon

- PowerGate Plus — PVS 30/50/75/100/135/150/225/250/375/500/1000 (USA)

Siemens AG

- Sitop Series — 1500, 2000, 2300, 3000, 4000, 4600
- Sinvert — 60M – 1700MX

SMA Technologie AG

- SB — 700, 1100, 1100LV, 1800, 2500, 2800i, 3000, 3300, 3800 5000US, 6000US, 7000US
- SMC — 4600A, 5000A, 6000A, 7000HV
- SC — 100 outdoor/indoor, 100LV, 125LV, 150, 200, 250, 350, 200HE, 250HE, 350HE, 400HE, 500HE, 560HE, 630HE, 400MV, 500MV, 700MV, 1000MV, 1120MV, 250U, 500U

Sputnik Engineering

- SolarMax — 20C; 25C; 30C; 35C; 35C; 50C; 80C; 100C; 300C

SunTechnics GmbH

- STZ Series — 40, 60, 80, 100, 280

Xantrex Technology Inc

- PV Series — PV10, PV20, PV30, PV150GTI
- GT Series — GT100E, GT250E, GT500E (Europe)
  GT2.5DE, GT2.8SP, GT3.8DE, GT3.8SP, GT5.0SP (Europe)
  GT100-480, GT250-480, GT 500-480, GT 500-MV (USA)
  GT2.8, GT3.3N, GT3.8, GT4.0N, GT5.0 (USA)
  GT2.5AU, GT5.0AU