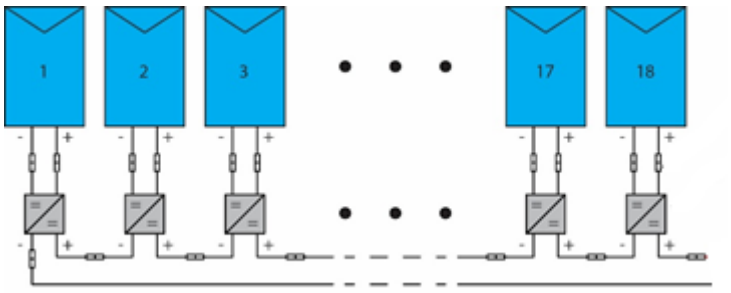
Technical Note – String Fusing Requirements in SolarEdge Systems According to IEC Standards

Introduction

String design and installation is significantly different in a SolarEdge system when compared to a traditional string inverter. PV modules do not get connected in series directly. Every PV module in the array is connected to the input of a SolarEdge power optimizer, and the power optimizer output cables are connected to each other in series.



Consequently, the behavior of a SolarEdge system under fault conditions differs from that of a traditional string inverter system.

This document compares the overcurrent protection mechanisms of both systems and analyzes the systems' responses to various fault scenarios. From this analysis it follows that string fuses are not required in SolarEdge systems because other safety methods are in place. These safety methods make SolarEdge systems safer, since as this document explains, the system shuts down after a first fault occurs, and the shutdown occurs faster than in a string inverter system using fuses.

String Fuse Requirements

According to IEC 62548 and other standards, there is a need for string overcurrent protection (string fuses) if the possible reverse current is higher than the fuse rating of the PV module. According to EN 60269-6 a PV fuse has to disconnect a current that is 1.35x its rating within one hour, meaning cables and modules have to withstand currents up to 35% higher for one hour. In shorter time frames higher currents may occur, meaning cables and modules are able to withstand higher currents for up to one hour.

In a SolarEdge system, the PV modules are not connected directly. To understand if there is a need for string fuses one has to consider if reverse current can affect the PV modules.

To create reverse current in a PV system, a string or a part of a string has to be short-circuited. This can be caused either by two insulation faults (line-earth faults) or by a line-line fault.

Short-circuits Due to Line-Earth Faults

String Inverter Systems

In string inverter systems an earth fault will create an insulation fault indication at the inverter and a transformer-less inverter will also disconnect from the grid, however the fault remains. In the case of a second insulation fault in another part of the d.c. system (either in the same string or in a different string), the string or part of it is short-circuited. Then a critical reverse current, being higher than the fuse rating of the PV module, can flow through the PV modules. A string overcurrent protection device with a lower current rating than the fuse rating of the PV module, can interrupt this current. In case of a reverse current lower than the module fuse rating, this current will not be interrupted, and there may be risk of a fire at the earth fault location. From the standard's point of view this risk is considered low and therefore protection is not required.

Furthermore, the cables should to be sized to have the appropriate current carrying capabilities.

SolarEdge Systems

In SolarEdge systems, an earth fault will create an insulation fault reaction leading to system shutdown. Not only is the inverter disconnected, but the optimizers shut down and enter safety mode, reducing the string current to 0A (see the SolarEdge system safety declaration here). In case of a second fault, the SolarEdge system is designed to minimize the chance of reverse current to flow and subsequently reduces fire risks.

Short-circuits Due to Line-Line Faults

Due to the use of double-insulated single-core cables the risk for line-line faults without having an insulation fault is quite low. Therefore to protect PV modules from the effects of short-circuits no additional overcurrent protection devices (such as string fuses) are required by the standard. Nevertheless, such faults have to be considered.

String Inverter Systems

In string inverter systems a line-line fault can create a critical reverse current. To protect the PV modules, string overcurrent protection is necessary if the PV module fuse rating is insufficient. However even with string fuses, when the current is lower than the module fuse rating there is a current at the fault location, and it may cause a fire.

Furthermore, the cables should be sized to have the appropriate current carrying capabilities.

SolarEdge Systems

SolarEdge power optimizers provide internal current limitation. Due to the optimizer topology and the control of the switches, no reverse current can flow into a PV module. The optimizers limit current at the PV module input to 10A or 11A (model-dependent) and limit current at the optimizer d.c. output circuit to 15A. The SolarEdge power optimizers have been certified to provide zero backfeed current to the PV module, and zero backfeed current to the rest of the string – i.e. the string current could flow in only one direction. Therefore, there is no risk for reverse currents in the modules.

In most cases, a line-line fault affects the fixed-voltage control and immediately leads to system shutdown, including shutdown of the optimizers, reducing the string current to 0A. However if the cables are not sized to have current carrying capabilities appropriate for the maximum current, there may be a need to have overcurrent protection devices to protect the cables until the shutdown occurs. To eliminate the need for such devices, cables should be able to carry the maximum current, which is (n-1) x 15A, where n is the number of strings and 15A is the optimizer's maximum output current. For example in a 3-string system a 30A current could occur temporarily.

It is recommend to use cables that can carry the maximum current continuously. Typically a cable with a cross section of 4mm² is able to carry more than 30A, even at higher temperatures, so such cable may be used in 3-string systems, even if the potential reverse current is considered to be continuous (and not interrupted by the system, as explained above).

No string overcurrent protection is needed if the cables are able to withstand the potential reverse current for 15 seconds. In comparison to the traditional string inverter systems, there is no current after this time and no risk of fire at the location of the fault itself.

Overload Protection

String Inverter Systems

In string inverter systems, string currents can be higher than the STC values in the module the datasheet. Therefore a safety margin is used (for example of 10%) to account for higher irradiances and other ambient conditions which may increase the current.

SolarEdge Systems

In a SolarEdge system, the string current is limited to the optimizer's maximum output current, even if module current increases due to ambient conditions. Therefore no safety margin is needed when calculating maximum string current.