Technical Note – String Fusing Requirements in SolarEdge Systems

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 for most common installations¹, string fuses should be used only in cases where four or more strings are installed.

All equipment within the inverter-optimizers segment (connectors², cables, disconnectors, etc.) must be rated to 36A.

When the strings are directly connected to the inverter, the fuses in one polarity are sufficient to protect both polarities, as required by HD 60364-7-712 cl. 712.432.101.

String Fuse Requirements

According to IEC 62548 and US NEC -2017, Article 690.9, there is a need for string overcurrent protection (string fuses), if the possible reverse current is higher than the max rating of the PV module. According to EN 60269-6, a string fuse has to disconnect a current that is 1.35x (IEC)/1.56x (US NEC) its rating within one hour, meaning cables and modules have to withstand currents up to 35% (IEC)/56% (US NEC) 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 the inverter. Hence, when evaluating whether string fuses are required, the installer has to consider if reverse current can affect all system’s components such as: PV modules, optimizers, combiner box, connectors, etc.

Fault Scenarios

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 consecutive ground faults or by a line-line fault.

A schematic of the two insulation faults is depicted in the following figure:

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¹ Excluding the use of M1600 optimizer
² https://ec.staubli.com/AcroFiles/Catalogues/PV_Sol-Main-11014092_(en)_hi.pdf#page=12-13

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Short-circuits due to Line-Earth (Ground) 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 DC 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 is required, with a lower current rating than the max rating of the PV module, to interrupt this current. In case of a reverse current lower than the module 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.

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 a safe level around 0A. In case of a second fault, there might be scenarios where current will flow momentarily. When there are three parallel strings or fewer installed, the SolarEdge system sustains the resulted current, and the optimizers minimize the chance of reverse current flowing to the modules. Thus, no additional string protection is required.

Short-circuits due to Line-Line Faults

Due to the use of double-insulated single-core cables, the risk of line-line faults is low. Therefore, in order 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 rating is insufficient. However, even with string fuses, when the current is lower than the module rating there is a current at the fault location, and it may cause a fire.

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 to a PV module. The optimizers limit current at the PV module input to up to 14A (model-dependent) and limit current at the optimizer DC output circuit to up to 18A\(^3\). The SolarEdge power optimizers are certified to provide zero backfeed current to the PV module, and zero backfeed current to the rest of the string, meaning that the string current can flow in only one direction. Therefore, there is no risk of reverse currents in the modules.

\(^3\) Excluding the use of M1600 optimizer
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 a safe level around 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.

When installing three parallel strings or fewer, 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 a 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. In addition, the optimizers limit the current at the PV module input. Therefore, no safety margin is needed when calculating maximum string current.