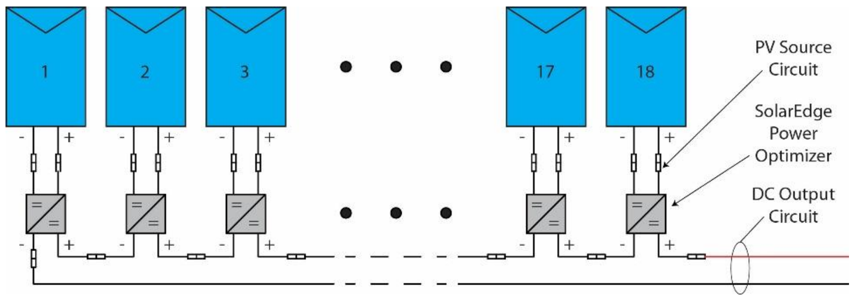
String Fusing Requirements in SolarEdge Systems, Technical Note

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 first 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.

NEC Requirements

For string inverter systems, NEC article 690.9 outlines the overcurrent protection requirements for photovoltaic source circuits. The intent is to provide overcurrent protection for circuits connected to more than one electrical source. All sources of current need to be considered: multiple series strings of PV modules connected in parallel to the inverter as well as the string inverter itself.

String Inverter Systems

String Inverters

Grounded installations with transformer-based inverters contain Ground Fault Detector Interrupt (GFDI) which detects ground current ≥1A. In these systems, fault current through the ground is limited to the GFDI limit (1A for inverters up to 25kVA).

Transformer-less inverters have a built-in Isolation Monitor Interrupter (IMI) circuit, which disconnects the inverter and ceases power export as soon as leakage current to ground is detected. However, some inverters may have a backfeed current >0A.

Strings

To prevent backfeed current from strings from flowing through other strings, diodes are needed. This is a costly solution that is rarely implemented. Typically, fuses are installed, but they don't prevent backfeed current, rather they eventually limit it in overcurrent fault situations. The only time a series fuse is exposed to overcurrent in these systems is when there is a low voltage (blind spot) fault on a grounded string conductor, and then a subsequent high voltage fault that short circuits the PV array. In that scenario, a current up to the short circuit current of the array flows through the string fuse which will clear with sufficient current.

PV Modules

PV modules have a fuse rating, so that if backfeed current greater than the fuse rating occurs, the fuse will blow and the backfeed current will be stopped.

SolarEdge Systems

SolarEdge Transformer-less Inverters

The UL1741 safety standard requires that utility interactive inverters be evaluated under abnormal operating conditions. One of the abnormal tests determines the amount of current the inverter contributes to a faulted circuit connected to the inverter input terminals. SolarEdge inverters have been verified to provide zero backfeed current to the input source circuits, and have a built-in Isolation Monitor Interrupter (IMI) circuit, which disconnects the inverter and ceases power export as soon as leakage current to ground is detected.

The IMI circuit, which is evaluated as part of the inverter's UL1741 compliance, disconnects fault current flow above 150mA within less than 40ms (and disconnects lower fault currents within 300ms). Since the SolarEdge systems are ungrounded, once the inverter is disconnected there is no current flow to ground faults.

Strings with SolarEdge Power Optimizers

SolarEdge power optimizers provide internal current limitation as described in NEC article 690.8(B)(2). The power optimizers limit current at the PV module source circuit input to 10 amps and limit current at the optimizer DC output circuit to 15 amps. The SolarEdge power optimizers have been certified to provide zero backfeed current to the PV source circuit, and zero backfeed current to the rest of the string – i.e. the string current could flow in only one direction.

PV Modules

The power optimizer backfeed limitation of 0A prevents any backfeed current from reaching the modules, regardless of module fuse rating.

Fault Scenarios – Three-String System

There are two fault scenarios to consider:

- Scenario 1 – A fault to ground in the middle of a string (fault #1 in the diagrams below)
- Scenario 2 – A fault in the wires at the end of a string (fault #2 in the diagrams below)

Scenario 1

String Inverter System

Backfeed current from the other strings flows to the fault. Since there are 3 strings connected to the inverter in parallel, the fault current from the other strings is 2 x Isc, and is not interrupted. If 2 x Isc is greater than the module fuse rating, NEC requires fusing on each of the string in order to prevent the risk of fire due to overcurrent.

SolarEdge System

The power optimizers in the faulted string prevent the backfeed current from the other strings from reaching the fault (see current direction in red in diagram below), and the current is limited to the 15A of the single faulted string. Since the optimizers are rated for this current, there is no fire hazard. Furthermore, the inverter IMI will detect the ground current and shut down within 40 or 300msec (depending on the current value). Since the SolarEdge system is ungrounded, as soon as the inverter is disconnected there is no connection to ground and therefore the current flow immediately stops.

Scenario 2

String Inverter System

Current from all strings flows to the fault. The fault current is 3 x Isc, and is not interrupted. If 3 x Isc is greater than the NEC permitted PV wire ampacity, NEC requires fusing on each of the string in order to prevent the risk of fire due to overcurrent.

SolarEdge System

Current from all strings flows to the fault. The fault current is 3 x 15A. The inverter detects the ground current with its built-in IMI circuit and disconnects the inverter in less than 40ms (well below typical[1] fuse clearing times of 5s and longer). Since the SolarEdge system is ungrounded, as soon as the inverter is disconnected there is no connection to ground and therefore the current flow immediately stops.

Since a total of 45A (3 x 15A) of current can flow on the final stage of the home-run cable continuously (Figure 2) the home-run cable ampacity in that section needs to be sufficient for this current. It is possible

[1] http://www.cooperindustries.com/content/dam/public/bussmann/Electrical/Resources/product-datasheets-a/Bus_Ele_DS_4203_PVS-R.pdf

to step up the conductor size after adding each power optimizer string since each section of the circuit need only be sized for the continuous current. The fault current duration is short enough to ignore any size increases due to the 45A fault current.

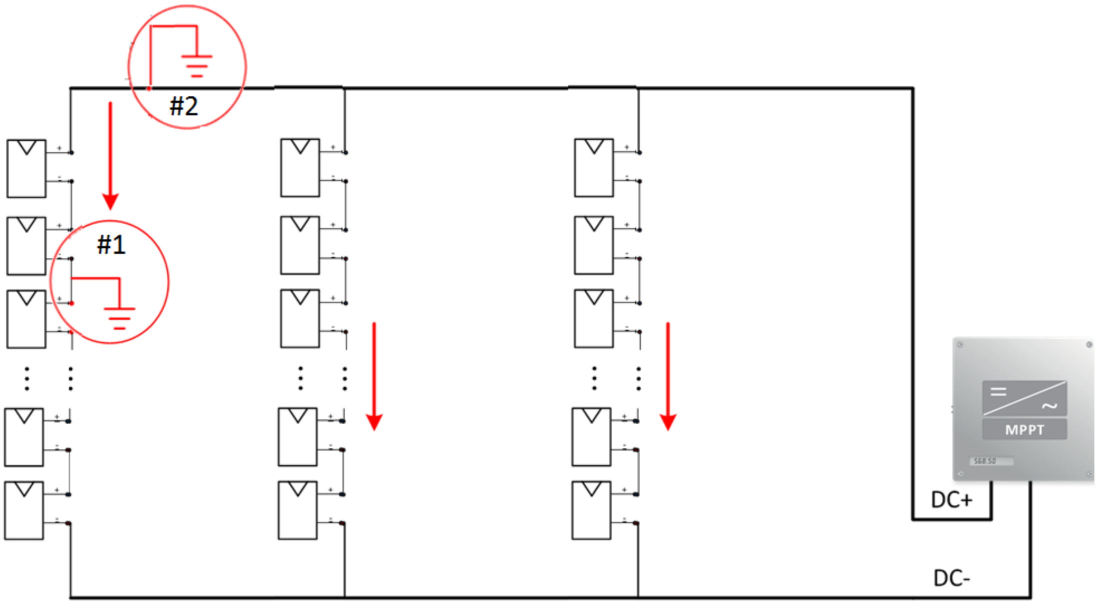


Figure 1 – Fault scenarios in a string inverter system

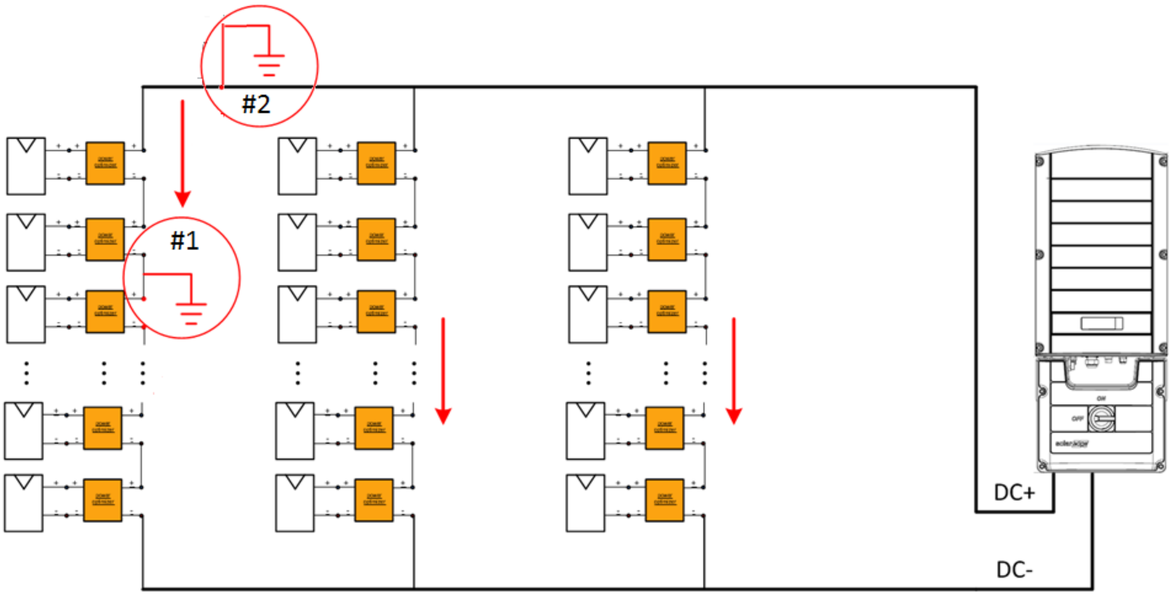


Figure 2 – Fault scenarios in a SolarEdge system