RE: Protection of SolarEdge Power Optimizer Circuits

To Whom It May Concern:

This letter provides an explanation of the National Electrical Code (NEC) compliance of the SolarEdge 1000Vdc fused combiner that has no main disconnect switch. Due to the unconventional nature of this new product, it is worth reviewing the requirements of the National Electrical Code (NEC) to verify the compliance of this device. Starting in the 2017 NEC, it has been permitted to use a non-load-break isolating device to isolate the fuses used on the dc side of PV systems. The 2008 NEC was the first version to specifically require that source circuit combiners be listed. The 2011 NEC had specific requirements for load-break switches for fuse servicing. Since most combiners over the past 15 years have had integral disconnects as part of their listing, the movement away from integral master disconnects for these devices is likely to generate questions of code compliance.

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INTRODUCTION OF THE ISOLATING DEVICE IN 690.15

The 2017 NEC included a major rewrite and reorganization of Article 690, Solar Photovoltaic Systems. As part of that rewrite, Part III, Disconnecting Means was heavily revised. This part was split into two categories, (1) 690.13 PV System Disconnecting Means, and, (2) 690.15 Disconnection of Photovoltaic Equipment. The SolarEdge DC Combiner falls under 690.15 and includes the fact that fuses require disconnection for servicing. The key issue is whether or not a non-load-break isolating device would be compliant to service the fuses. In the 2017 version of 690.15 in the NEC, the threshold current that isolating devices can be used is 30-amps. Therefore, if the circuit has a maximum circuit current no greater than 30 amps, an isolated switch is permitted to be used to isolate circuits on equipment. This does not mean that these switches can ever be opened under load. In fact, any switch that does not have sufficient load break capacity for an operating circuit must be clearly labeled, “do not disconnect under load”, or “not for current interrupting.”

Here is a review of each of the last three versions of 690.15 in the NEC:

2017 NEC:

"690.15 Disconnection of Photovoltaic Equipment. Isolating devices shall be provided to isolate PV modules, ac PV modules, fuses, dc-to-dc converters inverters, and charge controllers from all conductors that are not solidly grounded. Where the maximum circuit current is greater than 30 amperes for the output circuit of a dc combiner or the input circuit of a charge controller or inverter, an equipment disconnecting means shall be provided for isolation…."

A. Location. Isolating devices or equipment disconnecting means shall be installed in circuits connected to equipment at a location within the equipment, or within sight and within 3 m (10 ft) of the equipment. An equipment disconnecting means shall be permitted to be remote from the equipment where the equipment disconnecting means can be remotely operated from within 3 m (10 ft) of the equipment."

C. Isolating Device. An isolating device shall not be required to simultaneously disconnect all current-carrying conductors of a circuit. The isolating device shall be one of the following:

1. A connector meeting the requirements of 690.33 and listed and identified for use with specific equipment
2. A finger safe fuse holder
3. An isolating switch that requires a tool to open
4. An isolating device listed for the intended application

An isolating device shall be rated to open the maximum circuit current under load or be marked "Do Not Disconnect Under Load" or "Not for Current Interrupting."

2020 NEC:

"690.15 Disconnecting Means for Isolating Photovoltaic Equipment. Disconnecting means of the type required in 690.15(D) shall be provided to disconnect ac PV modules, fuses, dc-to-dc converters, inverters, and charge controllers from all conductors that are not solidly grounded.

B. Isolating Device. An isolating device shall not be required to have an interrupting rating. Where an isolating device is not rated for interrupting the circuit current, it shall be marked "Do Not Disconnect Under Load" or "Not for Current Interrupting." An isolating device shall not be required to simultaneously disconnect all current-carrying conductors of a circuit. The isolating device shall be one of the following:

1. A mating connector meeting the requirements of 690.33 and listed and identified for use with specific equipment
2. A finger-safe fuse holder
3. An isolating device that requires a tool to place the device in the open (off) position
4. An isolating device listed for the intended application

D. Type of Disconnecting Means. Where disconnects are required to isolate equipment, the disconnecting means shall be one of the following applicable types:

1. An equipment disconnecting means in accordance with 690.15(C) shall be required to isolate dc circuits with a maximum circuit current over 30 amperes.

2. An isolating device in accordance with 690.15(B) shall be permitted for circuits other than those covered by 690.15(D)(1)."

2023 NEC:

"690.15 Disconnecting Means for Isolating Photovoltaic Equipment. Disconnecting means of the type required in 690.15(A) shall be provided to disconnect ac PV modules, fuses, dc-to-dc converters, inverters, and charge controllers from all conductors that are not solidly grounded.

A. Type of Disconnecting Means. Where a disconnect is required to isolate equipment, the disconnecting means shall be one of the following:

1. An equipment disconnecting means in accordance with 690.15(C)
2. An isolating device as part of listed equipment where an interlock or similar means prevents the opening of the isolating device under load
3. For circuits with a maximum circuit current of 30 amperes or less, an isolating device in accordance with 690.15(B)

B. Isolating Device. An isolating device shall not be required to have an interrupting rating. Where an isolating device is not rated for interrupting the circuit current, it shall be marked "Do Not Disconnect Under Load" or "Not for Current Interrupting."
An isolating device shall not be required to simultaneously disconnect all current-carrying conductors of a circuit.

The isolating device shall be one of the following:

1. A mating connector meeting the requirements of 690.33 and listed and identified for use with specific equipment
2. A finger-safe fuse holder
3. An isolating device that requires a tool to place the device in the open (off) position
4. An isolating device listed for the intended application

C. Location and Control. Isolating devices or equipment disconnecting means shall comply with one or more of the following:

1. Located within the equipment
2. Located in sight from and readily accessible from the equipment for those to whom access is required
3. Lockable in accordance with 110.25
4. Provided with remote controls to activate the disconnecting means where the remote controls comply with one of the following:

   a. The disconnecting means and their controls are located within the same equipment.
   b. The disconnecting means is lockable in accordance with 110.25, and the location of the controls are marked on the disconnecting means."

While the organization of 690.15 has varied in the 2020 and 2023 NEC, the basic concepts are essentially unchanged. Therefore, the 2017, 2020, and 2023 versions of the NEC explicitly allow for circuits to be deenergized using an isolating device (non-load-break switch) as long as the maximum circuit current is below 30 amps. This does not relieve the need to be able to remove current from these circuits either by turning off the circuits or by interrupting the circuits where required at the inverter. Since this combiner produces a combined source circuit current well over 30 amps, the inverter is required to have an equipment disconnecting means that can be operated under load. As we will show later in this

document, the SolarEdge required procedure for servicing fuses in this combiner requires that the inverter dc disconnect be turned to the off position prior to testing and verifying that the finger-safe fuse holders are safe to open.

Figure 1 shows a typical SolarEdge three-phase commercial installation using this dc combiner. Since the SolarEdge inverter dc disconnect is lockable, the 2017, 2020, and 2023 NEC allow any distance between the inverter and the combiner box.

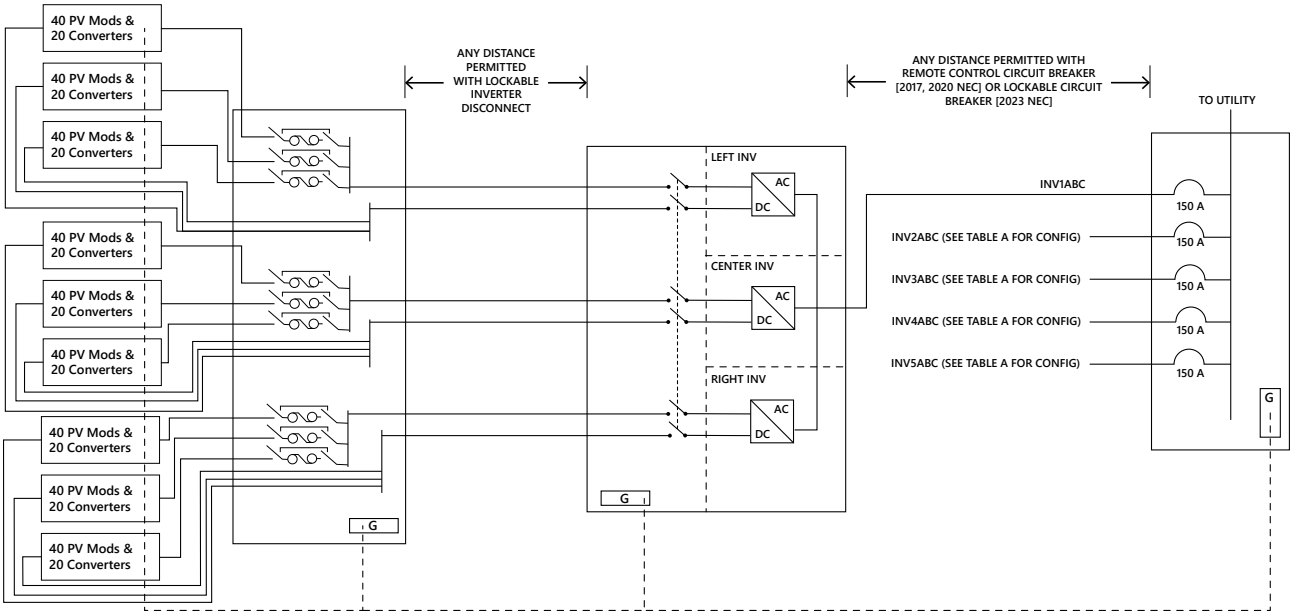

Figure 1: Typical Commercial SolarEdge Installation

SOLAREDGE FUSE SERVICING PROCEDURE

The SolarEdge architecture with the dc optimizers allows the dc converter circuit to power down to safe dc levels. Turning off the inverter stops normal dc current flow and brings the dc voltage down to a safe voltage (30Vdc or less). The inverter has a dc disconnect switch which is the dc equipment disconnecting means required for the dc side of the inverter (above 30 amps). Turning off this dc disconnect isolates the dc optimizers from inverter communications, placing the dc optimizers in safe mode, and prevents the inverter from restarting. The dc combiner finger-safe tilt-out fuse holders work as isolating devices for each of the fuses.

DC COMBINER OPERATING PROCEDURE

1. Locate the inverter associated with the dc combiner from the location provided on the label on the dc combiner box cover.
2. At the associated inverter, turn the dc disconnect switch to the “off” position to stop dc current and reduce the dc voltage to a safe level (30Vdc or less in 30 seconds or less).

3. Once the dc disconnect is turned off, place a locking device on the dc disconnect. If lock-out, tag-out procedures are required, place the appropriately filled out tag on the lock.
4. Proceed back to the associated dc combiner and check each circuit entering the dc combiner for dc current using a dc clamp-on ammeter. Verify that all circuit currents are zero.
5. Open the cover of the dc combiner and check that safe dc voltage (30Vdc or less) is present using the voltage probe test points in the dead front cover of the dc combiner.
6. Once all current is verified to be zero and all circuits are in safe dc voltage range, ONLY NOW are fuse holders permitted to be opened to test or replace fuses, or to fully isolate the PV array from the inverter.
7. Once the fuses are removed from the fuse holders, it is permissible to remove the dead front and access the conductor terminations or fuse holders.

REQUIRED LABELS ON THE DC COMBINER

- Label inside cover of dc combiner (PROVIDED BY MFG.)
  - Operating procedure for fuse servicing and basic circuit diagram
- Labels on dead front inside cover of dc combiner (PROVIDED BY MFG.)
  - DO NOT OPEN FUSE HOLDERS UNDER LOAD
  - TEST AND VERIFY ZERO CURRENT AND SAFE DC VOLTAGE PRIOR TO OPENING FUSE HOLDERS
  - Maximum current per circuit (30 amps) (PROVIDED BY MFG.)
- Label on outside cover of dc combiner (TO BE PROVIDED BY INSTALLER)
  - Inverter location or directory identification

Summary:

The SolarEdge DC Switchless Combiner is compliant with the 2017, 2020, and 2023 editions of the NEC. The SolarEdge operating procedure requires the inverter equipment disconnecting means to be opened and the circuits tested for zero current and safe voltage prior to opening the finger-safe fuse holders. Following these basic procedures is compliant with electrical safety standards and the requirements of the 2017, 2020, and 2023 NEC. Proper equipment marking, including field-applied marking on the combiner showing the location of the inverter to which the combiner is connected, is a basic requirement for compliance with the equipment safety standard and the NEC.

Sincerely,

Bill Brooks, PE
Principal, Brooks Engineering