Technical Note - Main Distribution Panel Considerations with an EV Charging Single Phase Inverter or StorEdge Single Phase Inverter

Version History

- Version 1.1, Dec. 2018 –
  - Corrected the Max PV formula
  - Added accompanying letter from Bill Brooks, PE
- Version 1.0, Oct. 2018 – Initial release

Introduction

The purpose of this document is to provide guidance on a few key questions or concerns some AHJs may have with regard to permitting and inspecting SolarEdge systems as they differ from typical installation conventions common to most PV inverters.

The concerns addressed can be highlighted as:

- The overcurrent protective device [OCPD] (circuit breaker) for the branch circuit between the main distribution panel [MDP] and the EV-Charging Inverter or StorEdge Inverter needs to be sized for the load rather than the generation potential since the maximum load can be double or more that of the maximum generation. While sizing the breaker to 125% of the PV inverter current rating is standard practice, it will not meet the load requirements of the integrated charger or backed-up loads panel.
- A concurrent consideration is to determine the maximum allowed PV current based on the busbar rating and service OCPD rating, since the busbar is permitted to support 120% of current from utility and other power sources. The maximum allowed PV current is often applied to the rating of the OCPD rather than output current rating of the inverter.
- The NEC includes a requirement that each source interconnection have a dedicated OCPD disconnection.
- Supply-side connection considerations of loads vs. sources.

This document applies to the following inverter products:

- SolarEdge EV Charging Single Phase Inverter
- SolarEdge StorEdge Inverter

NEC Requirements

For string inverter systems several articles in the NEC apply to the connection of PV circuits as “power production sources“. In this document, each section will be followed by the specific NEC sections referenced, listed by year of the code edition. Please reference applicable NEC edition of the code requirements which your local jurisdiction has adopted.

Accompanying this note is a letter written by Bill Brooks, Professional Engineer and Principal of Brooks Engineering; a lead contributor to NEC 690. All code-related discussions laid forth in this document were confirmed by Mr. Brooks as compliant with the applicable code section.

OCPD Selection

Generally speaking, the OCPD for any source or load will be sized to approximately 125% the max continuous current rating of each input or output circuit. As such, SolarEdge specifically sizes some inverter models for the max output current to align specifically with the recommended OCPD sizing (e.g. the 3.8kW inverter has a max continuous current of 16A, which multiplied by 125% aligns with a 20A breaker). The NEC requirement for busbar sizing bases the calculations on 125% of continuous current from the inverter, not on the circuit breaker rating. This means that an inverter with a 16-amp maximum current rating can be installed on any circuit breaker rated 20-amps up to the maximum overcurrent device rating of the inverter. The maximum overcurrent device rating for EV charging and StorEdge inverters is expressed in each device’s technical specifications.

EV Charging Inverter

As an integrated device (both generation and load) the SolarEdge EV Charging Inverter OCPD selection is dictated by the EV charger load current rather than the PV source current. The maximum generation current is determined and published as part of the device's current protection listing as covered by the UL1741 SA certification. Therefore, when selecting the correct OCPD, and corresponding conductor selection, the EV charger load current is the determining factor.

This product has the capability to adjust its maximum load current from the grid to support multiple maximum charging rates as is outlined in the EV Charging Single Phase Inverter Installation Guide. The allowable configurations are shown in Table 1 and allow the device to limit the maximum EV charging current from the grid to values no greater than 40A to keep the load on the utility service within its ratings based on the load calculations outlined in Article 220 of the NEC.

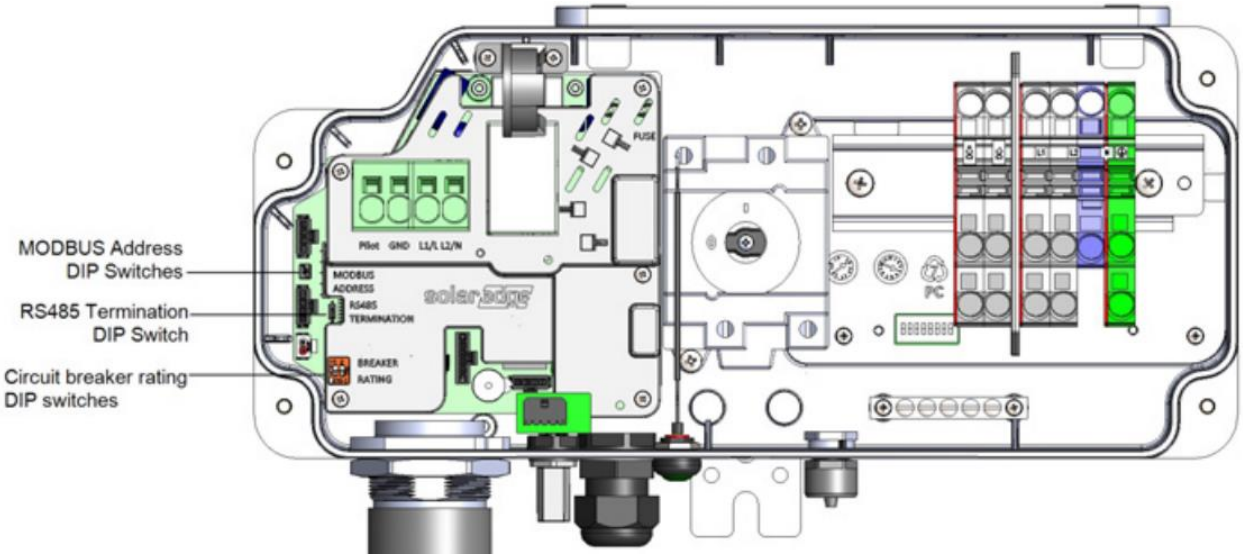

Table 1: Required Dip Switch Settings Based on Maximum Allowed Current and Breaker Ratings

Circuit Breaker Rating	Dip Switch Settings		Maximum Allowed AC Current from Grid
	1 (left)	2 (right)	
20A	OFF	OFF	16A
30A	ON	OFF	24A
40A	OFF	ON	32A
50A	ON	ON	40A

StorEdge Inverter

The 3.8kW StorEdge Inverter was specifically designed for installation on an 100A MDP as the inverter output current to the MDP is limited to 16A (see the *MDP Capability* section below). However, the maximum load on the backed-up loads service panel may reach 5kW (equivalent to 21A), so it is appropriate to size the OCPD to this device at 30A. Similar to the EV charging product, the connected circuit breaker size is based on the load current rather than the generation current.

Question & Answer

A common question or comment from a plan-checker or inspector might be *"Doesn't an inverter with a 16A output require a 20A breaker?*". To which the proper response is: "*The NEC* (see references below) *requires the MINIMUM size breaker be 125% of the output current from the inverter. However, in this case the current required by the load(s) necessitates a larger breaker.*" All four editions of the NEC below are consistent on this issue.

References:

- 2017 - 690.9(B)(1)
- 2014 - 690.9(B)(1)
- 2011 - 690.8(B)(1) (a)
- 2008 – 690.8(B)(1)

MDP Capability

A standard consideration when installing any distributed energy source or load circuit on the load side of the service disconnect is to calculate how much current the MDP of the service is capable of receiving and/or supplying. For the purposes of this section we will ignore load considerations as the specific guidance to be addressed is in reference to current supplied from multiple sources. This code consideration is generally referred to as the "120% rule". Simply stated, the sum of all sources of supply to a busbar or conductor, utility and other power sources, cannot exceed 120% of the busbar or conductor rating.

To determine the max PV current which can be added to a service, installers need to determine the MDP busbar and service OCPD ratings. An important clarification was added in the 2011 NEC to differentiate the rating of the breaker from the rating of the inverter. The specific case in the 2011 NEC was for inverters similar to the StorEdge product that includes energy storage.

2011 NEC 705.12(D)(2) EXCEPTION:

"EXCEPTION: WHERE THE PHOTOVOLTAIC SYSTEM HAS AN ENERGY STORAGE DEVICE TO ALLOW STAND-ALONE OPERATION OF LOADS, THE VALUE USED IN THE CALCULATION OF BUS OR CONDUCTOR LOADING SHALL BE 125 PERCENT OF THE RATED UTILITY-INTERACTIVE CURRENT FROM THE INVERTER INSTEAD OF THE RATING OF THE OVERCURRENT DEVICE BETWEEN THE INVERTER AND THE BUS OR CONDUCTOR."

This clarification was provided to direct users of the NEC away from a common mistake in previous versions of the NEC to use the rating of the OCPD connected to inverter output in the 120% calculation for storage-based PV systems. The 2014 edition of the NEC and onward simply changed the calculation from the size of the breaker to a calculation of 125% of the inverter's output current.

2014 705.12(D)(2)(3)(B)

"WHERE TWO SOURCES, ONE A UTILITY AND THE OTHER AN INVERTER, ARE LOCATED AT OPPOSITE ENDS OF A BUSBAR THAT CONTAINS LOADS, THE SUM OF 125 PERCENT OF THE INVERTER(S) OUTPUT CIRCUIT CURRENT AND THE RATING OF THE OVERCURRENT DEVICE PROTECTING THE BUSBAR SHALL NOT EXCEED 120 PERCENT OF THE AMPACITY OF THE BUSBAR."

EV Charging Inverter or StorEdge Inverter

The maximum inverter output current supplied to the MDP from each of these devices is the same; therefore they are not differentiated in reference to this topic.

The maximum allowable PV current supplied to the MDP is defined as 120% of the busbar rating, minus the main service breaker rating, divided by 125%.

$$Max\ PV\ [A] = \frac{Busbar\ Rating\ [A] x 120\% - Main\ Service\ Breaker\ Rating\ [A]}{125\%}$$

Question & Answer

The question or comment you might expect to get from a plan-checker or inspector regarding this topic might resemble "*Doesn't the "120% rule" say to use the sum of breaker values of the primary and secondary sources (grid and inverter) to calculate the Max PV inverter output current?*" The answer to which is: "*No, the applicable code* (see references below) *applies to determining the Max PV current, hence the current rating of the source is used in the 120% rule, not the breaker rating to which it is connected* (or as explained below)."

References:

- 2017 - 705.12(B)(2)(3)(b)
- 2014 - 705.12(D)(2)(3)(b)
- 2011 - 705.12(D)(2)(Exception)
    - The code explicitly mentions "energy storage device" in the exception, which can be interpreted to include an EV battery.
- 2008 - 705-12(D)(2)
    - There is no specific exception in the NEC 2008 code but confusion over this issue was the motivation for the exception in the 2011 edition. Since this was amended in the 2011 edition it is often possible to convince an AHJ to allow installation based on the 2011 exception as an alternative method [90.4]. Should your AHJ demand strict adherence, an option would be to downsize the MDP's OCPD from the grid, thereby reducing the sum of the combined breaker values. If the above options are not available, the only remaining options are to install a new service panel rated for the sum of the supply breakers or add a supply side connection with a properly rated panel.

Dedicated OCPD

Some concern has been raised regarding the requirement for a "Dedicated Overcurrent and Disconnect" for any Utility Interactive Inverter. Since these devices have multiple capabilities, a jurisdictional representative could perceive they somehow violate the code (see references below). The language cited in the references below was placed in the NEC to make it clear that power outlets or other loads were not tapped off the circuit conductors running to inverters. The language means that the circuits connected to the circuit breaker must be dedicated to the equipment to which it is connected. What is connected downstream of the listed device is regulated by 690.10 in the 2008, 2011, and 2014 editions of the NEC and Article 710 in the 2017 NEC.

EV Charging Inverter & StorEdge Inverter

Each of these inverters independently carries multiple UL Standard certifications, and both are single devices in a single enclosure. As such, their independent functions do not require independent OCPDs.

Question & Answer

The question or comment you might expect to get from a plan checker or inspector here could be something like "*Doesn't the inverter require its own OCPD, independent of any potential loads?*" The answer to which is: "*No, these devices carry the appropriate certifications for their multiple functions. The rule is there to ensure load circuits or outlets are not connected between the circuit breaker and the listed multifunction equipment.*"

References:

- 2017 - 705.12 (B) (1)
- 2014 - 705.12 (D) (1)
- 2011 - 705.12 (D) (1)
- 2008 - 705.12 (D) (1)

Supply-Side Connection Load Consideration

If either of these inverters are installed on the supply-side of the service disconnecting means, the circuit breaker or disconnect becomes another service disconnect for the building. The issue that adding another service disconnect presents for a project is if the building already has six service disconnects. Since the NEC only allows a total of six service disconnects for a service disconnecting means, the service equipment would have to be upgraded to consolidate the existing disconnects and the new disconnect to keep the total number of disconnects within the six allowed.

EV Charging Inverter & StorEdge Inverter

Each of these devices operates as a load as well as a source, therefore the load on the service must be calculated according to Article 220 to determine if the existing service can handle the increased load, or if a service upgrade is necessary.

Question

Specifically, asking the question "*Is the service sufficiently sized to support the rated MDP current as well as the additional maximum load we could be adding with this device?*" The answer to which needs to be confirmed to be: "The load calculations from Article 220 show that the service is sufficiently sized for this additional load." If it is not a service upgrade is necessary.

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RE: SolarEdge Technical Note Regarding the Installation of the EV Charging and StorEdge Inverters

To Whom It May Concern:

This letter provides an explanation of the specific aspects of the installation of the SolarEdge EV charging and StorEdge inverters in compliance with the National Electrical Code (NEC). A key issue that this letter specifically addresses is related to the installation of these inverters on small residential 100-amp services. Both of these inverters have models that are limited to an output source current of only 16-amps of ac output power. With no other capabilities, a 20-amp circuit breaker would be the minimum size interconnecting overcurrent device. However, the EV charger product is capable of drawing up to 40-amps from the utility source and the StorEdge inverter is capable of drawing 21-amps from the utility source. Since the load draw is greater than the PV output current in both cases, the interconnecting overcurrent device is required to be greater than the minimum breaker size.

Since many authorities having jurisdiction (AHJs) have not been exposed to this type of equipment in recent years, SolarEdge proactively developed a technical bulletin to explain the proper installation of this equipment. Given the fact that many AHJs have learned about "the 120% rule" as it is often termed, there is a common misinterpretation of this rule in Article 705. Since the original version of the rule dating back to 1987 related to the size of the interconnecting circuit breaker, it is easy to see how a larger breaker size could cause AHJs to believe that the inverter output is greater than the 120% rule would permit.

The three most common editions of the NEC currently being enforced throughout the United States include the 2017, 2014, and the 2011. All three of these versions provide details on how to properly install the EV charger and StorEdge inverters connected to distribution panels in buildings. The key limitation related to the 120% rule for busbars in panelboards is the output of the PV inverter, not the load presented by the EV charger or energy storage system. For instance, the 120% rule, as stated in all three editions, would allow a 100-amp main service panel to have an interconnected PV breaker of 50-amps provided the PV output was no more than 16-amps. The text from the three NEC editions are presented below for direct reference.

2011 NEC:
705.12(D)(2) *EXCEPTION:*

(2) Bus or Conductor Rating. The sum of the ampere ratings of overcurrent devices in circuits supplying power to a busbar or conductor shall not exceed 120 percent of the rating of the busbar or conductor.

"Exception: where the photovoltaic system has an energy storage device to allow stand-alone operation of loads, the value used in the calculation of bus or conductor loading shall be 125 percent of the rated utility-interactive current from the inverter instead of the rating of the overcurrent device between the inverter and the bus or conductor."

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2014 NEC:
705.12(D)(2)(3)(b)

"(b) Where two sources, one a utility and the other an inverter, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the inverter(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar."

2017 NEC:
705.12(B)(2)(3)(b)

"(b) Where two sources, one a primary power source and the other another power source, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar."

Given the potential misinterpretations related to this subject, it became necessary for the NEC to explicitly differentiate the output of the inverter from size of the interconnecting breaker. The first edition to make this explicit differentiation was the 2011 NEC edition with the exception shown above. While this exception does not specifically address the EV charger product, it does explicitly address the StorEdge product. Since the overcurrent device sizing issue related to the 120% rule is identical with the EV charger and StorEdge inverters, they should both be permitted to use the 705.12(D)(2) exception in areas enforcing the 2011 NEC edition. Since the 2014 and 2017 NEC editions base all calculations on the output current of the inverter, it is explicitly clear that both inverters would be permitted to be connected to 100-amp service equipment. This also further clarifies that the 2011 and prior editions were never intended to limit load current on these interconnecting overcurrent devices when applying the 120% rule.

The key takeaway from this discussion is that sizing requirement for the 120% rule is the output current of the inverter multiplied by 125% and not the rating of the circuit breaker since the maximum rating of the circuit breaker connected to the inverter is not related the output of the inverter. The minimum rating of circuit breaker connected to the output of the inverter cannot be less than the output of the inverter [690.8(B)(1)(a) in 2011, and 690.9(B) in 2014 and 2017]. However, the maximum rating of the overcurrent device connected to the output of the inverter is established by the product listing, not the output current rating of the inverter.

There are two other issues that this SolarEdge technical bulletin address related to the installation of these inverters. One issue is the statement in 705.12 that all interconnections be made at a "dedicated overcurrent device". Some AHJs and contractors may interpret this requirement as preventing the installation of inverters such as the EV charger and StorEdge products since these products include both power sources and loads. The specific issue that this requirement for a dedicated device exists is to prevent installers from putting undefined loads on the load side of the overcurrent device while sizing the conductors based on the size of the overcurrent device. The additional current provided by the PV inverter could overcurrent downstream conductors because the PV inverter is a source in addition to the interconnecting breaker. Products such as the EV charger and StorEdge inverters have been certified for a specific overcurrent device size and conductor size based on the limitations of their current ratings which address all possible load scenarios. These products, which contain both sources and loads, are interconnected to other power sources through a single dedicated overcurrent device. Both SolarEdge products discussed in this technical bulletin are compliant with the dedicated device requirement.

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The last issue discussed in the SolarEdge technical bulletin is the connection of these devices on the utility side of all other service disconnecting means for a building. A PV source that does not supply loads to other equipment is not considered a service and is permitted to be connected on the supply side of the service disconnecting means as stated in 230.82(6) of the NEC. Since both of the devices discussed in this letter include loads, their interconnecting disconnecting means are service disconnects and would be required to meet the requirements of any service disconnect added to an existing service.

Summary:
The SolarEdge EV charger and StorEdge inverters present capabilities that are new to many installers and AHJs. It is important to understand how these products are properly installed so that they can function as they were intended and in accordance with their product certifications. Misinterpretations of the required busbar sizing in the NEC could lead AHJs to requiring service panel upgrades where none is required. Properly understanding the relevant electrical code sections is key to proper enforcement. The 120% rule was intended to place a simple, practical limit on the output of power sources connected to panelboards on the load side of service disconnecting means. The 120% rule is not related to sizing of load circuits which is one of the reasons why the NEC changed the criteria for sizing in 705.12 to the source output current rather than the overcurrent device size.

Sincerely,

Bill Brooks, PE
Principal, Brooks Engineering