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POWER BY DESIGN

Considerations when Specifying PV System Output Equipment

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AC EQUIPMENT SPECIFICATIONS: WHAT SHOULD WE LOOK AT?

When it comes to choosing the equipment used to interconnect the combined output of a PV system to the utility grid, it is important to ensure that the equipment is sized in order to withstand the full amount of power capable of being delivered by the PV system. Between the PV system's inverters and the point of interconnection with the utility, there are often found potentially 4 types of devices: PV AC combiner panels, AC disconnects, PV meters, and transformers. Of course, connecting all of this equipment together is a set (or multiple sets) of output feeder conductors, which will deliver the power from the AC combiner panel to the conductors or busbars located within the utility service/distribution equipment. Each of these pieces of equipment must be sized to carry both the full output current of the PV system, as well as be rated to withstand the maximum voltage output level, in order to be both NEC compliant and safe to operate.

MINIMUM REQUIRED VOLTAGE RATINGS

First, we'll take a look at voltage ratings. Sizing equipment for the proper voltage level is simple. The NEC's short and plain-spoken approach to voltage ratings is covered in a few short lines of Article 110.4:

> *Throughout the Code, the voltage considered shall be that at which the circuit operates. The voltage rating of electrical equipment shall not be less than the nominal voltage of a circuit to which it is connected.*

For this definition, nominal voltage will be taken as the line-line voltage level of a particular grid type; for example, in a 120/208V Wye grid, the nominal voltage would be 208V.

Any piece of equipment will have a maximum voltage rating called out in its list of specifications. For AC equipment, this value is typically 240V, 480V, or 600V. For PV systems with an output configuration of 120/208V Wye, or 240V Delta (to name a few), we can choose a piece of equipment that has a voltage rating anywhere between 240V and 600V. It's not very common to find AC equipment rated for only 208V; this is because 240V grid types are by and far the more common of the two, and the voltage rating we are dealing with is a *maximum* voltage rating. There is no rule against using a piece of equipment rated for a higher voltage rating than the system it is being used for, only the opposite (as detailed in 110.4). That being said, transformers are a special case in that they must exactly match their voltage ratings with the nominal voltage of the circuit on either side, since matching the rating of the transformer to each grid type is imperative to the proper operation of the system. For example, it is not permissible to connect a transformer with a 240V rating to a 208V grid type.

AMPACITY OF EQUIPMENT AND CONDUCTORS

Next, we'll take a look at the required current ratings of the equipment. There are two major classifications of current that we are going to consider when designing interconnection equipment: nominal current and fault (short-circuit) current.

When sizing for nominal current, let's first examine NEC 690.8 and 690.9, which are code sections regarding conductor ampacity and overcurrent protection sizing of PV source and inverter output circuits. According to 690.8(A), the calculation of the maximum circuit current shall be performed as stated for each portion of the PV system, from the modules' output circuits all the way to the combined inverter output circuit. 690.8(A)(3) states that, for inverter output circuits, *the maximum current shall be the inverter continuous output current rating.*

Secondly, the output conductor ampacity must be sized according to 690.8(B), which states:

> *PV system currents shall be considered to be continuous. Circuit conductors shall be sized to carry not less than the larger of 690.8(B)(1) or (2):*
>
> *(a) One hundred and twenty-five percent of the maximum currents calculated in 690.8(A) before the application of adjustment and correction factors.*
>
> *(b) The maximum currents calculated in 690.8(A) after the application of adjustment and correction factors.*

In the case of the combined inverter output circuit, this means that we must multiply the sum of the combined inverter outputs by an additional factor of 1.25 for continuous use (the NEC definition of which is *where the maximum current is expected to continue for 3 hours or more,* and PV systems are expected to operate anywhere from 6-8 hours per day).

This calculation also counts for busbars and terminal ratings as much as it counts for circuit conductors. <u>Any and all</u> equipment between the combined inverter output and the point of interconnection must have an ampacity greater than or equal to the maximum current calculated in 690.8(A) and 690.8(B).

Furthermore, the informational note for 690.8(A)(3) in the 2014 edition of the NEC states:

> *Both stand-alone and utility-interactive inverters are power-limited devices. Output circuits connected to these devices are sized on the continuous-rated outputs of these devices and are not based on load calculations or reduced-size PV arrays or battery banks.*

This means that, no matter what size PV array is connected to the DC input of the inverter, the inverter's continuous output rating must still be used to size the output circuit conductors and/or busbars, as well as all equipment upstream. The NEC does not support calculations based on module efficiency, module PTC rating, or other production-oriented calculations.

While these calculations may provide a better understanding/estimate of the PV system's output, they are not to be used to size the PV system output conductors and overcurrent protection, and the NEC should be the authority in sizing circuits and their protection methods.

NOMINAL VS. FAULT (SHORT-CIRCUIT) CURRENT

Now that we've covered nominal current, let's consider fault current. As with any power-generating device, PV inverters are capable of producing some amount of short-circuit (sometimes called interrupting) current in the event of a fault somewhere in the system. This fault current, however, is much lower in magnitude than the utility's available fault current, simply due to the technological differences between the utility grid's primary sources of energy (coal/gas/steam powered turbine generators) and your standard, run-of-the-mill PV grid-interactive inverter. We won't delve too deeply into the how's and why's in this document, but in short, a turbine generator-powered utility grid is capable of delivering much more current in the event of a fault than a PV inverter is, on the order of magnitude of 10 to 20 times more.

Just as with a nominal current rating, every piece of AC equipment also has a stated maximum short-circuit current rating, which is the amount of current that piece of equipment can withstand before it physically breaks down and can no longer operate as intended. For example, a circuit breaker may be rated for 50A nominal, and 22,000A short-circuit. This means that from 0A to 50A, the breaker will remain closed. From 50A to 22,000A, the breaker will trip open at a rate consistent with its time-delay curve. Above 22,000A, the breaker will physically fail due to the large amount of energy flowing through it, which can result in anything from the breaker's connectors becoming fused and incapable of opening the circuit, to the breaker being vaporized and causing physical harm to anyone standing too close.

How do we determine the minimum required fault current rating of a piece of AC equipment? In almost every case, a comprehensive system fault analysis will have to be performed by a knowledgeable professional engineer in order to accurately calculate the fault current at every point in the system. This is often referred to as the point-to-point method. Once the point-to-point method has been employed using the known available fault current from the utility and the PV generating sources, the AC equipment can be sized to withstand the calculated maximum fault current values in the system.

By properly sizing all equipment between the final combined output of the PV system and the utility point of interconnection, we are ensuring full compliance with the NEC, and preventing the creation of unsafe operating conditions for the equipment and anyone servicing them.

For questions or comments about the content of this guide, please contact:
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