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Solar PV Engineering and Installation Corrections

QUESTION #20

Original question:
You are working on a jobsite and the wrong inverter was sent, because the old inverter was thought to be less safe and less efficient by the business owner. What must you do to make sure that the new ungrounded inverter is installed correctly when adapting the plan from the grounded inverter?

A. Switch to a larger grounding electrode conductor.
B. Not use 90°C rated USE-2 for your source circuits on the roof outside of conduit.
C. Tap the transformer on the ungrounded inverter.
D. Switch the white wire from the negative to the positive.

QUESTION 20 REVISED:
You are replacing an inverter that was installed in 2008 and it was called a grounded inverter at that time. There is white electrical tape marking the negative USE-2 wire. What is the best solution when replacing this inverter with a typical modern "non-isolated" functionally grounded inverter?

A. Switch to larger grounding electrode conductor
B. Rewire the dc disconnect to open up positive and negative
C. Not use 90°C rated USE-2 for your source circuits on the roof outside of conduit.
D. Switch the white wire from positive to negative

Correct answer B

In 2008, most inverters were known as grounded inverters, which I now call fuse grounded inverters. You would have trouble finding one today. These inverters were installed using earlier versions of the NEC. In versions of the 2014 NEC and earlier, we would have had to have a white marked or colored grounded conductor, which was usually the negative.

The best way to replace this inverter, would be by taking the white tape off of the negative and opening the disconnect on the negative and the positive. When this type of inverter was installed, we did not open the disconnect on the grounded conductor.

QUESTION #52

There are 15 PV source circuits and an equipment grounding conductor on a rooftop in sunlight in a circular raceway, which is elevated 3" above the roof going from the array to a combiner 22 feet away in a location with a constant breeze keeping the conduit cool. The ASHRAE 2% average high design temperature is 35C. The PV source circuits are 12 AWG THWN-2 and the ground wire is 12 AWG THWN-2. The terminals in the combiner box are rated for 75C. What is the maximum Isc for modules used in this system?

A. 10.35A
B. 7A
C. 16A
D. 24A

QUESTION 52 EXPLANATION REVISED: HIGHLIGHTED ARE THE CHANGES

Explanation: There are a few steps that we have to do here and first and easiest is to follow 690.8(A)(1) and 690.8(B)(1) by taking the 12AWG copper terminal temperature ampacity in the 75°C column of Table 310.16 (2017 NEC 310.15(B)(16)), which is 25A as seen in the table below:

Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18*	–	–	14	–	–	–	–
16*	–	–	18	–	–	–	–
14*	15	20	25	–	–	–	–
12*	20	25	30	15	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	35	40	45	8

Next, we can divide 25A by 1.56, which equals: 16.0A, so for this branch of the wire sizing family tree, we could have a PV module with an ampacity of up to 16.0A.

The next thing we are going to do is to reverse engineer the conditions of use (adjustment and correction factors) method we see in 690.8(B)(2). Here we are going to use the 90°C column of Table 310.16 for 12 AWG (not the terminals this time) and we are also not going to have the extra 125% for "required ampacity for continuous current" this time.

Big change here when going from the 2014 to the 2017 NEC and beyond, is that we no longer have to derate for conduit over a rooftop in sunlight (unless the conduit is ⅞ of an inch or less, which is not recommended). So, now **we get to ignore the raceway being 3" over the roof. This was formerly known as table 310.15(B)(3)(c) Raceways and Cables Exposed to Sunlight on Rooftops and we no longer use it.**

Since we have 15 PV source circuits (positives and negatives) in conduit, then we have 30 current carrying conductors in a raceway that we have to derate for using Table 310.15(C)(1), which is formerly known as Table 310.15(B)(3)(a) in the 2017 NEC, which was just a name change.

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

* Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be simultaneously energized.

As we can see in the table above, with 30 current carrying conductors (equipment grounding conductor does not carry current), we can carry 45% of the current we could have carried if there were 3 or less conductors in conduit, so the derating factor for 45% is **0.45**, which is significant!

The other derating factor we have is for the ambient temperature being over 30°C and we look to table 310.15(B)(1), which was 310.15(B)(2)(a) in previous to 2020 versions of the NEC, which was just a name change.

We go by a 35°C design temperature from the question.

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)				
For ambient temperatures other than 30°C (86°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.				
Ambient Temperature (°C)	**Temperature Rating of Conductor**			**Ambient Temperature (°F)**
	60°C	**75°C**	**90°C**	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158

So our derating factor here is only 0.96, but then we can multiply 0.96 by 0.45 to get our total derating factor of 0.432.

To get our rated current, we need to take our 12 AWG ampacity of 30A in the 90°C column of 310.16.

Derated ampacity of the conductor here is then 30A x 0.432 = 12.96A

Since we also have to multiply Isc by 1.25 to get our rated current then, we can calculate backwards this equation:

Isc x 1.25 = derated ampacity = 12.96A

Now to solve for Isc, divide both sides by 1.25 (same as multiplying by 0.8)

Isc = 12.96 / 1.25 = 10.4A

Comparing the two checks, we get 16A and 10.4A, so we use the more conservative number here, which is 10.4A.

Discussion: This is a complex and difficult question to answer and may be more difficult than anything you see on the NABCEP Certification exams, however something like this was once on a certification exam. The answer here would have been different if based on the 2014 NEC, but will be the same for subsequent versions due to the removal of Table 310.15(B)(3)(c). Remember that you only need to use the terminal temperature check for the first check where you use the extra 125% for required ampacity for continuous current. You can see the huge derating taking place for so many conductors in conduit, so in that case, you could just skip the 156% step, since it is obvious that with 30 current carrying conductors in conduit, you are going to have a lot of derating. If I were taking a NABCEP exam, I would skip this question, take an educated guess, flag it (which the platform allows you to do) and save it for the end, so I do not run out of time for the faster to answer questions. Or if I was well practiced up, I would just do a bunch of shortcuts in my head and look up 90C ampacity of 12 AWG wire, which is 30A, in 310.16 and divide it by (0.96 x 0.45 x 0.8).

Changes in wire sizing table names from 2017 NEC and earlier to 2020 NEC and later:

310.15(B)(16) = 310.16
310.15(B)(17) = 310.17
310.15(B)(2)(a) = 310.(B)(1)
310.15(B)(3)(c) = 310.15(C)(1)