L4 Quiz Key: Solar Electrical Safety

1) NFPA 70E provides guidance for which of the following?
a) Electrical System Design
b) Roof Safety and Worker protection
c) Electrical Safety in the Workplace
d) PV Installation Best Practices

Electrical Safety in the Workplace
Explanation
NFPA 70E - Standard for Electrical Safety in the Workplace, from the National Fire Protection Association, helps employers and workers reduce the hazards that workers are exposed to during electrical work. Its recommendations are in-line with those from OSHA and consistent with those in NFPA 70, the National Electrical Code (NEC).

2) According to NFPA 70E, employers have the responsibility to do which of the following if employees are working on electrical systems? (**choose three**)
a) Establish lockout/tagout (LOTO) procedures
b) Provide equipment necessary to execute LOTO
c) Meet employee LOTO health insurance requirements
d) Adequately train employees to design electrical systems
e) Provide LOTO training to employees

Establish lockout/tagout (LOTO) procedures, Provide equipment necessary to execute LOTO, Provide LOTO training to employees
Explanation
NFPA Article 120 provides the guidance on how to comply with OSHA 29 CFR Part 1910.147. Employers are required to develop, implement, and enforce lockout/tagout programs, provide the necessary equipment to execute the LOTO procedures, and 'provide effective training as mandated for all employees covered by the standard.'

3) On a grid-direct residential PV installation site (no energy storage), what **two** power sources will always be present?
a) Wind generator
b) Fossil fuel generator
c) Utility grid
d) PV array

Utility grid, PV array
Explanation
AC electricity is supplied by the utility grid and must be appropriately isolated from equipment being worked on using LOTO procedures. The worker is also exposed to DC electricity, from the PV modules, and they must also isolate DC electricity from the PV

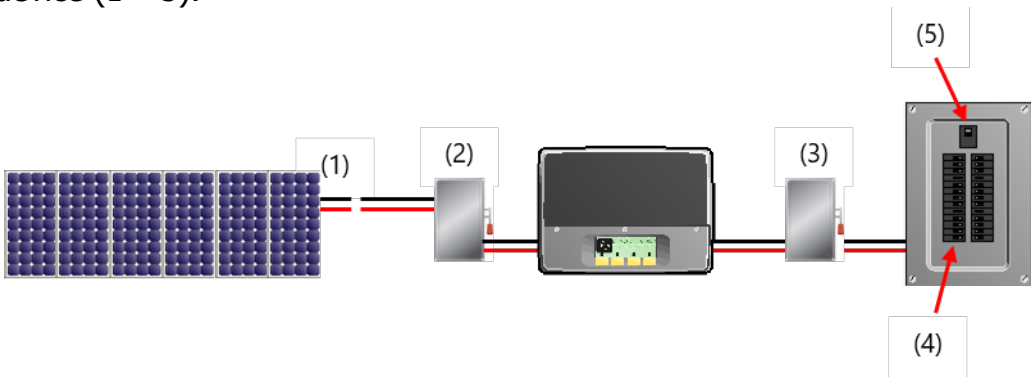
modules. Remember, any time the PV modules are exposed to sunlight, they will produce voltage. Residential PV systems are allowed by the National Electrical Code (NEC) to have a maximum voltage of 600 volts.

4) A residential home has an existing multimode PV system (utility grid-connected with batteries). The system also includes a back-up generator. The workers will be installing an additional 4kW PV array. Which **five** sources of electricity must the worker identify and ensure an electrically safe work area?

a) Utility grid
b) Battery bank
c) Back-up generator
d) Wind generator
e) Existing PV array
f) New PV array

Utility grid, Battery bank, Back-up generator, Existing PV array, New PV array
Explanation
For this particular system, along with the utility grid, the home has an existing PV array, battery bank, and back-up generator. The new PV array being installed is another source of electricity that must be isolated as it is being installed. No worker should be exposed to energized equipment or circuits during the installation, and appropriate electrical PPE must be used when testing and/or commissioning the system.

5) In the PV system depicted, use the list below to identify locations for each lock-out/tag-out device (1 – 5).



a) DC Disconnect — 1) ___
b) PV source circuit (home runs) — 2) ___
c) Inverter output circuit breaker — 3) ___
d) Main circuit breaker — 4) ___
e) AC Disconnect — 5) ___

1) PV Source circuit (home runs), 2) DC Disconnect, 3) AC Disconnect, 4) Inverter output circuit breaker, 5) Main circuit breaker
Explanation
From left to right in the diagram, starting with the PV array: 1) PV source circuit conductors leave the array and pass through a 2) DC disconnect, which would be installed next to and/or integrated within the inverter. Moving to the right, the inverter output circuit passes

through the 3) AC disconnect, on its way to the main AC service panel, where the 4) inverter circuit breaker is located. Lastly, 5) is the main circuit breaker associated with the electrical panel. Workers should always be aware of how many sources of electricity are on a site, and familiarize themselves with all disconnecting means and isolating devices. Also, workers should be comfortable reading electrical drawings, and understand how, where, and when to eliminate the hazards to ensure a safe work environment.

Using a PV module with the following parameters, answer questions 6) and 7).

	STC Specification
Voc	**42.5**
Vmp	**34.4**
Imp	**8**
Isc	**8.8**
Pmax	**275**

6) What is the expected open-circuit voltage for a PV system with one PV source circuit of 13 modules in series, operating under standard test conditions (STC)?

a) 42.5 Vdc
b) 552.5 Vdc
c) 240 Vac
d) 600 Vdc
e) 447.2 Vdc

552.5 Vdc

Explanation

To calculate the expected open-circuit voltage at STC for this PV source circuit, we multiply the PV module specified open-circuit voltage (Voc) by the number of modules connected in series. In this case:

Module Voc = 42.5 V
Number of modules in series = 13
Voc of the source circuit = module Voc x # of modules in series
= 42.5 V x 13
*= **552.5 V***

Remember, when connecting modules in series, the voltage adds and the current (amps) stays the same. We do not use Vmp for our calculation because the circuit is open and not in operation.

7) For a PV system with two source circuits of 13 modules in series, what is the expected maximum power current (Imp) and maximum power voltage (Vmp) of the PV output circuit, after the source circuits are wired in parallel?

a) 8 amps, 447.2 volts
b) 16 amps, 447.2 volts
c) 8.8 amps, 552.5 volts
d) 17.6 amps, 42.5 volts

16 amps, 447.2 volts

Explanation

There are two components to this question:

1. *Determine the expected maximum power voltage, or Vmp, and*
2. *Calculate expected maximum power current, or Imp.*

First, we calculate the expected maximum power voltage by multiplying the module Vmp by the number of modules in the PV source circuit. In this case:

Module Vmp = 34.4 V
Number of modules in series = 13
Vmp of the source circuits = module Vmp x # of modules in series
= 34.4 V x 13
= 447.2 V

This question asks for the maximum power voltage (Vmp), not the open-circuit voltage (Voc). Vmp is the value used when the system is operating; Voc is the value used for a system that is turned off (open circuit).

Now that we have calculated the voltage, we can determine the expected maximum power current(Imp) of the combined strings, or PV output circuit. First, we must identify the number of PV source circuits that are wired in parallel. In this case, there are two circuits in parallel, which means that each circuit will contribute its own Imp. Remember, when PV source circuits are wired in parallel, the current (amps) is additive and the voltage stays the same. In this case, the maximum power current of the PV output circuit is:

Module Imp = 8 A
Number of PV source circuits in parallel = 2
Combined maximum power current = Module Imp x # of PV source circuits in parallel
= 8 A x 2
= 16 A

8) PV technicians should only work on energized circuits when (**choose three**):
a) Testing for PV array voltage
b) Wiring PV modules in parallel
c) Commissioning the PV system
d) Explaining to the homeowner how to operate the PV system
e) Troubleshooting the PV system
f) Wiring the inverter output circuit to the utility grid
g) Wiring PV modules in series

Testing for PV array voltage, Commissioning the PV system, Troubleshooting the PV system

Explanation

The only time workers on a PV site should be exposed to live electrical circuits is when testing, commissioning, or troubleshooting the PV system. Live circuits should NEVER be worked on during the PV installation. All electrical work should be performed by a qualified person. All hazards must be identified and eliminated or mitigated. Use LOTO procedures and appropriate PPE. Know the proper safety procedures and methods for the task and obtain appropriate safety training!

9) When using a meter to test PV array voltage of a residential grid-direct system, a worker should wear appropriate PPE, including which **one** of the following?
a) Steel toe boots
b) Electrically insulated gloves
c) Hard hat
d) Kevlar pants

Electrically insulated gloves

Explanation

While performing any type of voltage testing, a worker should wear the appropriately-rated electrically insulated gloves. The NEC limits PV system voltage on one- and two-family dwellings (our homes) to 600 volts, so the electrical gloves must AT MINIMUM be rated for 600 VDC if working on a residential system.

10) A series arc-fault in a PV system can be caused by which of the following? (choose three)
a) Loose wire terminations
b) Low voltage
c) Manufacturer defects within the PV module
d) Loose PV module quick connectors
e) Extreme irradiance
f) Extreme temperature

Loose wire terminations, Manufacturer defects within the PV module, Loose PV module quick connectors

Explanation

A series arc-fault occurs when a high-resistance point occurs in a current-carrying circuit. The connection loses good continuity, but the flow of current isn't stopped – rather it arcs across the failure point, generating enormous amounts of heat very quickly. Because the current in the circuit is not different than normal, overcurrent protection devices don't help,

nor does ground-fault protection, since the fault isn't to ground. As a result, undetected arc-faults are very likely to cause a fire.

11) PV circuits inside a building must be in a _____ raceway from point of building penetration to the first readily accessible disconnecting means.

a) PVC
b) PV
c) Metal
d) Schedule 80
e) Disconnecting

Metal

Explanation

Because DC PV circuits are energized whenever modules are exposed to sunlight, extra precautions are required to protect these circuits from damage, and to provide a path to ground. The NEC requires a metal raceway (such as EMT or FMC) or metal clad cable (MC) for DC PV circuits inside a building, prior to the first readily accessible disconnect. It is a good idea to provide this additional level of extra protection for all DC PV circuits anywhere inside a building.

12) True or False: Short circuiting a battery bank is not a safety hazard if operating at less than 50V.

False

Explanation

Regardless of the voltage potential, short-circuiting a battery is one of the most dangerous things that could be done when working with batteries! Batteries hold a significant amount of energy, and when short-circuited they will instantly release all of the stored energy. Hazards can include an arc-flash, fire and/or explosions, and the release of dangerous chemicals. Proper PPE must be worn by any technician who is working on or near batteries. And, of course, this person must be qualified and aware of the hazards presented by batteries.

13) Electric shock risk and severity depend on a variety of factors. Choose **four** from the list below.

a) Voltage
b) Current
c) Path of current through the body
d) Time of day
e) Duration of current through the body
f) Height of worker

Voltage, Current, Path of current through the body, Duration of current through the body

Explanation

The severity of an electrical hazard depends greatly on the following:

1. *the electrical potential, or **voltage**, of the circuit or equipment that has been contacted, and*

2. *the amount, path, and duration of* ***current*** *that passes through the body.*

A very small amount of current through the body can cause serious injury or death.

14) A worker who has experienced an electric shock may experience:

a) Electrical burns
b) Heart attack or irregular heartbeat
c) Headaches
d) Problems with breathing, swallowing, vision, hearing
e) Loss of consciousness
f) All of the above

All of the above

Explanation

After an electric shock, a person could experience any of the above, not to mention death. Please be safe when working on Solar PV and any electrical system. Obtain appropriate training, become a qualified person, and understand the hazards – and how to eliminate or mitigate them – before performing work. Always wear the proper personal protective equipment for the task at hand.

15) An arc-flash hazard, caused by the release of energy from an electric arc, will likely consist of which **three** of the following?

a) Extreme temperatures
b) PV array over voltage
c) Blinding light
d) Intense pressure and sound
e) Radioactive material

Extreme temperatures, Blinding light, Intense pressure and sound

Explanation

An arc flash is caused by the release of energy from an electric arc, during a fault – or short-circuit - situation. Some possible causes include:

1. *Accidental contact of energized circuits or equipment*
2. *Equipment that is not rated properly for the amount of current available.*
3. *Deterioration, corrosion, contamination or otherwise compromised electrical equipment*
4. *Accidental contact with a tool while performing energized work*

16) A ground fault occurs when a PV circuit conductor makes contact with which of the following?

a) Equipment grounding conductor
b) PV module frame
c) Metal Enclosure
d) Metal Conduit
e) Racking system
f) All of the above

All of the above

Explanation

Ground faults are more likely to occur within poorly installed PV systems. Ground faults occur when any energized PV circuit conductor – DC positive or negative – comes into

contact with the equipment grounding conductor, or ANY metal that is properly grounded (for instance metal conduit, aluminum or steel racking, or an aluminum PV module frame).

17) Ground faults in a PV system are commonly caused by _____ and _____.

a) Faulty inverters
b) Compromised conductor insulation
c) Pinched wires between module frames and mounting structure
d) Workers prepping module wiring while on the ground
e) Microinverters

Compromised conductor insulation, Pinched wires between module frames and mounting structure

Explanation

Ground faults occur when an energized PV conductor comes into contact with any grounded metal surface that is connected to ground. Two common causes are:

1. *conductors getting pinched between a module frame and the metal racking, and*
2. *compromised conductor insulation*

Pinched conductors are easily avoidable, and often occur when workers are moving too fast and fail to see that a module frame was set on a conductor. When the clamps holding the module to the racking are tightened, they pinch the wire and damage the insulation. Compromised insulation could also be caused by careless wire pulling or movement of the conductors or conduit due to expansion and contraction. Good installation procedures and processes can be followed to help eliminate ground faults. Proper wire management is critical in the PV industry, where we want to make sure every system is installed correctly and safely.

18) What can be used to isolate the PV array from the inverter? Choose **two**.

a) Blanket
b) DC disconnect
c) Reflective Tarp
d) AC Disconnect
e) PV module quick connectors

DC disconnect, PV module quick connectors

Explanation

The DC power from the PV array must be treated as live at all times and must be isolated only by Lockout/Tagout methods. Using LOTO on the DC disconnect or on the PV source circuits at the array is the only way to safely isolate the array. Using a covering on the array is not sufficient. Many tarps and other coverings still let through enough light to produce dangerous levels of current and voltage. Securing a covering in place is very difficult and does not ensure an electrically safe working environment. Additionally, the PV cells can receive exposure to sunlight through PV module back sheets; this is especially problematic for ground mounted systems.

19) Workers should always check for _____ in all circuits before opening a non-load break rated device, such as a fuse holder or PV module quick connectors.

a) voltage
b) wind
c) irradiance
d) current
e) heat

current

Explanation

It is critical to always use a clamp-on meter to check for current before opening any fuses or non-load break rated connectors or devices (such as tip-out fuse folders or PV module connectors). If current is flowing where or when it shouldn't be, opening non-load break rated devices under load can result in arcing and possibly fires.

20) True or False: Unqualified persons are permitted past the restricted approach boundary only if they are supervised.

False

Explanation

According to NFPA 70E, shock protection boundaries include the ***restricted approach boundary,*** *where unqualified persons are* ***not*** *permitted. Within the restricted approach boundary qualified persons may pass, with appropriate PPE. Within the* ***limited approach boundary****, unqualified persons are allowed to pass with continuous guidance and escort from qualified person.*