FUNDAMENTALS OF PHOTOVOLTAICS FOR THE FIRE SERVICE

TOPIC: 5: Codes and Standards

TIME FRAME: 1:00

LEVEL OF INSTRUCTION: Level 1

BEHAVIORAL OBJECTIVE:

Condition: Given a written test

Behavior: The student will confirm their knowledge of the life safety considerations in the Codes and Standards that govern the application and operation of photovoltaic cells and components by completing the written test.

Standard: With a minimum 80% accuracy according to the information contained in:

- Fundamentals of Photovoltaics for the Fire Service, Rodney Slaughter, September 2006

MATERIALS NEEDED:

- Writing board or pad with markers/erasers
- Appropriate audiovisual equipment
- Appropriate audiovisual materials

REFERENCES:

- Fundamentals of Photovoltaics for the Fire Service, Rodney Slaughter, September 2006

PREPARATION: At the heart of the building codes are the life safety considerations for the building occupants and emergency responders. The intent of this section is to highlight a few of the important safety requirements inherent in the California Building, Electrical, and Fire Codes and the National Standards as they relate to photovoltaics.

PRESENTATION	APPLICATION
	Slide 1 - Agenda “Codes & Standards”
I. OBJECTIVE	Slide 2 – Behavioral Objective
A. At the end of this section you will be able to cite specific code references as they relate to photovoltaic systems	
	Slide 3 –Wiring Identification
II. Wiring Identification	**Overhead Question:** Where do PV circuits exist within the building envelope and how do you identify and disconnect the system?
A. You can mentally trace the path of PV circuits from the PV array through the building to the controller, batteries and/or on to the inverter next to the main electrical panel	
B. Direct current photovoltaic conductor is run outside a building membrane in metallic conduit or from the point of penetration of the surface of the building to the first disconnect mechanism	
C. An extra measure of protection, the NEC specifies that conductors of different output systems (utility grid, generator, hydro electric, or wind) will be contained in separate raceways, cable trays, cable, outlet box, junction box, or similar fittings	

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D. Never cut into these conduits or raceways	
	Slide 4 –System Disconnects
III. System Disconnects	
A. The Uniform Fire Code (11.1.7.1) and the NEC (690.13 & 690.15) address the ability to disconnect an electrical system	
B. The Uniform Fire Code specifies that the disconnecting means is accessible to the fire department	
	Slide 5 –System Disconnects
C. NEC requirements provide the details for disconnecting all components and conductors in the system which include:	
1. Provide a mechanism to disconnect all current-carrying conductors of a PV power source from all other conductors in the building	
2. The PV disconnect installed at a readily accessible location either on the outside of a building or inside nearest the main point of entrance of the system conductors	
3. The PV system disconnect can not be installed in bathrooms	

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4. Each PV disconnect shall be permanently marked to identify it as a photovoltaic system disconnect 5. The PV system disconnect will not have more than six switches or six circuit breakers mounted in a single enclosure 6. The PV system disconnect shall be grouped with other disconnecting means 7. A PV disconnect is not required at the photovoltaic module or array location 8. A mechanism will be provided to disconnect equipment, such as inverters, batteries, charge controllers from all sources 9. If the equipment is energized from more than one source like PV, generator, or batteries the disconnect shall be grouped and identified 10. With batteries, where there are more than twenty-four 2-volt cells connected in series (48 volts, nominal), will have a disconnect accessible only to qualified persons that	Slide 6 –System Disconnects

PRESENTATION	APPLICATION
a) disconnects the grounded circuit conductor(s) in the battery electrical system for maintenance 11. A single disconnecting means shall be permitted for the combined ac output of one or more inverters or ac modules in an interactive system 12. The disconnect for ungrounded conductors shall consist of a manually operable switch(es) or circuit breaker(s) complying with all of the following requirements: a) Located where readily accessible b) Externally operable without exposing the operator to contact with live parts c) Plainly indicating whether in the open or closed position d) Have an interrupt rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment 13. When all terminals of the disconnect could be energized in the open position, a warning	

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sign shall be mounted on or adjacent to the disconnecting means

14. The sign shall be clearly legible and have the following words or equivalent:

WARNING
ELECTRIC SHOCK HAZARD.
DO NOT TOUCH TERMINALS

TERMINALS
ON BOTH THE LINE AND LOAD SIDES MAY BE ENERGIZED
IN THE OPEN POSITION

15. There are a number of redundant system disconnects built into a PV system

16. Disconnects can be located next to the main electrical panel, the inverter, the controller, and the battery bank

17. As mentioned earlier, an inverter or an ac module in a grid-tied or interactive solar photovoltaic system will automatically de-energize its output from the PV system and the AC distribution network of the building upon the loss of voltage in the system

18. The system will remain in this state until the electrical

PRESENTATION	APPLICATION

production and distribution network voltage has been restored

19. Importantly, a normally interactive solar photovoltaic system can be permitted to operate as a stand-alone system to supply loads that have been disconnected from electrical production and distribution network sources

20. You would find this arrangement in grid-tied systems with a battery back-up or generator back-up system

Slide 7 –Wiring

IV. Wiring (Conductors)

A. The type and size of wiring used in photovoltaic systems is determined by several factors, including whether the current is direct or alternating

B. Low voltage DC systems often have larger wiring sizes as compared to AC systems

C. The circuit conductors and overcurrent devices are sized to carry not less than 125 percent of the maximum calculated currents

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D. Wiring exposed to the weather must be rated and labeled for outdoor use	
E. To reduce fire hazards, roof mounted PV systems, conductors, and components are all required to be grounded	
	Slide 8 –GFI
V. Ground Fault Protection	
A. The ground-fault protection device or system detects a ground fault, interrupting the flow of fault current, and providing an indication of the fault	
B. Specific requirements are listed in the NEC for providing ground fault protection for PV systems and components. These include:	
1. Labels and markings applied near the ground-fault indicator at a visible location, stating that, if a ground fault is indicated, the normally grounded conductors may be energized and ungrounded	
2. In one- and two-family dwellings, live parts in photovoltaic source circuits and photovoltaic output circuits over 150 volts to ground shall not be accessible to other than qualified persons while energized	

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Slide 9 –GFI

3. The DC circuit grounding connection shall be made at any single point on the photovoltaic output circuit

4. Locating the grounding connection point as close as practicable to the photovoltaic source better protects the system from voltage surges due to lightning

5. Exposed non–current-carrying metal parts of module frames, equipment, and conductor enclosures shall be grounded regardless of voltage

Slide 10 – PV Modules

VI. PV Modules

A. In a PV module, the maximum system voltage is calculated and corrected for the lowest expected ambient temperature

B. This voltage is used to determine the voltage rating of cables, disconnects, overcurrent devices, and other equipment

Slide 11 – PV Modules

PRESENTATION	APPLICATION
C. In one and two-family dwellings, photovoltaic source circuits and photovoltaic output circuits that do not include lampholders, fixtures, or receptacles and are permitted to have a maximum photovoltaic system voltage of up to 600 volts	
D. Other installations with a maximum photovoltaic system voltage over 600 volts shall comply with Article 490	Slide 11 – PV Modules
E. A label for the direct-current photovoltaic power source will be provided by the installer at an accessible location at the disconnecting means for the power source providing information on: 1. Operating current 2. Operating voltage 3. Maximum system voltage 4. Short-circuit current	Slide 12 – Batteries
VII. Batteries	
A. Storage batteries in a photovoltaic system should be installed in accordance with the provisions of NEC Article 480	

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B. The interconnected battery cells are considered grounded when the photovoltaic power source is installed in accordance with the NEC	
C. Storage batteries for dwellings will have the cells connected to operate at less than 50 volts nominal	
D. Lead-acid storage batteries for dwellings shall have no more than twenty-four 2-volt cells connected in series (48-volts nominal)	
E. In that, the batteries in photovoltaic systems are subject to extensive charge–discharge cycles, they typically require frequent maintenance such as checking electrolyte and cleaning the connections	
F. For this reason live parts of battery systems for dwellings should be guarded to prevent accidental contact by persons or objects, regardless of voltage or battery type	
	Slide 13 – Batteries
G. Flooded, vented, lead-acid batteries with more than twenty-four 2-volt cells connected in series (48 volts, nominal) shall not use conductive cases or shall not be installed in conductive cases	

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H. Conductive racks used to support the nonconductive cases shall be permitted where no rack material is located within 150 mm (6 in.) of the tops of the nonconductive cases	
I. This requirement shall not apply to any type of valve-regulated lead-acid (VRLA) battery or any other types of sealed batteries that may require steel cases for proper operation	
J. As mentioned earlier, equipment is provided to control the charging process of the battery	
K. All adjusting means for control of the charging process should only be accessible only to qualified persons	
L. The reason for this is that certain battery types such as valve-regulated lead acid or nickel cadmium can experience thermal failure when overcharged	
	Slide 14 – Batteries
M. Additional requirements for batteries can also be found in Chapter 52, NFPA 1, Uniform Fire Code (2006)	

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N. Stationary lead-acid battery systems having an electrolyte capacity of more than 100 gal (378.5 L) in sprinklered buildings or 50 gal (189.3 L) in unsprinklered buildings used for facility standby power, emergency power, or uninterrupted power supplies will also contain these safety features: 1. Valve-regulated lead–acid (VRLA) battery systems should have a listed device or other approved method to preclude, detect, and control thermal runaway 2. Battery systems are permitted in the same room as the equipment that they support 3. These systems should be housed in a noncombustible, locked cabinet or other enclosure to prevent access by unauthorized personnel unless located in a separate equipment room accessible only to authorized personnel 4. In other than State regulated occupancies and residential occupancies, battery systems should be located in a room separated from other portions of the building by a minimum of a 1-hour fire barrier	

PRESENTATION	APPLICATION
5. In assembly, educational, detention and correction facilities, health care, ambulatory health care, day care centers, residential board and care, and residential occupancies, battery systems should be located in a room separated from other portions of the building by a minimum of a 2-hour fire barrier 6. An approved method and materials for the control of a spill of electrolyte shall be provided 7. An approved method to neutralize spilled electrolyte should be provided capable of neutralizing a spill from the largest lead–acid battery to a pH between 7.0 and 9.0 8. Ventilation shall be provided for rooms and cabinets in accordance with the mechanical code and one of the following: a) The ventilation system shall be designed to limit the maximum concentration of hydrogen to 1.0 percent of the total volume of the room during the worst-case event of simultaneous “boost” charging of all the batteries, in accordance with nationally standards	

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b) Continuous ventilation shall be provided at a rate of not less than 1 ft3/min/ft2 (5.1 L/sec/m2) of floor area of the room or cabinet	
9. The battery environment shall be controlled or analyzed to maintain temperature in a safe operating range for the specific battery technology used	
	Slide 15 – Batteries
10. Doors or accesses into rooms, buildings, or areas containing stationary lead–acid battery systems should be provided with approved signs	
11. The signs will state that the room contains lead–acid battery systems, that the battery room contains energized electrical circuits, and that the battery electrolyte solutions are corrosive liquids	
12. Battery cabinets shall be provided with exterior labels that identify the manufacturer and model number of the system and electrical rating (voltage and current) of the contained battery system	
	Slide 16 – Batteries

PRESENTATION	APPLICATION

13. In the cabinet, signs will indicate the relevant electrical, chemical, and fire hazard

14. In seismically active areas, battery systems shall be seismically braced in accordance with the building code

15. An approved automatic smoke detection system shall be installed in such areas and supervised by an approved central, proprietary, or remote station service or a local alarm that will give an audible signal at a constantly attended location

Slide 17 – Fire Responsibilities

O. Fire service related activities

1. Fire and life safety plan review will ensure that firefighters have adequate access to the roof

2. It is important that fire inspectors and plan reviewers get involved in the building permit and inspection process and to pass available information of PV installations on to the operational section of their departments

PRESENTATION	APPLICATION
3. Fire fighters need to take this information and develop preplans for the commercial and residential structures in their jurisdictions	
4. Preplans should note electrical lock out and identify the location of PV components such as inverters, batteries, controllers, panels, and system disconnects	
5. Once a structure with a PV system becomes involved in a structural emergency or fire, your department will have all the available information at their fingertips	
VIII. SUMMARY	Slide 18 – Summary
A. Automatic disconnect, along with manual service disconnects throughout the PV system allow emergency responders to contain the electricity at the source	
B. Firefighters have successfully dealt with lead acid batteries and battery systems for decades	
C. The Building, Electrical, and Fire Codes ensure the safety for occupants and emergency responders	