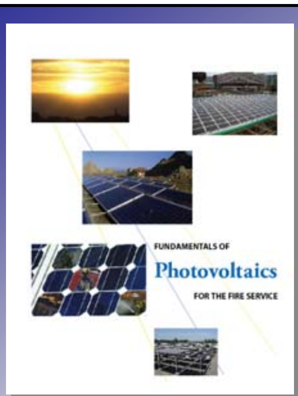

Program Funded By:
Sacramento Municipal Utility District
&
California Solar Energy Industries Association

Instructional Design By:
Rodney Slaughter

INTRODUCTION

Technical Review

Jon Bertolino Sacramento Municipal Utilities District	
Les Nelson CAL SEIA	Sue Kateley California Energy Commission
Lee Parker, Captain Modesto Fire Department	Scott Corrin, Fire Marshal U.C. Riverside Fire Department
Bob Gill, Chief Central Calaveras County Fire & Rescue	Russ Tingley, Fire Chief Hermosa Beach Fire Department
Howard Cooke, Fire Inspector Sacramento Fire Department	Dirk Drossel, Fire Inspector Burbank Fire Department

INTRODUCTION

Program Goal:

To provide fire service personnel with an awareness of photovoltaic systems, so that you can make informed decisions and operate safely during an emergency.

INTRODUCTION

Course Materials on Compact Disk:

- Student Manual
- Student Handout
- Instructor Guide
- Powerpoint Presentation

INTRODUCTION

Student Introductions

- Name
- Rank/Position
- Department or Agency
- What do you know about solar energy?
- What do you hope to learn?

AGENDA

- INTRODUCTION
- CELLS AND COMPONENTS
- PV PERFORMANCE
- PV APPLICATIONS
- CODES AND STANDARDS
- EMERGENCY RESPONSE

What are the chances of responding to an emergency where a photovoltaic system has been installed?

INTRODUCTION

2005 Worldwide PV Production
1,565 megawatts

2005 Worldwide PV Production:
Germany at 53% or 837 MW
Japan at 14% or 292 MW
U.S.A. at 3% or 104 MW

By 2010, 2.5 gigawatts of PV production is projected worldwide

INTRODUCTION

California is the National leader
17,300 grid-connected systems

California's Goal:
One million solar roofs by 2017

Generating 3,000 MW of electricity

Double the worldwide PV output in 2005

INTRODUCTION

Livermore, California – Multi-family housing development outfitted with PV electric systems- the wave of the future!

Are photovoltaic systems safe to operate around?

INTRODUCTION

Yes! Under normal operating conditions

The PV industry has a good safety record

But, no technology is risk free!

Only one recorded PV electrical injury to a fire fighter was reported worldwide

INTRODUCTION

Emergency Conditions
Know the Potential Hazards:

- Electric Shock
- Inhalation Exposure
- Falls from Roofs
- Roof Collapse

INTRODUCTION

With a concentration of PV in San Diego, there were no reported injuries during the 2003 wild fires

SUMMARY

The fire service has been known to be resistant to technological changes in our society.

Alternative energy production is the next big technological change that the fire service will have to come to terms with.

SMUD and CAL SEIA have seen the need to inform emergency responders of how to work around photovoltaic technology safely.

AGENDA

- INTRODUCTION
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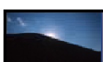
- EMERGENCY RESPONSE

"Give me the splendid silent sun with all its beams full-dazzling."
Walt Whitman, 1865

OBJECTIVE

To recall the principles of photovoltaics

To identify the components of a photovoltaic system



PV CELLS & COMPONENTS

SOLAR FACTS

One day of sunshine could supply all the world's energy for 4 to 5 years

The Sun's full intensity and brightness is 1,000 watts per meter squared (referred to as insolation)

This intensity can be diminished according to the micro climate and site specific conditions (shade)

PV CELLS & COMPONENTS

SOLAR FACTS

In the Northern Hemisphere, most photovoltaic systems are orientated towards true south to maximize the amount of light falling on the photovoltaic panels

Peak sun per day is about 5 hours, between 10 am and 3 pm (peak energy production)

PV CELLS & COMPONENTS

Anatomy of a Solar Cell

The solar cell is the smallest unit of the PV system

There are two types of manufactured PV's:

- Silicon cell or
- Amorphous silicon

PV cell has a thin layer of silicon 1/100th of an inch

Silicon is layered with other materials to create the photoelectric reaction

PV CELLS & COMPONENTS

Anatomy of a Solar Cell

Boron is used for the positive layer

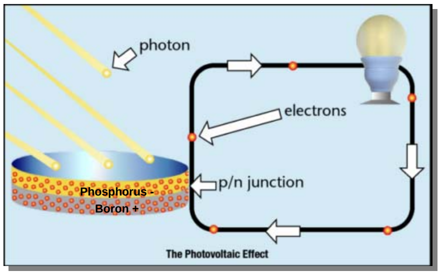
Phosphorus is used for the negative layer

Photons generated from the sun energize and knock loose the extra phosphorus electron which crosses the P/N junction to fill the hole on the boron atom

The energy released in the process produces .5 volt of direct current (DC)

PV CELLS & COMPONENTS

The Photovoltaic Effect



PV CELLS & COMPONENTS

MANUFACTURING PROCESSES

The purest silicon structure comes from the growth of a single crystal, monocrystalline, cut in to thin wafers

Multiple crystals cast together and sliced into thin wafers form polycrystalline structures

A chemical process that deposits silicon on a substrate material like glass or stainless steel as a thin film is referred to as amorphous

PV CELLS & COMPONENTS

MANUFACTURING PROCESSES

To improve PV efficiency and reduce cost, the industry is using materials such as cadmium telluride and gallium arsenide

Toxic and hazardous chemicals are used in the PV manufacturing process

When a module is exposed to fire or an explosion, trace chemicals can be released into the atmosphere

PV CELLS & COMPONENTS

Monocrystalline

Modules have output capacities of 14 to 15%

Monocrystalline achieves the highest efficiency in electric energy production

Its production cost is higher than other silicon types

PV CELLS & COMPONENTS

Polycrystalline

Pure molten silicon is cast into molds, then sliced into wafers, doped and assembled

Installation of polycrystalline modules on a rack system.

Polycrystalline is lower in conversion efficiency compared to Monocrystalline, averaging about 12 to 14% output capacity

PV CELLS & COMPONENTS

Amorphous

Made by vaporizing silicon and depositing it on a glass, steel or flexible surface

Some are flexible and are able to be rolled and used for remote electricity generation

The flexibility of amorphous technology allows it to be used in a wider range of applications

PV CELLS & COMPONENTS

A semitransparent amorphous silicon product used as a gas station canopy in Fairfield, California

Top - looking down on the canopy

Bottom – looking up through the canopy

PV CELLS & COMPONENTS

Amorphous

Production costs less than other production techniques, but the output capacity, is reduced to 5 to 7%

A square foot of amorphous silicon averages about 5 watts, monocrystalline or polycrystalline average about 10 watts per square foot

PV CELLS & COMPONENTS

The Photovoltaic System Includes

Modules/Array (Tiles or Shingles)

Optional Batteries

Battery Controller

Inverter

Mounting Systems

PV CELLS & COMPONENTS

Photovoltaic Modules

PV cells connected in series and parallel – the voltage and amperage is accumulated to achieve the desired electrical output

Photovoltaic cells connected together form a PV module

Weather-proof electrical connections connect modules together

In rare occasions junction boxes can overheat and can lead to roof damage and potential fire

PV CELLS & COMPONENTS

Photovoltaic Modules

Modules have a variety of sizes and rated output, with the standard size module at 24-volts, consisting of 72 solar cells

An average size crystalline module weighs between 30 and 35 pounds

Photovoltaic panels have no moving parts and require little maintenance

PV CELLS & COMPONENTS

Photovoltaic Array

Two or more modules connected together form a photovoltaic array

Residential system outputs of 600 volts are not uncommon

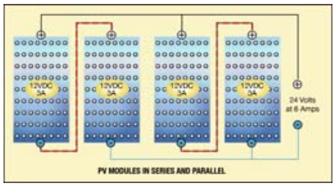
The average household in California uses about 6,500 kilowatt-hours per year

PV CELLS & COMPONENTS

Photovoltaic Array

The modules wired together in series to accumulate voltage, and the strings are wired together in parallel to Increase amperage, collectively they form the array

Array in Series and Parallel



PV CELLS & COMPONENTS

Photovoltaic Array

A PV system in the 3 to 4 kilowatt range would meet most homeowner's electricity needs

A 30 module array would operate at over 4,000 watts and weigh approximately 900 to 1,050 pounds

This weight spread equally over a 420 square foot area of the roof would result in a roof weight load of 2.5 pounds per square foot

PV CELLS & COMPONENTS

Photovoltaic Tiles and Shingles

PV tiles or shingles can be integrated into the home's roof covering

It takes more time, wiring individual tiles or shingles together

PV tile or shingle roofing system is less obtrusive but costs more

In High Fire Hazard Severity Zones, roofing systems must meet Class A of Title 24 CCR

PV CELLS & COMPONENTS

Photovoltaic Tiles and Shingles

Some manufacturers of PV roofing tiles have tested their products and meet the standard for Class A roofing

Manufacturers of PV shingles have achieved a Class A rating by using a fire resistant underlayment beneath the PV shingles

PV CELLS & COMPONENTS

Batteries

Lead acid batteries are used to store PV-generated electricity

Batteries are used in off-grid PV systems, although battery back-up can be used in grid-connected applications

Without batteries, a grid-tied PV system cannot provide PV electricity when the utility grid is not energized

PV CELLS & COMPONENTS

Batteries

Pinnacles National Monument in California installed a 9.6-kilowatt photovoltaic system. It eliminates the fuel bill for a diesel generator that produced 143 tons of carbon.

PV CELLS & COMPONENTS

Batteries

A battery is an electrochemical cell

The electrical potential between the positive and negative electrodes is about 2 volts direct current (DC)

The battery can off-gas oxygen from the positive electrode and hydrogen from the negative electrode

Escaping gases are highly flammable, sparks and open flames are not allowed near the batteries

PV CELLS & COMPONENTS

Batteries

Like the PV modules, batteries are wired in series and parallel to provide the voltage and amperage necessary for the operation of the electrical system

PV CELLS & COMPONENTS

Battery Charge Controllers

To keep battery charge levels in check, a charge controller is used in the PV system

The battery charge controller prevents over charging reducing the danger of off-gassing

Many controllers also protect the battery from over-discharges as well

PV CELLS & COMPONENTS

Battery Charge Controllers

Battery charge controllers are found in off-grid systems and grid-tied systems that have a battery back-up.

PV CELLS & COMPONENTS

PV Inverters

The PV array, batteries and charge controllers all function on direct current (dc)

Most household appliances run on alternating current (ac)

The inverter changes the direct current to alternating current at 60 hz

PV CELLS & COMPONENTS

PV Inverter

This sine wave inverter is used on a grid-tied system.

A look inside an inverter during the installation process.

PV CELLS & COMPONENTS

PV Inverters

There are three types of inverters; square wave, modified square wave and sine wave

Sine wave inverters produce a high quality waveform used to operate sensitive electrical equipment

Sine wave inverters are required for grid-tied PV systems

Grid-tied inverters are designed to shut down when there is no grid power

PV CELLS & COMPONENTS

Mounting Systems

PV modules can be mounted directly on the roof, in many cases specialized roof racks lift the array from the roof deck allowing air to circulate under the modules.

Many PV systems are designed to withstand 80 mile per hour winds.

PV CELLS & COMPONENTS

Mounting Systems

PV systems can also be mounted on the ground using customized racks, or they can be mounted on poles.

PV CELLS & COMPONENTS

Other Solar Technologies

Two solar hot water panels are on the left of this roof and 44 modules of this 7 kw PV array on the right of this 3,000 sq. ft. home. The system is backed-up with a generator.

Solar thermal panels (solar water heating collectors) are used to heat water for the swimming pool or for domestic hot water

The long rectangular panel at the bottom of this array is a solar water heating panel.

PV CELLS & COMPONENTS

Other Solar Technologies

Skylights are a function of passive solar design, allowing natural light to enter the interior of the building

A skylight with integrated photovoltaic will have a distinctive amorphous rectangular pattern in the glass

PV CELLS & COMPONENTS

Photovoltaic Identification

PV panels are Distinctive: making them relatively easy to recognize when you know what to look for!

SUMMARY

The greatest danger for emergency responders is the lack of PV knowledge needed to safely operate around this emerging technology

This section provided you with an introduction to the photovoltaic system

Identification of the PV array and all the related components is critical in an emergency response

AGENDA

- INTRODUCTION
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- EMERGENCY RESPONSE

"Is it fact, or have I dreamt it—that, by means of electricity, the world of matter has become a great nerve, vibrating thousands of miles in a breathless point in time."

Nathaniel Hawthorne, The House of the Seven Gables, 1851

Objective

To cite historical milestones in the development of PV's

To recall the factors that effect PV performance

PV PERFORMANCE

PV Historical Brief

1839	French scientist discovers the photovoltaic effect
1873	Will Smith discovered the photoconductivity of selenium
1876	Discovered selenium produces electricity when exposed to light
1905	Einstein published his paper on the photoelectric effect
1918	Polish scientist developed a way to grow single-crystal silicon
1954	Bell Labs developed the silicon photovoltaic (PV) cell
1958	Vanguard I space satellite used a small array to power radios

PV PERFORMANCE

PV Historical Brief

1962	Bell Telephone Laboratories launches the first telecom satellite
1964	NASA launches satellite powered by a 470-watt PV array
1982	One megawatt power station goes on-line in Hisperia, California
1982	Worldwide photovoltaic production exceeds 9.3 megawatts
1983	Arco Solar dedicates a 120 acre 6-MW PV substation
1984	SMUD commissions its first 1-megawatt PV facility
1999	Cumulative worldwide PV capacity reaches 1000 megawatts

PV PERFORMANCE

PV Performance

Limitations on technology: PV only converts as much as 20% of the suns energy

Environmental factors: overcast days caused by clouds and smog can lower system efficiency

Shade: chimneys, trees and nearby buildings shade panels and reduce the output for the entire array

Temperature: PV systems operate best at 90 degrees or lower

PV PERFORMANCE

PV Performance

Site Specific: availability of sunshine throughout the year, including average daily insolation, site latitude, magnetic declination (true south), tilt angle and site specific information such as local weather and climate

Design: Installers underestimate the rated PV module output by 15 to 25% from the manufacturers tested output, some energy is lost as heat in the DC-AC conversion

PV PERFORMANCE

PV Concepts

Voltage is the measure of electrical potential between two points

Amperage is the rate at which the electrons flow through the circuit.

Wattage is the rate an appliance uses electrical energy, or rather the amount of work done when one amp at one volt flows through one ohm of resistance

PV PERFORMANCE

PV Concepts

Ohm's Law is a mathematical equation to calculate the value of these terms

The Ohm's formula is:
Volts x Amps = Watts

You can flip this equation around to find other values

Watts ÷ Amps = Volts
or
Watts ÷Volts = Amps

PV PERFORMANCE

PV Concepts

Ohm's formula is used to calculate energy demand and for PV design

Watt-hour measures energy being used

One thousand watts consumed over the period of one hour is one kilowatt hour, (or kWh)

Installers will analyze the energy usage and customer expectations

Energy conservation plays a significant role in PV performance and customer satisfaction

SUMMARY

The physics of electricity never change, regardless of how the electricity is generated.

There are a number of factors that affect overall PV system performance including the technology itself.

Recognizing these factors is another key to personnel safety when working around PV systems.

AGENDA

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- CELLS AND COMPONENTS
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"The world we live in is but thickened light."
Ralph Waldo Emerson, The Scholar,1883

Objective

To identify PV applications and the components associated with each application

PV APPLICATIONS

In December of 1998 Astronauts Jerry L. Ross (left) and James H. Newman work together on the final of three space walks of the STS-88 mission. (Photo Credit: NASA)

Even if you don't use PV directly you are doing so indirectly.

Communication systems and satellites with integrated PV systems provide power that improves the efficiency of our everyday lives even though you may not be aware of it!

PV APPLICATIONS

Day Use	Integrated with Battery Back-Up
Calculators	Watches
Toys	Radios
Fans	Flashlights
Blowers	Telecommunication
Pumps	Landscape lighting

These are some of the common applications of PV that you are already familiar with

PV APPLICATIONS

Direct Current (DC) Systems

Components in a direct current system include:

Photovoltaic module or array

Battery charge controller

Batteries and

Direct current appliances

PV APPLICATIONS

DC to AC Systems

This PV system includes:

Solar Modules or Array
Battery Controller
Batteries
Plus an Inverter

In rural areas, people can power their homes by converting the direct current (DC) generated from the PV system to alternating current (AC)

PV APPLICATIONS

DC to AC Systems

This PV system includes:

Solar Modules or Array
Battery Controller
Batteries
Plus an Inverter

This battery charge controller monitors the energy level in the battery as it charges and discharges

PV APPLICATIONS

DC to AC Systems

This PV system includes:

Solar Modules or Array
Battery Controller
Batteries
Plus an Inverter

Battery backed-up PV systems provide electricity for a specific period of time without sunshine

PV APPLICATIONS

DC to AC Systems

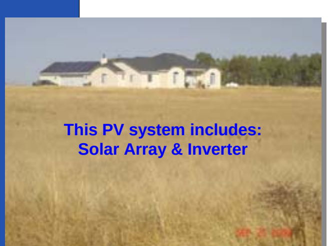
This PV system includes:

Solar Modules or Array
Battery Controller
Batteries
Plus an Inverter

These inverters convert direct current from the PV array and battery bank to alternating current

PV APPLICATIONS

Grid–Tied System



This system allows the building owner to generate and use PV power during the day and deliver excess power directly to the utility grid

PV APPLICATIONS

Grid–Tied System

In this system the utility grid provides the back-up power and eliminates the need for batteries in the system

To insure that the inverter is disconnected once the main electrical panel is locked out, fire personnel can also use the manual disconnect next to the inverter as an extra precaution

PV APPLICATIONS

Grid–Tied System

Loss of power from the grid will disconnect electricity in the building including the ability to use the electricity generated by the PV system

In this application where the inverter and main electrical panel is a distance from the meter another disconnect has been installed behind the meter on the utility pole

PV APPLICATIONS

Grid–Tied System

You may not be able to see a PV system on a flat roofed building from street level. The large inverters at the USPS processing and distribution center in Marina Del Rey, would be your first clue of the existence of a 127 kw monocrystalline PV system on the roof.

PV APPLICATIONS

BUILDING INTEGRATED DESIGN

The developing trend is to incorporate PV systems seamlessly into the building's exterior finish and landscape design

Laminated to the skylight glass are photovoltaic cells that produce electricity as well as serve as an element in the shading and day lighting design at the Thoreau Center for Sustainability, Presidio National Park, San Francisco, California.

PV APPLICATIONS

BUILDING INTEGRATED DESIGN (BID)

BID systems appear as PV roofing systems, windows, skylights or patio covers

PV canopies at CAL EXPO in Sacramento provide shade to parked cars

PV APPLICATIONS

BUILDING INTEGRATED DESIGN

Blending this technology into traditional building and landscape design is one of the many challenges designers are involved in and presents new challenges for emergency responders in identifying PV technology when sizing-up an emergency

The solar cube stands 135 feet tall on top of the Discovery Science Center in Santa Ana, CA

SUMMARY

PV is used in a wide range of applications were electricity is needed; from simple and inexpensive appliances to high end satellites.

The future trend will be to integrate PV seamlessly and unobtrusively into buildings and building sites.

This trend will make PV system identification a little more challenging for emergency responders.

AGENDA

- INTRODUCTION
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"Progress imposes not only new possibilities for the future but new restrictions."
Norbert Weiner, The Human Use of Human Beings, 1954

Objective

To reference codes and standards as they relate to personnel safety and photovoltaic systems

CODES & STANDARDS

Wiring Identification

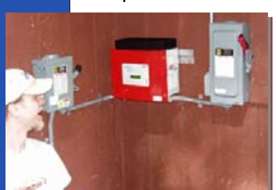
Direct current photovoltaic conductor (wiring) is run outside a building membrane in metallic conduit

National Electric Code specifies that conductors of different output systems will be contained in separate raceways, cable trays, cable, outlet box, junction box, or similar fittings

CODES & STANDARDS

System Disconnects

The Uniform Fire Code specifies that the disconnecting means is accessible to the fire department



In this system the inverter is flanked by two disconnects the right disconnects the array and the left disconnects the inverter from the main electrical panel

CODES & STANDARDS

System Disconnects

NEC requirements provides the detail for disconnecting all components and conductors in the system

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

Each PV disconnect shall be permanently marked to identify it as a photovoltaic system disconnect

CODES & STANDARDS

System Disconnect and Warning Labels

CODES & STANDARDS

System Disconnects

Importantly, a grid-tied PV system can operate as a stand-alone system to supply loads that have been disconnected from electrical production and distribution network sources

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

CODES & STANDARDS

Wiring (Conductors)

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

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

Wiring exposed to the weather must be rated and labeled for outdoor use

To reduce fire hazards, roof mounted PV systems, conductors, and components are all required to be grounded

CODES & STANDARDS

Ground Fault Protection

Specific requirements are listed in the NEC for providing ground fault protection for PV systems and components

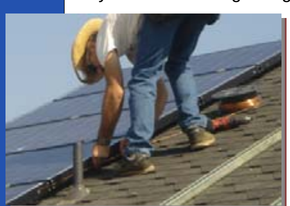
Labels and markings applied near the ground-fault indicator at a visible location, stating that, if a ground fault is indicated, the normally grounded conductors may be energized and ungrounded

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

CODES & STANDARDS

Ground Fault Protection

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



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

Installer connecting ground wire to module frames.

CODES & STANDARDS

PV Modules

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

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

CODES & STANDARDS

PV Modules

In one and two-family dwellings, photovoltaic source circuits and photovoltaic output circuits are permitted to have a maximum photovoltaic system voltage of up to 600 volts

Installations with a maximum photovoltaic system voltage over 600 volts shall comply with Article 490

CODES & STANDARDS

PV Modules

A label for the photovoltaic power source will be provided at an accessible location at the disconnecting means for the power source providing information on:

Operating current
Operating voltage
Maximum system voltage
Short-circuit current

The rated capacity of the module is provided on the back of each panel

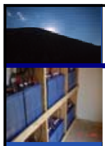
CODES & STANDARDS

PV Batteries

Storage batteries in a photovoltaic system should be installed in accordance with the provisions of NEC Article 480

Storage batteries for dwellings will have the cells connected to operate at less than 50 volts nominal

Lead-acid storage batteries for dwellings shall have no more than twenty-four 2-volt cells connected in series (48-volts nominal)



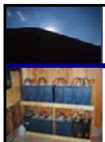
CODES & STANDARDS

PV Batteries

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

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

Some batteries do require steel cases for proper operation as these battery types such VRLA or nickel cadmium can experience thermal failure when overcharged



CODES & STANDARDS

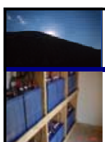
PV Batteries

Chapter 52, NFPA 1, Uniform Fire Code (2006)

Valve-regulated lead–acid (VRLA) battery systems should have a listed device or other approved method to preclude, detect, and control thermal runaway

Provide an approved method and material for the control of a spill of electrolyte

Provide ventilation for rooms and cabinets in accordance with the mechanical code



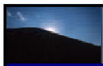
CODES & STANDARDS

PV Batteries

Chapter 52, NFPA 1, Uniform Fire Code (2006)

Provide signs on rooms and cabinets that contains lead–acid battery systems

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



CODES & STANDARDS

Fire Service Responsibilities

During plan review ensure that there is adequate access to the roof for firefighting operations

Fire Inspectors need to stay involved in the permit and plan review process

Pass available building and PV information on to the operational section of your department

Firefighters need to take this information and develop pre-emergency plans for these facilities

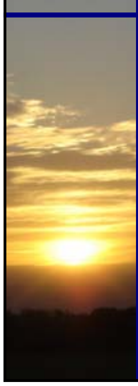
SUMMARY

Automatic and manual disconnects throughout the PV system allow firefighters to contain the electricity at the source

Firefighters have successfully dealt with lead acid batteries and battery systems for decades

The Building, Electrical, and Fire Codes ensure the safety for occupants and emergency responders

AGENDA



- INTRODUCTION
- CELLS AND COMPONENTS
- PV PERFORMANCE
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- EMERGENCY RESPONSE

"We are here to make a choice between the quick and the dead"
Bernard Baruch, U.N. Atomic Energy Commission, 1946

Objective

To identify and mitigate potential hazards while working around PV at the site of an emergency

To use this information to develop a standard operating guideline for your department

EMERGENCY RESPONSE

Fire Fighter Hazards

Inhalation Exposure Hazards

Electrical Shock & Burns

Falls from Roof Operations

Roof Collapse

Batteries

Emergency Response

How do you work with PV

What not to do around PV

EMERGENCY RESPONSE

Inhalation Hazards

During a fire or explosion the PV frame can quickly degrade exposing hazardous chemicals to direct flame and become dissipated in the smoke plume

EMERGENCY RESPONSE

Inhalation Hazards

Boron- No health effects to humans or the environment

Cadmium Telluride- A known carcinogen, the primary route of exposure is inhalation

Gallium Arsenide- The health effects have not been studied, it is considered highly toxic and carcinogenic

Phosphorus- The fumes from compounds are considered highly toxic. NIOSH recommended exposure limit to phosphorus is 5 mg/m3. A lethal dose of phosphorus is 50 milligrams

EMERGENCY RESPONSE

Inhalation Hazards

Recommended Practice:

- Wear SCBA and full protective clothing
- Shelter-in-place populations-at-risk downwind of fire

EMERGENCY RESPONSE

Electric Hazards

NIOSH reports reveal the number of firefighters who are killed and injured annually in electrical incidents

Electricity can cause a variety of effects, ranging from a slight tingling sensation, from involuntary muscle reaction to burns and death!

EMERGENCY RESPONSE

Electric Hazards

The physiological effects produced by electricity flowing through the body include:

Perception – (1 mA) tingling sensation

Startle Reaction – (5 mA) involuntary muscle reaction

Muscle Tetanization – (6 to 30 mA) painful shock

Respiratory Arrest – (.5 to 1.50 Amps) stop breathing

Ventricular Fibrillation – (1 to 4.3 Amps) heart stops

EMERGENCY RESPONSE

Electric Hazards

Variables in human resistance to electricity:

Amount of current flowing through the body

Path of current through the body

Length of time the body is in the current

Other Factors: Body size and shape, Area of contact, Pressure of contact, Moisture of contacts, Clothing & jewelry, Type of skin

EMERGENCY RESPONSE

Electric Burns

Burns that can occur in electrical accidents include electrical, arc, and thermal

With electrical burns, tissue damage occurs because the body is unable to dissipate the heat from the current flow

Temperatures generated by an electric arc can melt nearby material, vaporize metal in close vicinity, burn flesh and ignite clothing at distances of up to 10 feet

Arc temperatures can reach 15,000 to 35,000 degrees

A firefighter should never pull the electrical meter as a means of shutting-down power to a building!

EMERGENCY RESPONSE

Roof Hazards

In roof operations consider the weight of the PV array on a weakening roof structure and the fact that you may not be able to access the roof over the fire

To cut ventilation, select a spot at the highest point of the roof and as close to the fire as possible

Do not cut into PV modules!

Consider cross ventilation?

Roof vents, skylights, solar thermal panels, and PV array pose a trip hazard to fire fighters conducting roof operations

EMERGENCY RESPONSE

Battery Hazards

As a rule, batteries do not burn; or rather, they burn with great difficulty

If batteries are exposed to fire, however, the fumes and gases generated are extremely corrosive

Spilled electrolyte can react and produce toxic fumes and release flammable and explosive gases when it comes into contact with other metals

Due to the potential of explosive gases, prevent all open flames and avoid creating sparks

EMERGENCY RESPONSE

Battery Hazards

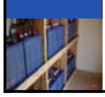
In battery emergencies, wear full protective clothing and SCBA on positive pressure

Extinguish lead-acid battery fires with CO_2, foam or dry chemical fire extinguishers

Do not use water!

Never cut into the batteries under any circumstances!

If the battery is punctured by a conductive object, assume that the object has electrical potential



EMERGENCY RESPONSE

Personal Protective Equipment

Firefighters should follow the minimum standard in NFPA 1971, Protective Ensemble for Structural Firefighting and NFPA 1500, Chapter 7 Personal Protective Equipment

This would include:
Turnout pants
Turnout coat
Boots
Gloves
Hood
Helmet
SCBA

Note: Jewelry such as; watches, rings, and necklaces are all a good conductor of electricity and should not be worn around electrical components

EMERGENCY RESPONSE

Personal Protective Equipment

When working in proximity to electrical circuits, use insulated hand tools

To check for electricity flowing between two contacts an AC/DC meter should be employed

Typically, hot sticks on many engines can only detect alternating current and would not detect curent in PV wiring or battery conductors

EMERGENCY RESPONSE

Emergency Operations

Size-Up – the roof and look for warning labels on electrical disconnects

Lock-Out & Tag-Out - all electrical disconnects, isolating the PV system at the inverter

Ventilation - consider where to cut or whether to use cross ventilation

Shelter-in-Place – Does the size of the emergency and the involvement of the array constitute the need to protect populations downwind?

EMERGENCY RESPONSE

Emergency Operations

The PV array will always generate electricity when the sun shines- there is no turning it off!

Walking or breaking PV modules could release all the energy inherent in the system simultaneously

Cut or damaged wires from a nighttime operation could become energized in the day-time

Spotlights during an evening operation is not bright enough for the PV system to generate electricity

Lightening is bright enough to create electrical surge!

EMERGENCY RESPONSE

Emergency Operations

You cannot block all the sunlight on the array with foam or a salvage cover

Foam will not block out all the sunlight and will slide off the array

Salvage cover will significantly reduce sunlight to the array but electricity can still be generated through the material of the salvage cover

EMERGENCY RESPONSE

Emergency Operations

Locate battery storage area (if applicable)

Extinguish lead-acid battery fires with CO_2, foam or dry chemical fire extinguishers

Use Class C extinguishing agents- CO_2 or dry chemical if a PV system shorts and starts a fire

Should the array become engulfed in a roof fire, use water in a fog pattern on the PV array

Be aware that biting and stinging insects could inhabit the module frame and junction boxes

SUMMARY

Photovoltaic technology is around you every day and it is here to stay!

Your fundamental understanding of photovoltaic systems will improve your confidence in working with and around solar technology safely.

The photovoltaic industry is counting on the fire service industry to operate safely and effectively around photovoltaic systems.