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Photovoltaic Systems Safety

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This course was made as a reference with helpful and easily-accessible instructions on how to work safely with photovoltaic (PV) systems. Some recommendations are based on the common sense and they will help readers to keep safe. This course includes description of specific hazards, their frequent causes, and ways to prevent and avoid them.

This course addresses the following sections:

1. The PV System Characteristics and Hazards section provides the background of PV system characteristics and relevant hazards involved with PV systems. Recommended safe-guards are provided.
2. The Safe PV Systems section presents a discussion of relevant safety standards and codes, as well as regulations that need to be followed and applied when designing, installing, testing and commissioning a PV system.
3. The For Your Health section contains a discussion of possible injuries and elaborates on basic First Aid concepts.

Safety is a permanent responsibility of every technician or engineer. Practicing safety requires:

1. Good work habits and a clean and tidy work area;
2. Adequate tools and equipment and their use;
3. Awareness of hazards and how to prevent them;
4. Training in CPR (cardiopulmonary resuscitation) and First Aid; and
5. Periodic reviews and assessment of safety processes.

This course provides safety instructions for people who work with photovoltaic (PV) installations. Photovoltaic systems generate direct current (DC) power from sunshine. This energy may be transferred to DC loads or kept in electrochemical batteries for use when there is no sunshine. Also, direct current can be inverted to alternating current (AC) power for AC loads or for export to an electric transmission or distribution network. This versatility of PV energy is one of the main reasons it is being utilized in an increasing number of applications.

A PV array consists of individually framed PV modules that are electrically linked to generate the voltage and current needed by the electric load. When exposed to sunshine, the most frequently available PV module generates about 22 V DC when open circuited and about 15 V when working at its peak power output. A 1' x 4' module with 4-inch square PV cells functioning at this voltage will generate about 3 A, in full sunshine. This is sufficient current and voltage to induce injury under worst case circumstances. If an array consists of more than two modules connected in series, the shock hazard grows. When working and operating any PV system, the safeguards described below should be observed:

1. The best safety method is an alert mind, a doubting nature, and a slow hand.
2. Never work on a PV installation alone.
3. Know the PV and associated electrical system before you start to perform work.
4. Discuss the test goals and methods with your partner. Observe and understand PV system electrical diagrams and connections.
5. Keep your test equipment in top operating condition. Inspect your test equipment and tools before you go to the PV system site.
6. Wear appropriate clothing. Wear an approved electrical safety hat. Wear eye protection, particularly if working on batteries. Remove jewellery. Wear dry leather gloves to reduce the probability of getting electrically shocked.

7. Measure first. Measure and record the conductivity from exposed metal frames and junction boxes to ground. Measure voltage from all conductors (on the PV system output circuit) to ground. Measure and record the operating voltage and current. Use only one hand whenever feasible.
8. Question everything. Expect the unforeseen and surprises. Do not presume that switches always function, that the actual installation matches with the electrical schemes, that current is not going through the grounding conductors, etc.

PV system characteristics and hazards

PV installations are made to satisfy a particular load and are rarely consistent in schematic and element usage. Some PV systems that are connected to an electricity grid use hundreds of modules linked in series and parallel to generate large quantities of energy. Operating voltages may surpass 600 V DC, and currents at the subfield level may be hundreds of amperes. Many stand-alone PV installations have fewer modules but use batteries to keep power for later use. One of the common 12 V batteries can generate over 6000 A if shorted--serious burns and injuries can happen. The point is, each installation presents hazards to engineers, technicians and maintenance staff. Helping you distinguish these hazards and avert injury is the main goal of this course.

PV system characteristics

The PV effect can be made with a number of different materials. However, there is a limited number that are technically feasible. Few elements with commercial potential are shown in Table 1. Since over 99.9% of PV power installations in service today use crystalline silicon material, we will focus our attention to these cells. Unless specially mentioned otherwise, reference to a PV cell system will mean a crystalline silicon PV cell system.

Table 1. Commercially used PV materials

| Material | Typical cell voltage at open-circuit | Typical cell current at short-circuit |
|--|--------------------------------------|---------------------------------------|
| Crystalline and Polycrystalline Silicon (x-Si) | ~0.6 V | ~ 35 mA/cm ² |
| Gallium Arsenide | ~ 1 V | ~ 27 mA/cm ² |
| Amorphous Si (a-Si) | ~0.9 V | ~15 mA/cm ² |
| Tandem a-Si (Two-cell) | ~1.8 V | ~10 mA/cm ² |
| Copper-Indium Diselenide (CIS) | ~0.4 V | ~35 mA/cm ² |
| Cadmium Sulfide, Cadmium Telluride | ~0.7 V | ~25 mA/cm ² |

The voltage on a PV cell system quickly grows when illuminated and reaches its peak value even at low solar conditions. For this reason, any PV installation should be treated electrically “hot” during the daytime. Each PV cell, regardless of its surface, generates around 0.6 V DC when open-circuited and exposed to sunshine. The current output of a cell directly changes with its surface and the solar irradiance. A 4-inch square cell generates around 3 A, in full sunshine.

A PV module system is a laminated, environmentally-sealed pack of PV cells, typically linked in series to generate a usable voltage. The more typical PV modules consist of 35 to 40 cells in series and produce an open-circuit voltage of around 22 V D.C.

When a number of PV modules are linked in series to produce the voltage needed to service the load, the scheme is called a source circuit (also called a string). A PV array contains parallel-connected source circuits that produce the current needed to meet the power requirements of the load. For bigger systems, a number of source circuits may be grouped and routed through big DC disconnect breakers. Such a grouping is called a sub-array or subfield. The PV system consists of not only the source circuits or sub-arrays, but also the related power conditioning, protection and safety elements, as well as support structures.

The current-voltage feature (I-V) curve of a PV module, source circuit, or array is particular to that device but all I-V curves have nearly the same shape. An I-V curve

can be found by modifying the impedance linked to the device output. At each point on the curve, the current-voltage product is the power of the equipment at that point. For each curve, there is only one point at which the power is the highest. This is the largest surface rectangle that can be drawn under the curve. This point is called the maximum power point, P_{max} , and is the favored operating point for a majority of the applications. Other points of interest are the short-circuit current, I_{sc} , and the open-circuit voltage, V_{oc} . If the equipment is required to function in the second or fourth quadrant (negative voltage or current), it will have to dissipate power. This will induce heating and early fault. Bypass diodes are utilized in most arrays to limit the negative voltage across a cell.

The current of the PV cell grows linearly with solar irradiance and/or the surface of the cell. The power output of silicon PV equipment reduces with growing temperature. The current of the equipment grows somewhat with temperature, but the voltage reduces at a more rapid rate. The result is a reduction in power of 0.4% to 0.6% per °C.

System types

PV systems are organized in few different ways. Some common categorizations are:

1. Stand-Alone system: A PV system that is not interconnected to the electricity transmission network. Most stand-alone PV systems utilize batteries to keep the energy generated during daylight hours for use at night or on cloudy days.
2. Grid-Connected system: A PV system connected to the electric transmission or distribution electricity network. The energy not used by the loads is exported to the electricity network; the load can get the energy from the electricity network when the PV system is not producing enough to meet demand.
3. Flat-Plate system: A PV system consists of modules that are flat in geometry and use natural (unfocused) solar irradiance. They utilize both direct beam and diffuse (or scattered) solar irradiance to generate electrical power, and some energy is produced even on cloudy days. The sum of direct and diffuse solar irradiance is called total global irradiance.

4. Concentrator system: A PV system consists of modules that contain focusing optics as part of their installation. They utilize only the direct beam solar irradiance. Since only the direct beam irradiance can be concentrated by lenses or mirrors, a focusing system will not produce energy on cloudy days. The high intensities generated by these modules also generate acute heating that must be dissipated by active or passive cooling systems.
5. Fixed-Tilt system: Any PV array with modules at a constant tilt angle and orientation. The array may be installed on a rooftop, on a pole, or on the ground. These systems utilize flat-plate modules only, since concentrator modules must track the sun to catch the direct beam irradiance.
6. Tracking system: A PV system with modules installed on a tracking unit that follows the sun. Single-axis trackers follow the sun daily from east to west, and two-axis trackers include elevation control to adapt for seasonal north-south sun movement. Tracked systems are more costly than fixed-tilt installations, but also generate more electric power per unit surface because they follow the sun and “see” the maximum irradiance at all times. Tracking installations may employ either flat-plate or concentrator modules.
7. Hybrid system: Any installation with more than one power source.

Balance of systems

The balance-of-systems (BOS) is determined as everything except the PV modules and the load. The BOS consists of:

1. The land, fencing, facilities, etc.
2. Module support installations
3. External wiring and connection boxes
4. Power conditioning elements-- inverters, controllers, transformers, etc.
5. Safety and protective elements-- diodes, lightning protection, circuit breakers,

ground rods and cables, etc.

6. Batteries
7. Electricity network interface and connection devices
8. Weather equipment (pyranometers, thermometers, anemometers, etc.)
9. Data acquisition devices for monitoring and evaluating the PV system operation

System hazards and related recommendations

You can get harmed operating on any PV installation. Cuts, bumps, falls, and sprains hurt just as much and induce as much lost time as the electrical shock and burn hazards typically thought of. Even though, main safety recommendations are just simple common sense, technicians, engineers and operational people still get injured in industrial accidents. Luckily, just a few have been hurt operating PV installations—no deaths have been reported. The objective is to decrease the number of injuries to zero. This needs good work habits, awareness and knowledge of potential hazards, and a program where safety recommendations are usually reviewed. The responsibility is yours.

Non-Electrical Accidents

There is a wrong belief among many that you can't get injured working on a small PV installation. Anyone who has witnessed a car battery explosion could argue this statement. Safety should be first in the mind of anyone operating PV installations. Some common accidents that may be found are elaborated below.

Exposure

PV installations are mounted where the sun is the brightest and no shade exists. When you work on a PV installation you should wear a hat, keep the limbs covered, and/or use enough lotion with a sunscreen factor of 15 or higher. In the summertime, consume a lot of liquid (never alcoholic), take a break, and get into the shade for a few minutes each hour. During wintertime, dress warmly and wear gloves where possible.

Insects and snakes

Spiders, wasps, and other insects often inhabit junction boxes in PV installations. Some wasps make nests in the array framing. Rattlesnakes use the shade made by the array, and fire ants are typically located under arrays or near battery boxes. Be ready for the unexpected when you open junction boxes. Look cautiously before you crawl under the array. It may sound funny, but fire ants or black widow spiders (let alone rattlesnakes) can induce painful injury.

Bumps and cuts

Majority PV installations consist of metal framing, junction boxes, bolts, nuts, guy wires, anchor bolts, etc. Many of these elements are sharp and can induce injury if you are not cautious. Wear gloves when working with metal, especially if you are drilling or sawing. Slivers from metal made by drilling bit usually remain around a hole and these can cause serious cuts to a bare hand. Wear a dielectric hard hat if you are working under an array or on an installation with hardware higher than your head.

Falls, sprains, and strains

Many PV installations are mounted in remote locations in rough terrain. Walking to and around the remote site, especially carrying materials or test devices, can end up in falls and/or sprains. Wear comfortable safety shoes, preferably with soft soles. Steel toe reinforced safety shoes should not be worn around PV installations because they decrease the resistance of a potential current path. Be cautious when lifting heavy equipment and elements, especially battery packs. Lift with the legs and not the back to prevent back strains. If climbing is needed, make sure the ladder is securely placed on the ground, and keep in mind a PV module can act as a windsail and knock you off a ladder on windy days.

Thermal burns

Exposed metal outdoors can reach temperatures of 80°C. This is too hot to manipulate and operate, but is unlikely to induce burns if prolonged contact is not made. Concentrating PV installations pose an additional hazard from burns. Some concentrating PV installations concentrate up to 400 suns on the PV cell. This

additional thermal energy is dissipated using active or passive cooling systems with temperatures far surpassing 100°C.

Instant contact can induce severe burns. Active cooling mechanisms consist of a heat transfer fluid that can scald flesh (it may also be caustic). Wear gloves when you have to work on PV installations in the summertime. Inspect the installation and make certain you do not bump into cooling elements.

Acid burns

Most stand-alone PV installations include battery packs. A large number of the battery packs are the lead-acid type, and the hydrochloric acid is a hazard. Chemical burns will happen if the acid gets in touch with an exposed part of the body—your eyes are especially vulnerable. Anytime you are working around lead-acid battery packs you need to wear non-absorbent gloves, protective eye wear, and a neoprene coated apron.

Electrical hazards

Typical electrical hazards result in shocks and/or burns, muscle contractions, and traumatic hurts related with falls after the shock. These hurts can happen anytime electric current is transferred through the human body. The amount of electric current that will flow is found by the difference in potential (voltage) and the resistance in the current path. At low frequencies (60 Hz or less) the human body behaves like a resistor but the resistance changes with circumstances. It is hard to guess when current will flow or the severity of the hurts that might happen because the resistivity of human skin changes from just under a thousand ohms to several hundred thousand ohms depending mainly on skin moisture.

If a current higher than 0.02 A (only 20 milli amperes) flows through the human body, you are in severe risk because you may not be in a position to let go of the current transferring conductor. This small quantity of current can be forced through sweaty hands with a voltage as low as 20 V, and the bigger the voltage the bigger the possibility that current will flow. High voltage shock (>400 V), may burn away the protective layer of outer skin at the entry and exit points. When this happens, the body

resistance is decreased and lethal currents may cause momentary death. The data in Table 2 show currents that can cause severe injury or death.

Table 2. Electric shock hazards

| Reaction | AC | DC |
|--|--------|--------|
| Perception - Tingle, Warmth | 1 ma | 6 ma |
| Shock - retain muscle control, reflex may cause injury | 2 ma | 9 ma |
| Severe shock - lose muscle control, cannot let-go, burns, asphyxia | 20 ma | 90 ma |
| Ventricular fibrillation - probable death | 100 ma | 500 ma |
| Heart frozen -- body temperature rise, death will occur in minutes | > 1 A | > 1 A |

Electrical shock is painful, and a possibly minor hurt is often aggravated by the reflex reaction of jumping back away from the origin of the electric shock. Anytime a PV installation consists of more than two PV modules, a shock accident should be presumed to exist.

The best possible method to avoid electric shock is to measure (always measure) the voltage from any conductor to any other conductor, and to ground. Use a clamp-on ammeter to measure and record the current flowing in the conductors. Never disconnect a conductor before you have checked the voltage and current. Do not assume everything is in perfect order. Do not trust breakers to function perfectly and do not “believe” diagrams. A digital voltmeter is a great tool, and using it frequently could save your life.

Battery hazards

Any electrical system with battery packs is a potential hazard. Areas of concern are:

1. Electrical burns: Shorting the terminals of a common battery pack that might be found in a PV installation can cause currents of over 6000 A to flow for a few seconds. Serious burns and death can happen even if the voltage is low.
2. Acid burns: Any battery pack acid can induce burns if it comes in contact with unprotected skin. Contact with the eye may induce blindness.

3. Gas explosion or fire: Most battery packs used in PV installations release hydrogen gas as a product of the charging process. This flammable gas is a hazard, and all flames and devices that could create a spark-such as a controller with relays-need to be kept away from the battery packs. The battery packs should be placed in a well-ventilated area.

Any time you work with battery packs you need to wear protective clothing, gloves, and goggles to protect the eyes. A neoprene coated apron is encouraged if you are going to measure specific gravity or open the battery pack to put water to the electrolyte. Wear rubber boots.

AC power hazards

If alternating current (AC) power is to be provided, inverter unit is needed to change the DC power from the PV installation to AC power. This device will have high voltage at both input and output when in service. The output is usually 120 V or 240 V, and enough current will be present to kill. All of the cautions for AC circuits that are provided in the National Electric Code need to be followed.

Working safely with PV systems

Almost all PV installations that are used in the United States are covered by rules in the National Electric Code (NEC). The objective of the NEC is to assure safe electrical installations are engineered and installed. Some PV installation designers neglect the NEC because they don't think it is applicable to their installations. Usually they conceive the "Code" as an impediment and a few have spent more time trying to circumvent applicable rules than it would have taken to meet them. We need to accredit the Code for its purpose - a set of rules that have added to making the electrical installations in the United States one of the safest in the world. Even though meeting Code requirements can be frustrating at times, most supervisors are willing to listen and work with you if you are making a good faith attempt to satisfy the Code requirements and install and operate a safe PV installation. These paragraphs sum up some important issues dealt by the NEC and present some safety processes that should be followed when testing existing installations-some of which may not meet all Code requirements.

Relevant safety codes

The National Fire Protection Association has sponsored the National Electric Code since 1911. The NEC is a how-to guide that upgrades as technology evolves and component sophistication grows. The Code is modified every three years and in 1984, Article 690 was put to give regulations pertaining to solar PV installations. The NEC is not a PV installation design reference guide and does not attempt to make process easy for the engineer, installer, operator or maintenance staff. However, complying with the Code is not elective- it is the law in most areas. You can negotiate with the local supervisor, but you cannot bypass the set requirements.

There are other regulations and standards that have been made for PV installations and elements that touch on safety concerns. Underwriters Laboratory (UL) has produced construction regulations and test processes for PV modules and selected other elements that might be installed in a PV installation. However, few elements from PV manufacturers have been submitted for UL certification. The IEEE Standards 928 and 929 provide recommendations for engineering terrestrial PV installations and connecting them to the electrical transmission network.

We will mainly take into account the NEC, particularly Article 690 which addresses PV installations. Some of the other sections of the NEC that may be applicable are:

- Article 240 - Overcurrent Protection
- Article 250 - Grounding
- Article 300 - Wiring Methods
- Article 339 - Underground Feeders
- Article 480 - Storage Batteries
- Article 705 - Interconnected Power Sources
- Article 720 - Low Voltage Systems

Before engineering and installing a PV installation you need to read Article 690. It has eight sections, A through H, with data on the topics shown below.

| Section | Topic |
|-------------------------------|---|
| A General | 690-1 Scope 690-2 Definitions 690-3 Other Articles 690-4 Installation 690-5 Ground Fault Detection & Interruption |
| B Circuit Requirements | 690-7 Maximum Voltage 690-8 Circuits Over 150 Volts to Ground 690-9 Overcurrent Protection |
| C Disconnecting Means | 690-13 All Conductors 690-14 Additional Provisions 690-15 Disconnection of Photovoltaic Equipment 690-16 Fuses 690-17 Switch or Circuit Breaker 690-18 Disablement of an Array |
| D Wiring Methods | 690-31 Methods Permitted 690-32 Component Interconnections 690-33 Connectors 690-34 Access to Boxes |
| E Grounding | 690-41 System Grounding 690-42 Point of System Grounding Connection 690-43 Size of Equipment Grounding Conductor 690-44 Common Grounding Electrode |
| F Marking | 690-51 Modules 690-52 Photovoltaic Power Source |
| G Connection to Other Sources | 690-61 Loss of System Voltage 690-62 Ampacity of Neutral Conductor 690-63 Unbalanced Interconnections 690-64 Point of Connection |
| H Storage Batteries | 690-71 Installation 690-72 State of Charge 690-73 Grounding |

Engineering and operating a PV system- NEC directions

This section will emphasize the main requirements of the NEC that are applicable to the design and operation of PV installations. This list is a reduction of the Code requirements and not aimed to substitute or supplement the NEC. Hopefully, it will provide increased awareness of the NEC by naming the broad concerns in the Code that the engineer should study. This section is based on the latest version of the NEC with articles referenced by numbers in brackets.

System current and voltage

When designing a PV installation, take into account the following:

1. Use open-circuit voltage as the rated voltage in any PV source circuit. [690-7a]
2. Voltages should be less than 600 Volts. [690-7c]
3. Conductors and overcurrent elements shall be able to transfer at least 125% of the short-circuit current of the source circuit. (690-8)
4. PV source circuit, inverter, and battery conductors shall have overcurrent protection. [690-9a]
5. A sign indicating the PV system operating voltage and current, the open-circuit voltage, and the short-circuit current shall be placed near the system disconnect point. [690-52]

Wiring and disconnect requirements

The Code needs certain rules for color of conductors and defines requirements for disconnecting the power source. Particularly:

1. The grounded conductor is to be white. [200-6]. Convention is for the first ungrounded conductor of a PV installation to be red, and the second ungrounded conductor black (negative in a centre tapped PV installation).
2. Single-conductor cable is allowed for module connections only. Sunshine resistant cable need to be used if the cable is exposed. (690-31 b)
3. Modules should be wired so they can be removed without interrupting the grounded conductor of another source circuit. [690-4c]
4. Any wiring junction boxes should be accessible. [690-34]
5. Connectors must be polarized and guarded to prevent electric shock. [690-33]

6. Means to disconnect and isolate all PV source circuits will be given. [690-13]
7. All ungrounded conductors should be able to be disconnected from the inverter. [690-15]
8. If fuses are utilized, you must be able to disconnect the power from both ends. [690-16]
9. Switches should be accessible and clearly marked. [690-17]

Grounding

The objective of grounding any electrical installation is to prevent unwanted currents from flowing (especially through people) and potentially causing equipment failure, personal hurts and injuries, or death. Lightning, natural and man-made ground faults, and line surges can cause high voltages to exist in an otherwise low-voltage installation. Adequate grounding, along with overcurrent protection, limits the potential damage that a ground fault can cause. Take into account the following and note the difference between the element grounding conductor and the grounded system conductor:

1. One conductor of a PV installation (>50 V) must be grounded, and the neutral wire of a centre tapped three wire system must also be grounded. [690-41]. If these requirements are satisfied, this is regarded sufficient for the battery pack ground (if battery packs are part of the installation) [690-73]. A ground is made by making a solid low resistance link to a permanent earth ground. This is usually done by driving a metallic rod into the earth, preferably in a moist location. [250-83]
2. A single ground point should be made [690-42]. This will prevent the possibility of potentially harmful fault current transferring between separate grounds. In some PV installations where the PV array is placed far from the load, a separate ground can be used at each location. This will allow for better protection for the PV array from lightning surges. If multiple ground points are utilized, they should be bonded together with a grounding conductor.

3. All exposed metal parts shall be grounded (equipment ground). [690-44]
4. The equipment grounding conductor must be bare wire or green wire. [210-5b]
5. The equipment grounding conductor must be large enough to handle the highest current that could flow in the circuit. [690-43]

Output of the PV system

Before the PV array is linked to a load, battery pack, or inverter, there are certain requirements mentioned in the NEC. Additional battery pack requirements are provided in NEC Article 480.

1. If an inverter is utilized to interconnect the PV installation to an electricity network, it must disconnect automatically if the electricity network power goes off [690-61]. If the inverter is functioning in a standalone hybrid system, it may continue to provide power to the load.
2. The output of a single-phase inverter should not be linked to a three-phase service. [690-63a]
3. The AC output from a PV installation inverter must be grounded in accordance with requirements for AC installations. [250-5]
4. A switch or fuse/switch mechanism must be included so that the PV installation output can be disconnected. [690-64]
5. The interconnection shall be made so that all ground fault interrupters keep active. [690-4]
6. If battery packs are utilized in an installation, they must be guarded to forbid unauthorized access if the voltage is higher than 50 V D.C. Otherwise, the voltage must remain lower than 50 V D.C. [690-b]
7. Charge controllers must be used with battery packs. [690-72]

Safety suggestions for testing a PV installation

Usually it is necessary to troubleshoot a PV installation that is not functioning properly. Safety should be the main issue, both in planning before you go to the site and during the actual testing. Some suggestions are provided.

Remember: Do not inspect a PV installation alone!

Before inspecting any PV installation, you should become familiar with the electrical scheme. How many modules make up a source network? What are the system voltages? What is the system expected current? How many circuits are there? Do overcurrent devices exist? Where? How can the installation be disconnected? What safety devices can be used?

When you get to the PV installation site:

1. Remove jewellery
2. Walk around the PV installation and record any evident hazards in the installation logbook or a notebook. Take photographs of the installation and any hazards.
3. Locate the safety devices, fire extinguisher, etc. and check their condition. Where is the nearest telephone?
4. Check the actual installation configuration against the electrical diagrams.
5. Locate and inspect all subsystems such as the battery packs, inverter, and the load.
6. Find out if, how, and where the installation is grounded. Check to understand if the AC and DC grounds are common.
7. Locate and evaluate all disconnect switches. Check any fuses. Find out if the switches are made to interrupt both positive and negative wires.

8. Disconnect the source circuits and measure all open-circuit voltage to check the adequate operation of the disconnect switch.
9. Measure and record the voltage from each conductor to ground, and from line to line.

Only when you are sure that you realize the circuit should you proceed with inspection.

1. Keep the work area clear of obstacles, especially the surface behind you.
2. Never disconnect a wire before measuring voltages.
3. Keep your hands dry and/or wear gloves.
4. Work with only one hand if practically possible.
5. Have your colleague stationed near the disconnect switches.
6. Once a conductor is disconnected don't leave the end exposed--tape it or use a wire nut for temporary covering.
7. Reconnect the conductors from one source circuit before disconnecting a second source circuit.

For your health

This section provides a review of the first aid procedures that anyone working on PV installations should be familiar with. It is suggested that each person also conduct a CPR course or equivalent training provided by the American Heart Association or the American Red Cross. This course provides a summary of first aid recommendations, but it is not intended to substitute formal education and training in first aid or CPR. If you witness an accident or are the first person to arrive at the accident location:

1. Survey the scene for possible hazards. Try to figure out if a shock hazard still exists. Is a live wire still lying on or near the victim's body? Is the victim still

holding a live wire? Are there other hazards such as fire or spilled caustic material that would put you in risk? You will be safer in helping a victim if you are with someone else, but don't postpone your assistance to wait for a help. Also, be mindful that some otherwise reliable people cannot be trusted in an emergency cases-everyone acts differently. You are on your own to guard yourself and save the victim.

2. Check the victim for breathing and pulse. Find out the victim's condition.
3. Call for help and provide the victim's condition. During an emergency, do anything you can to rapidly attract attention to the scene. Call an ambulance, get someone else to do it, or even pull a fire alarm, but get trained emergency personnel to the scene as fast as possible. Then take care of the victim using accepted CPR techniques.

Both electrical and non-electrical injuries can happen when working around/with PV installations. First aid techniques for each will be described.

Non-electrical injuries

These injuries and hurts include cuts, sprains, broken bones, exposure, and insect or snake bites. In majority of the cases they are not life threatening, but if care is not instantly provided, the victim may go into shock and could die. Act quickly.

Cuts

Stop the bleeding by using the following techniques in this order: direct pressure, elevation, pressure points, and a pressure bandage. If feasible, apply direct pressure with a sterile dressing (gauze pad) between the wound and your hand. Use a clean cloth if a sterile dressing is not available. If bleeding does not stop, elevate the wound area if possible. If the wound is still bleeding, apply pressure on a nearby pressure point. For example, if the lower arm is cut, apply pressure with fingers on the middle inside of the upper arm where a pulse is felt. Lastly, use a pressure bandage by adding more sterile dressings if necessary and wrap with a roller bandage. Use overlapping turns to cover dressing and secure by tying off the bandage over the wound.

Sprains, strains, dislocations, and fractures

It is sometimes difficult to notice and tell the difference between these injuries so treat them all as you would a fracture. Help the victim to move into the shade and/or comfortable position with as little movement to the harmed area as possible. The injury (usually an arm or leg) needs to be splinted to reduce the pain and prevent further harm. Splints can be made from rolled up newspaper, magazines, pieces of wood, blankets, or pillows. The splint can be tied up with bandages or cloth (a shirt torn into strips will do). The following techniques are applicable. Splint only if you can do it without causing more harm and pain. Splint an injury in the position you find it. Immobilize the limb and joints above and below the injury. Check the blood circulation by pinching nail beds of the fingers or toes. Red color should return in two seconds--if not loosen splint. If the injury is a closed fracture (no bone extruding) apply a cold pack to it. Do not apply a cold pack to an open fracture.

Cold exposure

Persons exposed to extended periods of cold may suffer from hypothermia. Symptoms that may happen are shivering, feeling dizzy, confusion, or numbness. Take the victim to a warm place, remove wet clothing, and warm the body slowly. Call an ambulance. Do not provide drink or food unless the victim is fully conscious. If fully conscious give him a warm drink a little at a time. Check the temperature of the drink.

Heat exposure

This is a usual hazard for PV installation maintenance staff because of the location of the installations. If you or your partner has cramps, heavy sweating, cool and pale skin, dilated pupils, headaches, nausea, or dizziness you may be reaching heat exhaustion. Bring the victim to the shade and provide him one-half glassful of water (if he can tolerate it) every 15 minutes. If heavy sweating happens have the victim lie down and raise his feet, loosen clothing, and put wet towels or sheets over him. If the victim has red dry skin, he may have heat stroke, which is life-threatening. Immerse in cool water, if possible, or wrap the body with wet sheets and/or fan the victim. Don't provide him anything to drink. Call an ambulance.

Insect/Snake bites

A small number of people may have an allergic reaction to an insect bite or sting. In these circumstances, it could be life-threatening. Signs of an allergic reaction are pain, swelling of the throat, redness or discoloration, itching, hives, decreased consciousness, and difficulty in breathing. If these symptoms happen call an ambulance. If a stinger from an insect is implanted into the flesh remove it (do not squeeze it). Then clean the area and put on a cold pack with a cloth between the skin and the ice. Try to arrange the victim so the bitten area is below the heart. Few people die from snake bites. However, if someone is hurt by a snake, they should promptly receive medical help. Call an ambulance. Keep the victim still and the bitten area below the heart to slow absorption of the snake venom. A splint can be utilized if the bite is on an arm or leg. Try to remember what the snake looked like. Do not cut a snake bite and try to suck the venom out.

Electrical injuries

The main priority in helping harmed people should always be your (the rescuer's) safety. This is particularly important in situations involving electrical hazards. Avert becoming a second victim. Electrical injuries consist mainly of shocks, burns, muscle contractions, and traumatic injuries related with falls after electric shocks. Electric shock is an overall term suggesting any situation where electric current flows through the body. The strength of a shock can range from a barely perceptible tingle, to a strong zap, to instant death. A stabbing pain or intense tingling and burning is frequently associated with electric shock. The points of entry and exit are usually badly burned.

Usually a shock involves involuntary muscle contraction. In the case strong muscles of the back and legs contract, this can lead to falls and broken bones. The big muscles of the chest, throat and diaphragm can contract and cause respiratory attacks.

When electric current goes through the heart, it can cause a spasmodic contraction and relaxation of the ventricles, called ventricular fibrillation. This is one of the main causes of death associated with shocks. Once a person's heart has begun fibrillating, it is hard to stop. Sometimes another electric shock, administered by a paramedic

using a defibrillator, can fix the heart to its normal beating cycle. Victim fibrillation requires trained (paramedic) assistance in minutes if they are to stay alive.