Working Safely with Photovoltaic Systems
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• Construction is the industry where most accidents occur
• There isn’t such a thing like being overly prepared – Expect the unexpected!
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Non-Electrical Hazards:

- **Exposure**: PV systems are installed where the sun is the brightest and no shade exist.

  - **You Should**:
    1. Wear a hat
    2. Keep your limbs covered
    3. Use plenty of sunscreen with a rating of 15 or higher
    4. Drink plenty of liquid (Gatorade or any beverage helps you to maintain the right level of salt, minerals and electrolytes is recommended - never alcoholic)
    5. Dress warmly during wintertime
Insects, snakes and other vermin

- Spiders, wasps and other insects often move in and inhabit junction boxes in PV systems.
- Rattlesnakes frequently use the shade provided by the array.
- Scorpions, spiders and fire ants are commonly found under arrays or near battery storage boxes.

- You should:
  1. Be careful before you crawl under the array.
  2. When you open a j-box be cautious and look for cobwebs, nests or any other clue that would indicate the presence of undesirable insects.
Cuts and bumps

- Most PV systems contain metal framing, junction boxes, bolts, nuts. Many of these items can have sharp edges.
- Metal slivers from a drill bit often remain around a hole

**You should:**

1. Wear gloves when handling metal. – It will prevent cuts and burning yourself with metallic object which are very hot after having been in the sun for a few hours.
2. Wear a hard hat made of non-conducting material – if you are under the array or on a system with hardware higher than your head.
Falls, sprains and strains

- Many solar systems are either mounted on roofs or in remote areas in rough terrain.
- Walking around the site, particularly carrying materials or test equipment, can result in falls and/or sprains

- You should:
  1. Wear comfortable shoes, preferably with soft soles – no steel toe reinforced shoes
  2. Lift with the legs and not with the back
Burns – Thermal

- Metal left exposed in the sun can reach temperatures of 80° C
- Concentrating PV system pose and added burn hazard, exceeding 100° C. Momentary contact can cause serious burns.

**You should:**
1. Wear gloves
2. Make sure that you don’t bump into cooling elements
3. Be cautious at all times
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Burns – Acid

- Stand alone systems and PV systems with battery back up contain batteries.
- A large percentage of batteries contain sulfuric acid
- Sulfuric acid will cause severe burns if it makes contact with an unprotected part of the body
- Eyes are particularly vulnerable

-You should:
  1. Wear non-absorbent gloves
  2. Protective eyewear
  3. A neoprene coated apron
  4. Never put any clothes that have come into contact with sulfuric acid in the washer machine
Electrical Hazards

• The human body is extremely susceptible to electric current (more than 0.02 amps can put you in serious danger)
• For low voltage PV systems (smaller than 50V) the likelihood of receiving lethal current is small because you’re protected by high skin resistance – however, sweaty hands and cuts can allow a low resistance path that can cause serious injury.
• High voltage shock (less than 400V) will burn away the protective layer of outer skin at the entry and exit points. High current will cause instant death.
• Many traumatic injuries are caused by falls or collision with hard objects as we recoil from the shock
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## Electric Shock Hazards

<table>
<thead>
<tr>
<th>Reaction</th>
<th>60Hz AC</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perception - Tingle warmth</td>
<td>0.001</td>
<td>0.006</td>
</tr>
<tr>
<td>Shock - Retain muscle control; reflex may cause injury</td>
<td>0.002</td>
<td>0.009</td>
</tr>
<tr>
<td>Severe shock - Lose muscle control, cannot let go; burns; asphyxia</td>
<td>0.02</td>
<td>0.09</td>
</tr>
<tr>
<td>Ventricular fibrillation</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Heart frozen - Body temperature rise; death will occur in seconds</td>
<td>&gt; 1</td>
<td>&gt; 1</td>
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</tbody>
</table>
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- Predicting the effect of electrical shock is difficult and depends on size, weight and condition of person; voltage and frequency of the source; and duration of contact with the source.
- Anytime a PV array contains more than 2 PV modules, a shock hazard should be presumed to exist (modern panels could make this possible even with one panel)

**You should:**
1. Measure voltage from any wire to any other wires and to ground
2. Never disconnect a wire before you have check the voltage and current
3. Don’t presume that everything is in perfect order, don’t trust switches to operate perfectly, and don’t believe schematics
Chemical Hazards

- Any system with batteries is a potential hazard. The three areas of concern are:
  a. Electrical burn: shorting the terminals of a typical battery that may be found in a PV system can cause currents of over 6000 amps to flow for a few seconds. Severe injuries can occur even though the voltage is low.
  b. Acid burns: battery acid will cause burn if it contact exposed skin. Contact with the eye may cause blindness.
  c. Gas explosion or fire: most batteries used in PV system release hydrogen gas as a result the charging process. This flammable gas hazard particularly in a confined area.

- You should:
  1. Keep all equipment that could make a spark away from the batteries
  2. Locate batteries in a ventilated area
  3. Anytime you work with batteries you should cover any exposed skin, put on protective clothing, gloves and goggles.
  4. Wear rubber boots.
AC Power Hazards

- The output of most inverters is 120 V AC or 240 V AC at 50 or 60 Hz
- 50 or 60 Hz are the frequencies at which the human body is most susceptible
- Any inverter found in a PV system can produce enough current to kill

Safe PV systems

- Several standards contribute to safe PV systems, for instance all parts should be Underwriters Laboratory listed or approved by the authority having jurisdiction.
- PV systems should be installed in compliance with the NEC regulations
- Since 1984 the NEC has included article 690, which covers the unique aspects of photovoltaic systems. Other sections that apply are:
  a. Article 240 – Overcurrent protection
  b. Article 250 – Grounding
  c. Article 300 – Wiring methods
  d. Article 339 – Underground feeders
  e. Article 480 – Storage batteries
  f. Article 705 – Interconnected power sources
  g. Article 720 – Circuits less than 50 volts
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System Current and Voltage

- 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 [690-53]
- Voltages for most systems shall be less than 600 volts [690-7c]
- Conductors and overcurrent devices shall be able to carry at least 156 percent of the short-circuit current of the PV source [690-8]
- Single-conductor cable is permitted in PV source circuits. Sunlight-resistant cable shall be used if the cable is exposed. [690-31b]
- Modules shall be wired so they can be removed without interrupting the grounded conductor of another source circuit [690-4c]
- Any wiring junction boxes shall be accessible for maintenance [690-34]
- Means to disconnect and isolate batteries, inverters and other equipment from all power sources shall be provided [690-15]
Grounding

- The purpose of grounding any electrical system is to prevent unwanted currents from flowing (specially through people) and possible causing equipment damage, personal injury or death.
- One conductor of a PV system (>50 V) must be grounded, and the center tap of a three-wire system must be also grounded [690-41]
- A single ground point shall be made [690-42]
- All exposed metal parts shall be grounded (equipment ground) [690-43]
- The equipment grounding conductor shall be bare wire or green wire [250-110]
- The equipment grounding conductor shall be large enough to handle the highest current that could flow in the circuit [690-45]

The PV System Output

- If any inverter is used to interconnect the PV system to a utility, it shall disconnect automatically if the power goes off [690-61]
- The ac output from a utility –interactive PV system inverter shall be grounded in accordance with the requirements for ac systems. [250-20]
Testing a PV System – Safety Hints

When you get to the PV System site:

- Remove jewelry
- Walk around the PV system and record any apparent hazards in the system logbook or a note book.
- Locate the safety equipment – i.e. fire extinguisher, first aid kit, etc.
- Check the actual system configuration against the schematics
- Locate and inspect all subsystems: batteries/panels, inverters, service panels, and load.
- Determine if, how and where the system is grounded
- Locate and inspect all disconnect switches – Check any fuses and determine if the switches are designed to interrupt both positive and negative conductors.
- Measure voltage from each conductor to ground and from line to line
Other Suggestions

- Keep the work area clear of obstacles
- Never Disconnect a wire before measuring voltages
- Keep your hands dry and/or wear gloves
- Once a wire is disconnected DON’T leave the end exposed- tape it or use a wire nut for temporary covering
- Reconnect the wires from one source circuit before disconnecting a second source circuit.
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Job Safety

- The Division of Occupational Safety (DOSH) is responsible for the enforcement of the California Occupational Safety Health Act (Cal/OSHA).
- Most inspections result from complaints filed by employees in the field but random inspections are conducted on a regular basis.
- It is illegal for an employer to refuse entry to DOSH personnel for any reason and a warrant will be obtained if necessary.
- All employers shall have and maintain an effective injury and illness prevention program.
- The construction or demolition of any building, structure, falsework, or scaffolding that is more than three stories in height will require a permit from DOSH before it can be initiated.
- Employees working with a hazardous material must be provided with a Material Safety Data Sheet for the material s/he is working with.
- Except for an injury that only requires first aid treatment, ALL injuries and illnesses work related must be reported.