ACP 6000-2-2024

Solar Photovoltaic (PV) Energy Entry-Level Technician Minimum Standard

December 2024

AMERICAN CLEAN POWER ASSOCIATION

Standards Committee

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Published by:

American Clean Power Association

1501 M Street, N.W.,

Suite 900

Washington D.C. 20005

www.cleanpower.org

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FOREWORD AND BACKGROUND

The Foreword and Background sections are included with this document for information purposes only and are not part of the American Clean Power Association (ACP) ACP 6000-2-2024 *Solar Photovoltaic (PV) Energy Entry-Level Technician Minimum Standard*.

Foreword

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Background

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1 Scope

The American Clean Power Association has created this entry-level, utility-scale solar photovoltaic (PV) operations and maintenance technician guideline to establish minimum competencies for such entry-level technicians. This standard establishes the minimum knowledge, skills, abilities, and competencies for an entry-level solar PV operations and maintenance technician to safely perform required and supervised preventive and corrective maintenance.

2 Purpose

This framework is intended to assist employers, workforce development and training professionals, academia, and others with standardized training and education for entry-level, utility-scale solar PV operations and maintenance technicians, serving as a point of reference for the development of a minimum program curriculum base. Programs should meet or exceed the framework developed.

It is important to note that employers within the solar PV energy industry are diverse. This standard is only intended to be a starting point in one's journey as a solar PV operations and maintenance technician in the United States. Each employer will require new hires and their employees to abide by their policies and procedures. This standard is not intended to conflict or contradict their policies, procedures, or expectations.

3 Terms and Definitions

Term	Definition
AC	Alternating current is an electric current that reverses its direction at regularly recurring intervals.
AED	An automated external defibrillator (AED) is a lightweight, portable device that delivers an electric shock through the chest to the heart.
arc flash	A dangerous condition associated with the release of energy caused by an electric arc that can create a high-intensity flash of light and heat (NFPA 70E).
array	The complete power-generating unit, consisting of any number of PV modules, typically connected in "strings."
arrestors	Typically installed near critical appliances or points of entry, such as an electrical panel or near a generator. When potentially dangerous lightning strikes, the arrester activates and diverts the lightning to ground, where it will disperse harmlessly.
bussing – busbars or bus conductors	Typically, metal bars or strips made of copper or aluminum – connect multiple electrical circuits within a system, serving as common points for distributing power.
CFR (*Code of Federal Regulations*)	The codification of the general and permanent rules and regulations (sometimes called administrative law) published in the Federal Register by the executive departments and agencies of the federal government of the United States.
CIP	Critical infrastructure protection.
clamp-on ammeter	A portable test instrument that measures current in a circuit by measuring the magnetic field's strength around a single conductor. Also frequently referred to as an amp clamp.
combiner boxes	Combines multiple direct current (DC) inputs from a solar PV array to a positive and negative feeder that then is connected to the inverter DC bussing.

Term	Definition
combined sensor	Integrates multiple monitoring functions, such as irradiance, temperature, wind speed, and humidity, to optimize system performance and efficiency.
CPR (cardiopulmonary resuscitation)	Cardiopulmonary resuscitation (CPR) is a technique designed to temporarily circulate oxygenated blood through the body of a person whose heart has stopped.
DC (direct current)	An electric current flowing in one direction only.
EAP (Emergency Action Plan)	Formalized written document that outlines the emergency response for personnel at a facility or site to include organizational actions for employees or personnel.
EL (entry level)	A job that is normally designed or designated for recent graduates of a given discipline and typically does not require prior experience in the field or profession. These roles may require some on-site training.
GED	Originally an acronym for the tests of General Educational Development (GED). Earning a GED diploma from a state is the equivalent to a U.S. high school diploma, so some students choose to take this certification exam if they were not able to complete a traditional high school program.
GSU (generator step up)	Very common in utility scale applications; sometimes also MPT or main power transformer.
high-voltage proximity detector	An electrical tester that helps to detect the presence of voltage. Voltage presence is useful information to have when troubleshooting or working on a failed asset.
I-V curve	Current-voltage characteristic curve, the “I” stands for current, and the “V” standards for voltage. An I-V curve is a graphical representation of the relationship between the voltage applied across an electrical device and the current flowing through it. This can be used to detect PV module mismatches, degradation, angle variations, or soiling that may impact the performance of a solar PV system.
I-V curve tracer	Specialist types of test equipment that sweep an electrical load connected to the solar PV module or string and measure both the current and voltage at multiple points during the sweep.
infrared thermal imaging camera	Used for building inspections (moisture, insulation, roofing, etc.), firefighting, autonomous vehicles and automatic braking, skin temperature screening, industrial inspections, scientific research, and much more.
inverters	The function of an inverter is to convert DC, produced by a battery or solar panel, into alternating current (AC).
JHA (job hazard analysis)	A job hazard analysis is a technique that focuses on job tasks to identify hazards before they occur. It focuses on the relationship between the worker, the task, the tools, and the work environment.
LOTO (lockout/tagout)	A safety procedure used in industry and research settings to ensure that dangerous machines are properly shut off and not able to be started up again prior to the completion of maintenance or repair work. Also frequently referred to as hazardous energy control.
LOTO affected employee from *CFR* 29 §1910.147(b)	An employee whose job requires him or her to operate or use a machine or equipment on which servicing or maintenance is being performed under lockout or tagout, or whose job requires him or her to work in an area in which such servicing or maintenance is being performed.
LOTO authorized employee from *CFR* 29 §1910.147(b)	A person who locks out or tags out machines or equipment to perform servicing or maintenance on that machine or equipment. An affected employee becomes an authorized employee when that employee’s duties include performing servicing or maintenance covered under this section.

Term	Definition
megohmmeter	Used to measure insulation resistance and powered by an inbuilt DC generator or battery of a higher voltage range.
MPP (maximum power point)	The maximum power produced by a PV module or string of modules, graphically represented as the “knee” of an I-V curve where the current and voltage produce the maximum power.
MPPT (maximum power point tracker)	Feature of PV inverters to track the power output and adjust the voltage to generate the maximum power for that circuit.
multimeter	An electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter may include features such as measuring voltage, current, and resistance.
NERC	The North American Electric Reliability Corporation.
NFPA (National Fire Protection Association)	A global self-funded nonprofit organization, established in 1896, devoted to eliminating death, injury, property, and economic loss due to fire, electrical, and related hazards.
OSHA (Occupational Safety and Health Administration)	An agency of the United States Department of Labor. Congress established the agency under the Occupational Safety and Health Act (OSH Act), which President Richard M. Nixon signed into law on December 29, 1970. OSHA’s mission is to ensure “safe and healthy working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education, and assistance.” The agency is also charged with enforcing a variety of whistleblower statutes and regulations.
PJB (pre-job briefing)	Gathering of workers to discuss work scope and hazards involved, responsible workers, associated work areas, or system impacts. The pre-job briefing ensures that the person in charge (PIC) and associated workers understand the scope of the work to be performed by discussing the tasks involved.
PMT (pad-mounted transformer)	A ground-mounted electric power distribution transformer in a locked steel cabinet mounted on a concrete pad.
POI (point of interconnection)	The point at which a solar PV system, or generating asset, is electrically connected to the electrical grid.
PPE (personal protective equipment)	Equipment worn to minimize exposure to hazards that cause serious workplace injuries and illnesses. These injuries and illnesses may result from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards.
PV (photovoltaic)	Conversion of light into electricity using semiconducting materials that exhibit the PV effect; typically used are PV solar cells that are electrically connected and designed to make a solar module (also referred to as a solar panel).
PV system	A photovoltaic system employs solar modules, each comprising several solar cells, which generate electrical power. PV installations may be ground-mounted, rooftop-mounted, wall-mounted, or floating. The mount may be fixed or use a solar tracker to follow the sun across the sky.
SCADA (Supervisory Control and Data Acquisition)	A control system architecture that uses computers, networked data communications and graphical user interfaces for high-level process supervisory management but uses other peripheral devices, such as programmable logic controller and discrete proportional–integral–derivative controllers, to interface with the process plant or machinery.
SPCC (Spill Prevention, Control, and Countermeasures)	Site-specific plan that develops, maintains, and implements prevention and action requirements for oil/chemical spills.

Term	Definition
string	Group of PV modules connected in series, through positive and negative leads.
three-part communication	Three-part communication begins with (1) the sender who gets the attention of the receiver, (2) the receiver receiving the message and repeating it for clarification and verification that the message was understood as intended, and (3) the sender acknowledges that the receiver heard and understood the message.
trackers	Mechanical device that orients a payload, such as solar panels, toward the sun to optimize solar production throughout the day as the sun moves across the sun.
UPS (uninterruptible power supply)	A device used to back up a power supply to prevent devices and systems from power supply problems, such as a power failure or intermittent outages. Frequently to keep monitoring and control systems online for renewable facilities.

4 General

4.1 The core competencies detailed in this document are divided into five (5) knowledge base areas: general work skills, operational theory and skills, safety training and skills, mechanical theory and skills, and electrical theory and skills.

4.2 Each skill set outlines minimum competencies that individuals should demonstrate to qualify as an entry-level solar PV technician.

5 General Work Skills

5.1 At the conclusion of a training program, the worker shall demonstrate the following:

5.1.1 Broad competencies aimed at ensuring confidence in general knowledge and skill sets, such as basic office, computer, communication, and soft skills

5.1.2 Understanding of physical requirements and fitness for duty, i.e., lifting, walking, and extreme weather exposure as relevant (heat, cold, precipitation, etc.)

5.1.3 Basic math skills

5.1.4 Professional oral and written communication skills

6 Operational Theory and Skills

6.1 Solar PV fundamentals:

6.1.1 Demonstrate an understanding of solar facility infrastructure, the components of the system's life cycle, PV fundamentals, and overall system operation

6.1.2 Identify, describe, interpret, and distinguish types of drawings (electrical, civil, and mechanical schematics)

6.1.3 Explain the basic principles of how solar PV systems work, and how they convert sunlight into electrical energy

6.1.4 Describe basic parts of solar PV modules

6.1.5 Describe Maximum power point (MPP)

6.1.6 Describe the basic function of an inverter:

6.1.6.1 Describe the difference between string inverters and central inverters

6.1.6.2 Describe MPPT

6.1.7 Demonstrate basic understanding and knowledge of the function and operation of each type of mounting system (fixed-tilt, single-axis tracker, dual-axis tracker):

6.1.7.1 Describe the basic wind stow and inclement weather operation

6.1.8 Describe different overcurrent protective devices (fuses, motor protection, circuit breakers, etc.) and surge protection devices:

6.1.8.1 Describe the protocol for system verification after a lightning strike nearby or within the plant

6.2 Describe site access procedures and restrictions

6.3 Describe NERC CIP regulations and cyber security in regard to site access, critical infrastructure control, and reporting requirements

6.4 Describe environmental rules and regulations, including waste handling, spill response for the chemicals in use on the site, permit conditions, and Spill Prevention Containment Countermeasures Plan and compliance

6.5 Demonstrate basic understanding and knowledge of electrical grid infrastructure to include power generation, transmission, and distribution levels

6.6 Demonstrate a basic understanding of site inspection maintenance:

6.6.1 Demonstrate understanding, knowledge, typical frequency, and practical ability

6.6.2 Describe what to look for during a site visual inspection

6.7 Demonstrate an understanding of the considerations for replacing solar PV modules, including proper handling, storage, and packaging of damaged modules

6.8 Demonstrate a basic understanding of wire management:

6.8.1 Demonstrate distinct types of electrical wiring and conductors on PV sites:

6.8.1.1 Describe general purpose of inline fuses for DC array

6.8.1.2 Demonstrate knowledge and understanding of mating connectors (e.g., MC4 connectors)

6.8.1.3 Describe typical failure modes of mating connectors

6.8.1.4 Demonstrate the ability to properly disconnect and connect mating connectors

6.8.1.5 Demonstrate the ability to replace failed mating connectors

6.9 Demonstrate a basic understanding, knowledge, and practical skills related to standard inverter maintenance requirement:

6.9.1 Describe the general operational modes of a solar PV inverter

6.9.2 Demonstrate basic understanding and knowledge understanding, knowledge, and practical ability of standard inverter maintenance requirements

6.9.3 Demonstrate understanding inverter human-machine interface

6.9.4 Describe inverter operational state, production, and faults

6.9.5 Demonstrate operations of the inverter based on operating procedures

6.9.6 Demonstrate proper inspection, use, and operation of a variety of electric, hydraulic, and hand tools

6.9.7 Demonstrate ability to clean/replace inverter cooling system filters or air intakes/exhausts

6.10 Demonstrate a basic understanding, knowledge, and practical skills related to combiner boxes, disconnects, and isolating devices:

6.10.1 Distinguish between load-break and non-load-break rated disconnects

6.10.2 Demonstrate knowledge of combiner box and disconnect maintenance procedures

6.10.3 Describe common failure modes of combiner boxes and disconnect components

6.10.4 Demonstrate the ability to check DC voltage and current at each combiner box or disconnect to identify performance issues

6.10.5 Show competence in safely opening and closing fused disconnects and replacing fuses

6.11 Demonstrate an understanding of single-axis tracker components and their functions:

6.11.1 Describe basic operation of trackers, including the following:

- **6.11.1.1** Normal, programmable operation
- **6.11.1.2** Stow position
- **6.11.1.3** Manual operations
- **6.11.1.4** Mechanical limits

6.11.2 Demonstrate an understanding of tracker maintenance

6.11.3 Describe potential tracker failures, misalignment, or performance issues and their impact on system production

6.12 Demonstrate understanding and knowledge of meteorological ("met") stations to include the following:

6.12.1 Irradiance sensor purpose and maintenance

6.12.2 Ambient temperature sensor purpose and maintenance

6.12.3 Wind speed sensor purpose and maintenance

6.12.4 Back of module temperature purpose and maintenance

6.12.5 Barometer purpose and maintenance

6.12.6 Relative humidity sensor purpose and maintenance

6.12.7 Combined sensor purpose and maintenance

6.13 Demonstrate an understanding of the use of testing equipment:

06.13.1 Infrared thermal imaging camera

6.13.2 Hand-held irradiance sensor

6.13.3 Hand-held temperature gun/infrared thermometer

6.14 Demonstrate an understanding of solar PV module cleaning

6.15 Demonstrate an understanding of the use of SCADA systems

7 Safety Training and Skills

7.1 Safety training and skills:

7.1.1 Successfully complete OSHA 10-hour course (or equivalent) course

7.1.2 Successfully complete a Hazardous Communication course under *CFR* 29 §1910.1200. Be able to articulate, based on a safety data sheet for a chemical used in the workplace, the PPE required, first

aid to be rendered, the physical handling characteristics, combustion characteristics, chemical reactivity, and waste disposal

7.2 Recognize and understand employee responsibilities for workplace electrical safety requirements under *CFR* 29 §1910.269, *CFR* 29 §1910 Subpart S, and NFPA 70E

7.3 Demonstrate an understanding of LOTO. Identify a system the energy isolating devices. Identify a LOTO lock, tag, and articulate the conditions for both application and removal. Articulate the functions of the authorized person and the affected person per company LOTO policy; *CFR* 29 §1910.147

7.4 Using an equipment manual, articulate the safety hazards and proper PPE when using tools or around specified machinery

7.5 Successfully complete a nationally recognized first aid course (i.e., American Red Cross, American Heart Association, National Safety Council, Global Wind Organization, etc.), including bloodborne pathogens training. Recognize and treat medical injuries, including CPR and use of an AED

7.6 Complete training on the site's Emergency Action Plan including communications, evacuations, and locations

7.7 Complete training on the site's spill response procedures, typically SPCC Plan

7.8 Describe the safety risks and hazards of the solar PV facility, to include the following:

7.8.1 DC and AC voltages and locations of the equipment

7.8.2 Arc flash:

7.8.2.1 Articulate the meaning of the various distances and energy levels on the arc flash label

7.8.2.2 Identify the PPE requirements for a piece of equipment based on its arc flash label and a scope of work with an exposed conductor

7.8.2.3 Articulate the proper boundaries for a piece of site equipment based on posted arc flash label given various levels of PPE, including the safe distance for an untrained person without PPE

7.8.3 Demonstrate the ability to perform a job safety analysis and document on an appropriate form. Use work instructions, equipment manuals, safety data sheet, and other resources based on a specified scope of work

7.8.4 Discuss and demonstrate an understanding of the hazards associated with night work, including the differences in response times between night shifts and normal business hours

8 Mechanical Theory and Skills

8.1 Identify, describe, and understand the following:

8.1.1 Describe mechanical leverage and demonstrate with various lengths of wrenches

8.1.2 Demonstrate setting torque with a torque wrench

8.1.3 Articulate the meaning of a torque mark

8.1.4 Understand maintenance/visual inspection of bearings

8.1.5 Understand the basic concepts of gears

8.1.6 Explain the use of couplings to connect rotating shafts for tracker systems

8.2 Fasteners, torque, and tension:

8.2.1 Demonstrate the basic understanding of the following:

8.2.1.1 Diverse types of fasteners

8.2.1.2 Proper techniques of mechanical, electrical, and hydraulic torque wrench assembly and use

8.2.1.3 Torque patterns

8.2.1.4 Difference between torque and tension

8.2.1.5 Measurements of torque

8.2.1.6 Proper use of washers and bushings

8.2.1.7 Difference between dry vs. lubricated threads

8.2.1.8 Proper techniques for torque marking

8.2.1.9 Use of various torques

8.3 Tracker mechanics:

8.3.1 Discuss and demonstrate an understanding of the following:

8.3.1.1 Types of gear and actuator trackers

8.3.1.2 Gearbox cleanliness, lubrication, and impurities

8.3.2 Demonstrate proper grease or lubrication maintenance for tracker systems

8.3.3 Discuss inspection methods to determine normal wear or damage

8.4 Transformer oil sampling:

8.4.1 Explain the proper safety procedures for oil sampling of transformers

8.4.2 Understand the process and significance of oil sampling including proper record keeping

8.4.3 Explain oil spill prevention techniques and the ability to report and clean up any spills observed or caused by work being performed

8.5 Tools and test equipment:

8.5.1 Demonstrate proper PPE for mechanical work and be able to identify the risks and hazards applicable to the tools and test equipment including hand and power tools

8.5.2 Describe the ergonomic hazards of vibration involved with tooling

8.5.3 Understand the difference between tool sizes and measurements to perform the job safely

8.6 Lifting equipment:

8.6.1 Demonstrate understanding of lifting mechanisms to include the following:

8.6.1.1 Breaker rack-out system

8.6.1.2 Inverter module lifting mechanism

8.6.1.3 General rigging operations

8.7 Cooling system:

8.7.1 Demonstrate understanding of cooling system purpose and components for solar PV inverters

8.7.2 Discuss general knowledge of the operation and inspection of cooling systems for inverters

8.7.3 Demonstrate understanding of the maintenance and replacement of the following:

8.7.3.1 Filters

8.7.3.2 Fans

8.7.3.3 Cooling fluid

8.7.3.4 Pumps

9 Electrical Theory and Skills

9.1 Electrical theory and skills:

9.1.1 Demonstrate basic understanding of electrical systems, symbols, and charts

9.1.2 Basic electrical theory and general knowledge:

9.1.2.1 Electrical Safety – describe general electrical safety awareness

9.1.2.2 Demonstrate proper identification of basic electrical meters and safe measurement techniques:

9.1.2.2.1 Meggers

9.1.2.2.2 Amp clamps

9.1.2.2.3 Multimeters

9.1.2.2.4 High-voltage proximity probe

9.1.2.2.5 Process for establishing and verifying an electrically safe work condition, commonly referred to as “live-dead-live” or “hot-cold-hot”

9.1.3 Demonstrate knowledge of AC/DC theory including being able to measure resistance, voltage, current, and power:

9.1.3.1 Demonstrate knowledge of the difference between series and parallel circuits and the impact of the configuration on system parameters

9.1.3.2 Demonstrate knowledge of electrical laws:

9.1.3.2.1 Ohm’s Law

9.1.3.2.2 Kirchhoff’s Laws

9.1.3.2.3 Power Law

9.1.4 I-V curve tracer:

9.1.4.1 Describe I-V curve tracing tools

9.1.4.2 Assist with field application of I-V curve tracing

9.1.5 Grounding:

9.1.5.1 Describe understanding of equipment grounding conductors

9.1.5.2 Describe understanding and knowledge of installed system ground

9.1.6 Inverters:

9.1.6.1 Describe general knowledge of function and operation of inverters

9.1.6.2 Demonstrate understanding of inverter electrical ratings

9.1.6.3 Identify components of inverter

9.1.7 Transformers:

9.1.7.1 Describe general knowledge of function and operation of transformers

9.1.7.2 Describe differences and similarities for the following transformers:

9.1.7.2.1 Main power transformer (GSU or substation)

9.1.7.2.2 PMT

9.1.7.2.3 Auxiliary transformer

9.1.8 Describe general knowledge of function and operation of protection relays

9.1.9 Demonstrate the understanding of checking fuse continuity

9.1.10 Describe general knowledge of function and operation of recloser or point of interconnection switchgear

9.1.11 Describe general knowledge of fiber optics:

9.1.12 Storage devices: expand to include knowledge function and dangers:

9.1.12.1 UPS:

9.1.12.1.1 Describe types and purposes of UPS for solar facilities

9.1.12.1.2 Describe danger associated with UPS

9.1.12.1.3 Describe isolation of UPS

9.1.12.2 Capacitor banks:

9.1.12.2.1 Describe types and purposes of capacitor banks used in the inverter

9.12.2.2 Describe danger associated with capacitor banks

9.1.13 Demonstrate understanding of the National Electrical Manufacturer Association/ingress protection enclosure ratings

10 References

Reference Title	Reference Number
Labor, Regulations Relating to Labor, Occupational Safety and Health Administration, Department of Labor, Occupational Safety and Health Standards; The Control of Hazardous Energy (Lockout/Tagout)	*CFR* 29 §1910.147
Labor, Regulations Relating to Labor, Occupational Safety and Health Administration, Department of Labor, Occupational Safety and Health Standards; Electric Power Generation, Transmission, and Distribution	*CFR* 29 §1910.269
Labor, Regulations Relating to Labor, Occupational Safety and Health Administration, Department of Labor, Occupational Safety and Health Standards; Hazard Communication	*CFR* 29 §1910.1200
Labor, Regulations Relating to Labor, Occupational Safety and Health Administration, Department of Labor, Occupational Safety and Health Standards, Subpart S—Electrical	*CFR* 29 §1910 Subpart S
Standard for Electrical Safety in the Workplace	NFPA 70E