Guidelines for Solar PV Operations Qualified Electrical Workers

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Introductory Information

Building, operating, and maintaining any power generation project requires an elevated level of electrical safety awareness, training, technical skills, knowledge, and the personal discipline to always act in a safe manner. Photovoltaic Solar (Solar PV) energy sites are unique in that there are so many tasks to be performed by so few technicians, often without the specializations found in traditional generation facilities. Electrical safety training is critical for all workers and managers, but each task on a solar PV site presents different hazards and mitigation procedures. Only those workers with the proven knowledge and skills for a task should be asked to perform that task, including the details of any electrical hazards that might arise and how to adequately safeguard themselves from those hazards. The purpose of this document is to develop a basic set of criteria for a Qualified Electrical Worker (QEW) program with suggestions for developing the training, managing the verification of skills and the implementation in the field including both the technical skills and the electrical safety elements to be considered. This is intended as a guideline to assist companies in preparing their own QEW program. Companies may consider this material in this guideline in accordance with their internal safety and other operating requirements as well as all applicable laws and regulations.

Solar PV technicians are expected to perform a wide variety of tasks, both mechanical and electrical, which can be extremely dangerous without proper training. Working in harsh environments and with changing conditions obviously complicates the situation. Additionally, they often work without direct supervision, so it is critical that skills be taught, and competency verified before the technician is considered qualified to perform the task alone. It is also critical that a culture of personal responsibility and an elevated level of conformance to procedures is nurtured as a part of the overall operational management strategy. Technicians can only be expected to remain safe if they clearly understand the risk associated with given tasks and are self-motivated to avoid unnecessary risk to themselves or others.

The guidelines and suggestions in this document may prove useful for both construction and maintenance technician. Although various agency requirements may apply, the focus will be primarily on operations and maintenance personnel as most construction tasks are performed before the site is energized and the general safety requirements for construction are well documented. Acceptance testing and commissioning technicians typically face the same challenges as the O&M staff and should be qualified appropriately.

Table of Contents

Scope and Purpose

Scope: This document provides guidance for the development of a solar PV energy industry Qualified Electrical Worker (QEW) program.

This program will define the minimum knowledge and technical abilities required to attain proficiency as a qualified person(s) permitted to work on or near exposed energized parts. Person(s) who successfully complete the program will demonstrate skills and knowledge in construction and operation of electrical equipment and installations, and the hazards involved. The program will ensure that personnel trained as a QEW will meet compliance with Occupational Safety and Health Administration (OSHA) Code of Federal Regulations (CFR) Subpart S 1910, the current edition of the National Fire Protection Association (NFPA) 70E, and other regulations and standards required to work in the United States solar PV energy industry.

Purpose: Establish recommendations for a QEW program for member companies and original equipment manufacturers (OEMs) who may adapt these recommendations to their own platform specific requirements.

Program Development Suggestions

A comprehensive qualification program should include, at an appropriate level, elements of classroom, self-study, and performance verification on the following skill sets:

Electrical principals

- Fundamentals of matter, energy, and electricity
- Photovoltaic principles Solar Panel/Module handling and safety
- Direct current (DC) fundamentals, including:
    - Ohm's Law and calculating voltage, current, resistance and power in the DC systems
- Battery theory and operation (control and communication back-up power)
- Alternating current (AC) fundamentals, including application of Ohm's and Kirchhoff's Laws to single- and three-phase circuits
- Inductance, capacitance, and reactance
- Inverter basic principles, components, and operations
- Transformer basic principles, components, and operations
- How transformers work
- Grounding and bonding (insulation, isolation, and equipotential grounding)
- Arc Flash studies, labels, exposure

Basic electrical skills

- Use of electrical test equipment and meters
- Interpretation of nameplates and data plates of common electrical devices
- Operation of disconnect switches and circuit breakers
- Explanation and use of overcurrent protective devices, molded- case circuit breakers, insulated-case circuit breakers and low-voltage power circuit breakers
- Operation of equipment
    - Inverters
    - Transformers
- Troubleshoot electrical control and power circuits
- Interpretation of electrical drawings and prints, including:
    - Single-line diagrams
    - Three-line diagrams
    - Ladder diagrams
    - Schematics
- Use of voltage testers, megohmmeters and micro-ohmmeters
- Use of hot lines tools
- Use of rubber gloves and arc flash clothing
- Demonstrate ability to read and understand arc flash labels
- Use of I-V curve tracers

Troubleshooting

- Types of electrical system drawings, layout, and the purpose of drawing type
- Interpretation of legends used on electrical drawings and schematics
- Identify and interpreting electrical symbols
- Standard American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE) device numbers

- How circuits and devices interact with each other
- To understand the “logic” functions in control systems
- To troubleshoot electrical problems using diagrams, one-line diagrams and schematics
- Use of electrical test equipment to determine energized equipment and hazards associated with troubleshooting installed equipment

Operation of solar PV projects

- Types and ratings of inverters
- Solar PV project components and layouts
- Key maintenance and operations performance indicators
- Supervisory Control and Data Acquisition (SCADA) basics
- Grid reliability requirements (North American Electric Reliability Corporation (NERC)/Federal Energy Regulatory Commission (FERC))
- Shutdown and isolation of solar PV inverters, combiner boxes, and tracker systems
- Understand the hazards associated with connecting and disconnecting solar panels/modules
- Switching and lockout/tagout (LOTO) considerations

Power Conversion System (PCS) operation

- Safety-related tasks
- Inverter operations
- Identification of voltage levels per make/model
- Electrically related tasks per make/model OEM (original equipment manufacturers) requirements
- Cooling system maintenance requirements
- Operational electrical components including UPS (Uninterrupted Power Supply), insulated gate bipolar transistors (IGBTs), auxiliary power supplies, capacitors, human-machine interface (HMI), EMI filters, etc.

Collections systems

- Pad mount transformer maintenance, testing, switching, and operation
- Medium-voltage and high-voltage cable and accessories
- Switchgear and other collection point devices
- Grounding systems and transformers
- Effects and prevention of transient voltages, including lightning, power surges and harmonics

Substation Basics

- Overview of substation design and operation
- Medium-voltage components and systems
- High-voltage components and systems
- Capacitor banks and switching
- Other power factor correction devices and calculations
- Protection and Control basics
- Communications systems requirements
- Main transformer basics including bushings, components, and auxiliary devices
- Battery maintenance and safety

Definitions

Accepted. An installation inspected and found by a nationally recognized testing laboratory to conform to specified plans or procedures of applicable codes.

Conductor. A material capable of carrying electrical current. When used in electrical circuits, the material is usually a wire, cable, or bus bar.

1. Bare. A conductor has no covering or electrical insulation whatsoever.
2. Covered. A conductor encased within material of composition or thickness not recognized as electrical insulation.
3. Insulated. A conductor encased within material of composition and thickness recognized as electrical insulation.

De-energized. An electrically safe work condition. Per NFPA 70E Article 100, an electrically safe work condition is a state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to verify the absence of voltage, and, if necessary, temporarily grounded for personnel protection.

Device. A unit of an electrical system that is intended to carry but not utilize electric energy.

Enclosed. Surrounded by a case, housing, fence, or walls that will prevent persons from accidentally contacting energized parts.

Energized. Electrically connected to a source of potential difference.

Equipment. A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like, used as a part of, or in connection with, an electrical installation.

Ground. A conducting connection, whether intentional or accidental, between an electric circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

Insulated. Separated from other conducting surfaces by a dielectric (including air space) offering a high resistance to the passage of current.

Listed. Equipment is "listed" if it is of a kind mentioned in a list that:

1. Is published by a nationally recognized laboratory that makes periodic inspection of the production of such equipment, and
4. States that such equipment meets nationally recognized standards or has been tested and found safe for use in a specified manner.

Overcurrent. Any current over the rated equipment current or the ampacity of a conductor. It may result from overload, short circuit, or ground fault.

Qualified person. One who has received training in and has demonstrated skills and knowledge in the construction and operation of electric equipment and installations and the hazards involved.

- Note 1 to the definition of "qualified person:" The employer may consider an employee qualified for some work scopes but unqualified for others.
- Note 2 to the definition of "qualified person:" An employee who the employer deems competent to participate in on-the-job training and conducts that training under the direct supervision of a qualified person is considered a qualified person for the performance of those duties.

Service. The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served. OBJ

Switch.

1. General-use switch. A switch intended for use in general distribution and branch circuits. It is rated in amperes and can interrupt its rated current at its rated voltage.
2. General-use snap switch. It is a general-use switch constructed so it can be installed in device boxes or on box covers, or otherwise used with wiring systems.

Voltage (of a circuit). The greatest root-mean-square (rms) (effective) difference of potential between any two conductors of the circuit concerned.

Voltage, nominal. A nominal value assigned to a circuit or system for conveniently designating its voltage class (as 120/240 volts, 480Y/277 volts, 600 volts). The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment.

Voltage to ground. For grounded circuits, the voltage between the given conductor and that point or conductor of the circuit that is grounded; for ungrounded circuits, the greatest voltage between the given conductor and any other conductor of the circuit.

Weatherproof. Constructed or protected that exposure to the weather will not interfere with successful operation. Rainproof, raintight, or watertight equipment can fulfill the requirements for weatherproof where varying weather conditions other than wetness, such as snow, ice, dust, or temperature extremes, are not a factor.

References—applicable standards

A. National Training Laboratories, Bethel ME.
B. NFPA70E, Standard for Electrical Safety in the Workplace, 2021 edition or its successor.
C. OSHA 29 CFR 1910 Subpart S, including 29 CFR 1910.332.
D. NETA/ANSI MTS Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems, 2019 edition or its successor.
E. NFPA 70B, Recommended Practice for Electrical Equipment Maintenance, 2019 edition or its successor.
F. NFPA 70, National Electric Code
G. OSHA 1910.269 (a)(2)(i-viii) Electric power generation, transmission, and distribution

Credit: AES

Qualified Workers

A person designated by the employer as competent to complete electrical work within a defined work scope and can identify and control the hazards associated with that scope of work.

A. Skills Required and Safety Requirements

Each qualified employee should also be trained and competent in:

1. Techniques to distinguish exposed energized conductors and circuit parts from other parts of electrical equipment.
2. Techniques to determine the nominal voltage of exposed energized conductors and circuit parts.
3. Minimum approach distances specified in this section are associated with the nominal voltages of exposed conductors and methods needed to maintain those distances.
4. Identification of limited, restricted, and arc flash boundaries.
5. Use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools when working on or exposed to energized parts of electrical equipment, and identification of electrical hazards and methods to control or eliminate these hazards.
6. Selection, operation, and limitations of test instruments.
7. Methods of verifying zero energy in electrical circuits or circuit parts.
8. Creation of an electrically safe working condition.
9. Development of job safety plans.
10. Assessment of risk of arc flash and electrical shock associated with the assigned task.
11. Selection of electric shock and arc flash personal protective equipment (PPE)

B. Unqualified Persons

1. Unqualified Persons. Basic Level workers (unqualified electrical workers) should be trained in, and be familiar with, electrical safety-related practices necessary to address electrical hazards they may encounter as part of their normal work activities. See Appendix A for additional details.

Electrical Safety training

1. The employer should determine through supervision and periodic inspections that employees are complying with the safety-related work practices recommended by this guideline.
2. Type of Training. The training should be classroom, on-the-job, or a combination of the two. The type and extent of the training provided should be determined by the risk to the employee.
    a. Training can be augmented by digital delivery platforms, but attendees of re-training must be able to ask questions and answer them immediately. Re-training occurs after an incident and an individual needs to get trained again.
3. Refresher training in safety-related work practices and applicable changes in this guideline should be performed at intervals not to exceed three years.
4. An employee should receive additional training (or retraining) for any of the following conditions:
    a. The supervision or annual inspections indicate the employee is not complying with the safety-related work practices.
    b. New technology, new types of equipment, or changes in procedures necessitate the use of safety-related work practices different from those that the employee would normally use.
    c. The employee needs to review tasks that are performed less than once per year.
    d. The employee needs to review safety-related work practices not normally used by the employee during regular job duties.
    e. The employee's job duties change.

5. Recommend providing qualified electrical workers with contact release training.
6. Electrical Safety Training Documentation. The employer should document that each employee has received the training. This documentation should be in accordance with the following:
    a. Made when the employee demonstrates proficiency in the work practices involved.
    b. Be retained for the duration of the employee's employment.
    c. Contains the content of the training, each employee's name, dates of training and the name of the trainer.
    d. All training documentation will be retained in accordance with the company records management system.

C. Practical Competency Assessments for Qualified Electrical Workers

A qualified instructor should verify:

1. Multimeter and other electrical meter use: demonstrate the correct use of the specific instrument(s), including:
    - Pre- and post-use meter inspection,
    - Limitations of meters,
    - Selection of appropriate meter settings, and,
    - Performance of required measurements.

    Note: Training on specific types of instruments can often be obtained from the instrument ` manufacturer.

2. PPE for a defined work task:
    - Required PPE selection and use,
    - Identification of voltage-rated gloves,
    - Inspection of voltage-rated gloves,
    - Use of voltage-rated gloves,
    - Determination of when and what arc-rated PPE is required,
    - Inspection of arc-rated PPE,
    - Storage of electrical arc-rated and shock PPE,
    - Proper selection of head, neck, and face protection, and,
    - Other similar decisions.

3. Interpreting key information on arc flash labels in accordance with NFPA 70E:
    - Demonstrate and explain the information and layout of the label.
    - Determine and select required PPE from the label or arc flash study.
        i. Be able to obtain the clothing levels from NFPA 70E (required by many labels)
    - What the working distance on a label or arc flash study means to the individual.
    - Determine restricted and limited approach boundaries.

4. Electrical Switch or Circuit Breaker Operation:
    - Describe the mechanical working of a switch or circuit breaker and operation.
    - Where to stand, which way to look, what hand to use for operation.
    - What PPE to wear.
    - Proper selection and use of live line tooling
    - Proper selection and use of protective grounds,
    - Methods to reduce the risk involved in circuit breaker/switch operation.
    - Best practice: Why holding one's breath during operation is important.
    - The way to verify breaker is in the Closed, Open or Grounded position.
    - Emergency procedures in an electrical incident.

- Verification of Zero Energy State: Verify the correct equipment, component, and device.
- Visual verification of the contacts/blades of the disconnect being open, proper setup of boundaries for shock and arc flash protection for unqualified personnel.
- Before-and-after multimeter operation verification.
- Verification that all terminals within the circuit are at zero energy state, both phase-to-phase and phase to ground.
- Confirmation of “ghost” voltages and back feeds that may be possible.

Credit: Invenergy

Suggested levels of competence for solar PV energy technicians

Level 0 Basic Skills

(Level 0 is chosen so the new employee recognizes their relative position and wants to move up in levels. It is recommended that a special hard hat sticker or identifying patch be used to alert other workers to that status.)

1. Entry level. A high school graduate or equivalent. Preferably a technical college graduate.
2. Unqualified to perform electrical tasks in the field unsupervised by a QEW. Might be qualified for mechanical tasks not requiring electrical isolation or exposure.
3. Completed training for worksite safety, basic electrical safety, construction safety, operation of the solar PV site.
4. Completed training in basic electrical theory, electrical equipment operation and electrical safety procedures.
5. Limited to low voltage circuits while under supervision by a QEW.

Minimum Competencies Level 0

Core Competencies — Level 0 Basic Skills

Electrical safety program, policies, procedures, and emergency response
Recognize electrical hazards
Purpose and limitations of hazard and warning signs and barriers
Trained to recognize and participate in LOTO
Use and application of PPE
Worksite safety
Basic electrical safety
Generator operation
Understand the proper use and importance of ground-fault circuit interrupters (GFCIs)
Be able to perform light maintenance tasks
Understand how electrical hazards affect the body

Level 1 Qualified Electrical Worker - PV Array

1. Be qualified Level 0.
2. Be able to perform most solar PV array tasks without direct supervision.
3. Have a comprehensive knowledge of solar PV schematics and lockout/tagout procedures.
4. Has demonstrated ability to perform electrical troubleshooting.
5. Tasks are typically limited to less than 1500VDC and less than 1000VAC circuits.
6. Possess a comprehensive knowledge of electrical safety, PPE selection and arc flash and shock hazards.
7. Must demonstrate skills to perform any specific task.
    a. Once that task is demonstrated successfully, they can perform it unsupervised.
8. Training would include OSHA regulations associate with electrical, NFPA 70E requirements, site-specific safety procedures, site-specific equipment training, basic human performance, Absence-of-Voltage testing, inspection, use and limitations of basic electrical test equipment, such as Volt-Ohm-Meter, insulation resistance, etc.

Minimum Competencies Level 1

Core Competencies — Level 1 Qualified Electrical Worker

(Plus all Level 0 Competencies)

Be able to perform low-voltage absence-of-voltage testing techniques
Be able to use basic electrical test equipment, such as Digital Muti-meter, insulation resistance
Be able to use and apply low-voltage testing equipment properly:
1. Inspections
2. Indications
3. Limitation of use
Be able to place low-voltage equipment in an electrically safe work condition
Perform basic lockout/tagout procedures
Select, inspect, maintain, store, and use PPE
Demonstrate ability to connect and disconnect MC4 connectors
Demonstrate ability to inspect and replace MC4 connectors
Determination of the limited and restricted approach boundaries
Determination of the arc flash boundary
Select required arc flash PPE and demonstration of arc-flash reduction procedures
Ability to implement site-specific safety procedures
Operation of site-specific equipment
Demonstrate absence-of-voltage testing techniques
Identify typical electrical hazards found on company facilities
Identify the degree of hazard (shock, arc flash and arc blast)

Understand how to minimize risk by using proper body position
Techniques used to perform a risk assessment
Clearance requirements around equipment
Application of safety barriers and signs
Operation of low-voltage electrical power system equipment
Inspection low-voltage equipment to determine its condition of maintenance
Inspection of low-voltage control circuits and components

Level 2 Qualified Electrical Worker - Distribution

1. Qualified Level 1.
2. Advanced testing and troubleshooting, including electrically live devices.
3. Able to perform lockout/tagout in accordance with developed procedures and release for troubleshooting.
4. Demonstrated the ability to execute work instructions for electrical and mechanical repair of on-site equipment.
5. Restricted to distribution level work 34.5kV and below.
6. Operate and maintain solar PV site equipment.
7. Application of low-voltage test equipment, including pre- and post-use inspections, connection of test instruments and interpretation of test results.
8. Serve as lead for two person crews performing electrical work.
9. When supervised by a Level 3 or higher, they perform work within substation or switchyard. Qualified to use other types of test equipment at the solar PV site as required by supervision.

Minimum Competencies Level 2

Core Competencies — Level 2 Qualified Electrical Worker

(Plus all Level 0 & 1 Competencies)

Inspect electrical power system equipment to determine its condition of maintenance
Test and inspect cables
Assist in the inspection of substation equipment
Use high/low-voltage electrical testers and understand their limitations
Troubleshoot, isolate, and perform maintenance on solar PV inverters, their controls and related equipment
Purpose and application of temporary protective grounds
Test temporary protective grounds
Assist in the use of and application of high-voltage testing equipment properly:
1. Inspections
2. Indications
3. Interpretation of test results

Level 3 Qualified Electrical Worker - Transmission

1. Meet qualifications for Level 2.
2. Perform Balance of Plant (BOP) tasks including switching, testing and troubleshooting.
3. Demonstrate knowledge of arc flash hazards on BOP devices.
4. Isolate BOP electrical devices.
5. Perform minimal risk substation tasks such as battery testing and general maintenance within the fence.
6. Operate and maintain solar PV site equipment.
7. Testing safety and procedures using higher voltage equipment

Minimum Competencies Level 3

Core Competencies — Level 3 Qualified Electrical Worker

(Plus all Level 0, 1, & 2 Competencies)

Use and application of energized electrical work permits
Ability to conduct electrical shock and arc flash risk assessments
Use of high-voltage test equipment
Create electrically safe work conditions for high-voltage equipment
Be able to perform complex lockout/tagout procedures
Be able to apply safety barriers and signage
Be able to operate high-voltage equipment, such as circuit breakers and switches
Be able to complete a routine energized electrical work permit for signature
Be able to inspect electrical power system equipment to evaluate its condition
Be able to troubleshoot both high- and low-voltage equipment
Be able to perform ground system testing and evaluation
Understand the purpose and importance of ground system maintenance
Be able to perform common maintenance tasks on solar PV generating equipment
Supervision and Human Performance training certification suggested

1. Field Supervisor Level Be qualified Level 3.
2. Fully understand hazards and the risk associated with working with electricity.
3. Can either perform required training for workers or can secure it through a third party.
4. Suggested management level human performance training, OSHA 29CFR 1910.269, NFPA 70E, and site-specific safety training.

Minimum Competencies Supervisor Level

Core Competencies — Field Supervisor (Site Manager)

Understand the Energized Electrical Work Permit and hierarchy of control methods
Understand the PPE program, their roles, and responsibilities
Understand PPE inspection, selection, training and use for their employees
Perform supervision and direction on major maintenance tasks
Perform and review risk assessments
Review maintenance documentation
Understand outage reporting and approval process with ISO/TSO
Understand the difference between qualified and unqualified personnel and the responsibilities of each
Understand lockout/tagout procedures and the requirement for annual audits
Understand their enforcement role for the electrical safety program
Understand their responsibility for developing basic emergency procedures
Understand the safety network structure at company facilities
Understand clearance requirements around equipment
Understand the basic theory behind conducting an arc flash hazard analysis
Understand the FERC/NERC applicable regulations and requirements

Common tasks by skill level

Solar PV project tasks are divided into three areas: solar PV array, inverters (Power Conversion System or PCS), collection systems and substations. Within each area are tasks appropriate for the technicians' various skill levels, so definitions of the needed qualifications should be clear to the individual technician and their supervisor.

Here are some examples of electrical maintenance areas:

Solar PV array (DC field)

- Solar PV modules
- MC4 connectors
- Wiring harnesses and In-line fuses
- Combiner boxes
- DC feeders
- Tracker control and motors
- Meteorological (Met) Stations
- Batteries (UPS and DC Controls)

Distribution

- Inverters
- Inverter grounding systems
- Several types of transformers
- Auxiliary power distribution
- Pad mount transformers
- Underground collections system
- Above ground collection system
- Isolation switches
- Switch gear
- Pole-mounted equipment
- Reclosers

Transmission

- Underground collections system
- Utility Poles
- Substation components:
    - Transformers
    - Protective relays
    - Pole-mounted equipment
    - Circuit breakers
    - Specialized electrical test equipment
    - Generators or back-up power supply

Below are charts with common task areas for various skill levels. In each case, comprehensive training sections should be developed based on the site-specific equipment and safety requirements. This training should include the technical task, the hazards and safety aspects of the task and a process to demonstrate competency to an appropriate level for review and recorded acknowledgement of that competency.

Level 0 Basic Skills

Assist with mechanical and de-energized electrical tasks
Perform site security and perimeter inspections
Perform simple lockout/tagout procedures
Operate low-voltage controls as required
Be able to use low-voltage power tools as required
Assist and document inspections on low-voltage equipment
Perform Meteorological (Met) Station maintenance
Grounds and road maintenance

Level 1 Qualified Electrical Worker – Solar PV array (DC field)

(Plus all Level 0 Tasks)

Perform PV Array maintenance:
1. Inspect PV modules, replace as needed
2. Wire management
3. Inspect MC4 connectors and inline fuses, replace as needed
4. Infrared testing of wiring, connectors, and PV modules
5. Splice DC wiring
Operate low-voltage circuit breakers and switchgear
Perform low-voltage enclosure inspections
Perform DC electrical testing
Operate combiner boxes
Operate re-combiner boxes
Perform maintenance on combiner boxes/recombiner boxes:
1. Perform inspections
2. Check fuse continuity and replace fuses as required
3. Inspect surge protection devices and replace as required
4. Perform Infrared testing
Perform maintenance on tracker:

1. Operate electrical switch/breakers
2. Inspect and replace motor
3. Check fuse continuity and replace fuses
4. Inspect surge protection devices and replace as needed

Inspecting secondary cable systems

Inspection of Surge Arresters

Infrared Testing of Surge Arresters

Understand simple and complex lockout/tagout procedures

Operate low-voltage electrical power system equipment, such as switches and circuit breakers

Understand how to inspect low-voltage equipment to determine its condition of maintenance

Inspection of system and equipment grounding

Level 2 Qualified Electrical Worker - Distribution

(Plus all Level 0 & 1 Tasks)

Operate inverter

Perform maintenance on inverter:

1. Perform inspections
2. Check fuse continuity and replace fuses as required
3. Inspect surge protection devices and replace as required
4. Check breaker operation and replace as required
5. Check switch and replace as required
6. Perform cooling system maintenance
7. Perform Infrared testing

Operate medium voltage switchgear

Operate recloser

Sampling transformer oil

Visually inspect transformer bushings

Assist in the visual inspection of outdoor substation equipment

Inspect and maintain substation fences and gates

Install temporary back-up generator

Inspect back-up generator

Check alarm circuits

Perform tests for continuity and voltage on fans
Inspect heat exchangers
Testing and application of temporary protective grounds
Assist in testing and inspection of high-voltage cables for learning
Inspection requirements of substation equipment
Assist with the use of high-voltage test equipment for learning
Assist in operating high-voltage electrical power system equipment for learning
Perform insulation resistance test on secondary cable systems

Level 3 Qualified Electrical Worker - Transmission

(Plus all Level 0, 1, & 2 Tasks)

Perform Pad Mount and Grounding Transformer Maintenance:
1. Transformer turns ratio (TTR) Test
2. Winding Resistance Test
3. Insulation Resistance Test
4. Thermal Imaging
Rack in medium-voltage circuit breakers
Rack out medium-voltage circuit breakers
Perform recloser maintenance
Perform insulation resistance test on station surge arresters
Perform insulation power factor on station surge arresters
Perform Circuit breaker maintenance:
1. Perform Contact resistance checks
2. Perform Insulation resistance checks
3. Perform Insulation power factor checks
4. Perform Vacuum bottle tests, such as integrity and remaining life
Perform Main Power Transformer Maintenance:
1. Sampling oil from power transformer
2. Perform dielectric test on oil
3. Perform insulation power factor test
4. Perform required inspections before re-energizing
5. Re-energize transformer
6. Filter the transformer insulating liquid

Perform Maintenance on Batteries:
1. Perform inspection
2. Verify room temperature or environmental parameters
3. Verify room ventilation
4. Inspect electrolyte levels, correct as required
5. Verify float voltage
6. Verify output voltage
Monitor protective relay alarm via SCADA
Monitor for potential protective relay failures not detected by SCADA
Maintain transmission line clearances
Perform insulation resistance test on secondary cable systems
Testing fiber optic cables
Perform inspection of medium-voltage cable systems:
1. Perform visual inspection
2. Perform conductor phasing test
3. Perform conductor resistance/continuity test on neutral wires
4. Perform off-line PD test
5. Perform insulation resistance test or VLF test
6. Perform infrared tests of accessories

Appendix A. Unqualified Electrical Worker Guidelines

Training (Unqualified Electrical Worker)

This category includes all management and support staff that are performing non-electrical tasks near electrical equipment, regardless of its energized state. All unqualified personnel should remain outside of the limited approach boundary of any exposed circuits and circuit parts energized above 50 volts unless under the direct supervision of a QEW. All unqualified personnel should be trained in and familiar with the following information:

- Minimum approach distance for the various voltages for equipment at each facility.
- Not to cross the limited approach boundary, unless continuously supervised by a QEW.
- The risk associated with energized equipment.
- The tasks that can only be performed by QEWs (Qualified Electrical Worker) (Qualified Electrical Worker).
- How to protect themselves when working around electricity.
- The importance of obeying electrical hazard signs and tags.
- Who to report electrical hazards to after they have been identified.

Sample training guide for Unqualified Workers

1. For an unqualified person to recognize and avoid hazards, it will be important that they understand the basics of electricity including:
    - Voltage.
    - Amperage.
    - Resistance.
    - How to read and comply with Arc Flash Hazard Analysis Labels.
    - Using nameplate data to determine the Limited Approach Boundary.
    - Devices that store energy after they have been de energized.
    - Job briefing requirements.
2. The more common electrical hazards the unqualified personnel might encounter.
3. The common types of electrical injuries *Be able to describe specific electrical hazards at your facility.*
4. The unqualified personnel need to know how electrical shock occurs and how the severity of the electrical shock is determined.
5. Typical electrical accidents explained involving “Arc Flash,” “Arc Blast,” and Electrical Burns.
6. Discuss ways to avoid electrical shock.
    - Do not touch covered or insulated conductors.
    - Do not open electrical cabinets or panels.
    - The risks involved when jewelry is worn, even in the office space.
7. Damaged equipment can result in serious electrical hazards. Describe the facility’s policies on damaged equipment and the procedures for reporting damage.
8. The purpose and use of Ground Fault Circuit Interrupters (GFCI)
9. Lockout/Tagout procedures at the facility. The importance of placing electrical equipment in an electrically safe working condition to prevent an electrical shock. Basic ability to recognize Lockout/Tagout equipment.
10. Describe/ and review safe work practices and procedures at the facility. Show trainees a copy of any written safe work practices adopted by the company related to electrical safety.
11. Emphasis that the training received does not mean the attendees are qualified to perform any

electrical task.

Appendix B. Human Performance Guidelines

Personal responsibility and human performance factors are critical to any organizational success. This has become a core component of many electrical safety programs, quality management initiatives and workforce development criteria. QEWs in the solar PV energy sector often work in small groups without direct supervision. Personal integrity to properly perform tasks in a safe manner must be part of the workplace culture all day, every day.

The HOP Hub (http://www.hophub.org) addresses some of the organizational, leadership and worker responsibilities that are necessary for establishing and maintaining a high level of safe behavior in high-risk industries. A culture that is truly organized around safe behavior reduces the risk created by human error and contributes to the prevention or mitigation of damages in case of an incident.

The HOP Hub has materials to help develop a human performance program and implement a QEW process.

The NFPA 70E Informative Annex Q lists the five basic principles of human performance:

1. People are fallible and even the best people make mistakes.
2. Error-likely situations are predictable, manageable, and preventable.
3. Individual performance is influenced by organizational processes and values.
4. People achieve high levels of performance largely because of the encouragement and reinforcement received from leaders, peers, and subordinates.
5. Incidents can be avoided through an understanding of the reasons that mistakes occur, and applications of the lessons learned from past mistakes.

In implementing a strong QEW program for the solar PV industry, human performance tools should be available to all workers and managers. These would include safety and job skills briefings before a task is undertaken, clear procedure adherence guidelines, clear three-way communication channels and safety or technical stop-work authorization.

For more information on developing and implementing an effective human performance program, see these references, among other sources.

Appendix C. Other Training Considerations

Task	• Objectives
Personal Protection Equipment (PPE)	• What is a caught-in or -between hazards • Types of caught-in or -between hazards • What PPE is • Why PPE is used • Types of PPE to use • How to care for PPE • Required PPE in the industries
Health Hazards in Construction and **Hazardous Materials**	• Explain what "the right to know" is • List several types of PPE used to handle hazardous materials • Describe basic first aid requirements for exposure to hazardous materials • Describe what spills and leaks are • Define what labels and SDSs (Safety Data Sheets) are and the importance of their use • Define LOTO (Lockout Tagout) • Define a confined space • Define to categories of respirators
Materials Handling	• What is material handling? • Material handling hazards • Proper lifting of materials • How to avoid material hazards
Tools	• When to inspect tools • Appropriate types of PPE to use with tools • When to use guards • Proper storage of tools • Safe handling techniques for hand and power tools
Excavations	• Excavation hazards and risks. • Proper protective systems. • Who inspects? • Proper base and backfill required for underground cable
ARI Signalperson certificate (5 years)	• Identify basic crane terminology and definitions • Explain boom deflection, center of gravity, and how to compensate for it • Identify the hazards and safety concerns associated with overhead lifting • Recognize and apply the applicable OSHA and ASME standards. • Demonstrate hand signals per ASME B30.5 and B30.3. • Demonstrate voice communication • Explain the pre-lift planning process
Crane Rigging **ARI Level 1 Rigging certificate** (5 years)	• Define responsibilities and safety rules for rigging and hoisting loads • Inspect, select, maintain, and reject rigging equipment and hardware • Identify rigging hardware and slings along with defining their limitations • Identify load ratings, safety factors, and stresses imposed by hoisting • Calculate material load weights • Identify capacities of rigging and attach the appropriate rigging

Alternating Current Theory	• Explain the difference between AC and DC • Identify electronic component influence on AC circuits • Define the use of transformers • Describe inverter/converter basics • Explain three phase AC basics • Define electric motor basics • Define reactive poser, impedance, and power factor basics
Direct Current Theory	• Define Direct Current • Identify the basic components of a circuit • Identify the source and load • Define HVDC
Voltage Test Procedures (50 Volts or Higher)	• Define volts, amps, ohms • Explain the causes of an Arc Flash event • List the current thresholds that can harm the human body • List the types of Arc Flash PPE required to work on circuits 50 volts or higher • List the types of burns associated with electrocution and arc flash • List the various safety electrical boundaries • Explain the use of insulated electrical tools and how to identify them
Electrical Hand Tools	• Demonstrate the inspection process required for different electrical hand tools
Electrical Measurement Safety	• Describe the IEC 61010 category ratings and how they affect the end user • Demonstrate the ability to safely use and care for the metering equipment • Demonstrate the inspection process required for metering equipment • Describe the safety specifications for DMMs and testers • Demonstrate the ability to avoid electrical measurement hazards
Multimeters	• Types of multimeters (analog and digital) • Basic multimeter safety • Basic multimeter functionality • Explain multimeter symbols and their meaning • Demonstrate the inspection process required for multimeters • Describe multimeter care and maintenance
Amp Clamps	• Demonstrate safe and accurate multimeter usage • Define what an Amp Clamp is • Define the symbols on an Amp Clamp • Demonstrate the safe use of an Amp Clamp
Megohmmeters	• Explain basic Megger / Hipot safety • Demonstrate Megger usage
I-V Curve Tracer	• Understand purpose of I-V testing • Demonstrate I-V tracer usage • Demonstrate understanding of I-V testing results
Infrared Testers	• Explain the safe use of an Infrared (IR) tester • Describe the features of an IR tester • Explain the distance to spot ratio • Explain the field of view • Describe Emissivity as it relates to IR scans

Phase Rotation Meter	• Describe what a Phase Rotation Meter is and what it does • Explain the symbols on a Phase Rotation Meters • Demonstrate the safe use of the Phase Rotation Meter
Proximity Sensor	• Describe Proximity Sensor functionality • Demonstrate the safe and accurate Proximity Sensor usage • Demonstrate the three-step procedure using a Proximity Sensor

Electrical Systems, Components, and Schematics	• List the two common electrical drawings used in the field
	• Identify various electrical drawing symbols and labeling
	• Identify potential energy sources on an electrical drawing
	• Identify the elements of:
	  ○ Safety-chain/loop
	  ○ Latching
	  ○ Lock-out
	  ○ PLC (Programmable Logic Controller) to Motor-Control
	  ○ Reversing sub-circuits
	• How to interpret block diagrams
	• Follow established lockout/tagout procedures
	• Perform pre-energization checks and follow all electrical safety precautions
	• Understand schematics to build and troubleshoot motor control circuits
	• Troubleshoot motor control circuits, components, and devices
	• Distinguish and define the differences of Battery types

Inverter	• List the inverter components • Describe the function of each of the inverter components • Explain the inverter functions and control modes • Understand the cooling system function • Describe possible and likely faults
Maintenance Practices	• Explain the importance in following maintenance procedures • Explain hazards associated when performing maintenance procedures and mitigation techniques • Identify the consequences of not following proper maintenance procedures • Explain the importance of maintenance records and work documentation
Protective Devices	• Understand NSI standard device numbers identifies the features of a protective device such as a relay • Perform relay operations • Understand reporting and data to understand cause of typical faults • Troubleshoot motor control circuits, components, and devices
Basic Hydraulics	• Describe hydraulic systems and what they are used for • Demonstrate interpreting a hydraulic schematic • Explain a basic hydraulic system • Troubleshoot a hydraulic system
Electrostatic Discharge (ESD)	• Define Electrostatic Discharge (ESD) • Identify how ESD damages electronic parts • Define correct handling procedures for ESD sensitive electronic parts
SCADA and Data Analysis	• Define what SCADA is and what it does • Describe information that SCADA produces • Explain the benefits of using SCADA

Fiber Optics	• Define fiber optics • Describe how information passes through a fiber optic system • Differentiate analog and digital operation • Demonstrate light loss measurement • Define the basic components of a fiber optic system • Define how a fiber optic system works on a solar PV inverter • Define how a fiber optic system works on a cell tower
Meteorological (Met) Station	• Define purpose of meteorological stations • List meteorological components
Tracker System	• Describe functionality and purpose of the tracker system • List tracker system types and typical components • Understand system performance impacts on tracking misalignment

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