

Objectives and Task Analysis for the Photovoltaic System Installer

Introduction

This document presents an in-depth task analysis for practitioners who specify, install and maintain photovoltaic (PV) power generation systems and equipment. This task analysis was developed through extensive interviews and relationships with contractors, manufacturers, trade organizations, codes and standards developers, and educators, and includes significant input from subject matter experts in the field. Numerous experiences from the evaluation of installations, maintenance requirements, and the performance and reliability of PV systems were also heavily considered in the development of these tasks.

The purpose of this task analysis is to define a general set of competencies or skills typically required of practitioners who install and maintain PV systems. Specifically, the task analysis helps establish the basis for training curricula, and helps define requirements for the assessment and credentialing of practitioners. These tasks, or modified version thereof, may be used as guidelines for states or organizations that wish to train, test, certify or otherwise qualify existing or new workers to install PV systems. The principal goals of these efforts are to help develop an accredited training infrastructure, that produces a knowledgeable, skilled and experienced workforce, and thus helping to ensure the safety, quality and consumer acceptance of PV installations throughout the U.S.

Scope

This task analysis is intended to be all-inclusive of the skills expected for any qualified PV installer, and does not differentiate skills or experience that may be common among existing tradespersons. Furthermore, this list only defines what the tasks are, not how they are accomplished – these issues are mainly dealt with through training and assessment mechanisms. In general, these tasks include fundamental electrical skills expected of journeymen electricians, as well as special skills related to PV technology and its application.

Although these tasks are primarily targeted toward the installer as opposed to the system designer, in many cases the installer must be knowledgeable about many aspects of systems design, and may be required to adapt designs and equipment to fit a particular application or customer need, and often are required to select and specify balance-of-system (BOS) components. For this reason, the task analysis includes several items involving the verification of the system designs. Electrical codes, safety standards, and accepted industry practice are central to this task analysis, and are implicit to nearly every task.

Fundamentally, these tasks assume that the installer begins with adequate documentation for the system design and equipment, including manuals for major components, electrical and mechanical drawings, and instructions. While these tasks have been developed based on conventional designs, equipment and practice used in the industry today, they do not seek to limit or restrict innovative equipment, designs or installation practice in any manner. As with any developing technology, it is fully expected that the skills required of the practitioner will develop and change over time, as new materials, techniques, codes and standards evolve.

Specific tasks in this document are classified as either *cognitive* or *psychomotor* skills for the purposes of identifying the types of training and assessment methods that generally apply. Cognitive skills require knowledge processing, decision-making and computations, and can generally be assessed by a written examination. Psychomotor skills require physical actions and hand-eye coordination such as fastening, assembling, measuring, etc, and more appropriately assessed through qualified experience. The tasks are also ranked according to their priority or importance. *Must* items are considered high priority tasks, and are expected competencies for all PV installers. These include items involving safety and other tasks with a high consequence and high chance of error. *Should* items are medium priority tasks, and are generally expected of all competent installers. *Could* items are considered low priority tasks, but usually performed by the quality installer.

Primary Objective for the PV Installer

Given basic instructions, major components, schematics and drawings, the PV installer is required to specify, configure, install, inspect and maintain a grid-connected PV system that meets the performance and reliability needs of the customer, incorporates quality craftsmanship, and complies with all applicable safety codes and standards by:

1. WORKING SAFELY WITH PHOTOVOLTAIC SYSTEMS.....3

2. CONDUCTING A SITE ASSESSMENT3

3. SELECTING A SYSTEM DESIGN4

4. ADAPTING THE MECHANICAL DESIGN.....4

5. ADAPTING THE ELECTRICAL DESIGN5

6. INSTALLING SUBSYSTEMS AND COMPONENTS AT THE SITE.....5

7. PERFORMING A SYSTEM CHECKOUT AND INSPECTION.....6

8. MAINTAINING AND TROUBLESHOOTING A SYSTEM6

1. Working Safely with Photovoltaic Systems		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>As part of normal safety considerations, any PV installer must be able to:</i>		
1.1 Maintain safe work habits and clean, orderly work area	Cognitive, Psychomotor	Must
1.2 Demonstrate proper use of tools and equipment	Cognitive, Psychomotor	Must
1.3 Demonstrate safe and accepted practices for personnel protection	Cognitive, Psychomotor	Must
1.4 Demonstrate awareness of safety hazards and how to avoid them	Cognitive, Psychomotor	Must
1.5 Demonstrate proficiency in basic first aid and CPR	Cognitive, Psychomotor	Must
<i>The installer must be able to identify electrical and non-electrical hazards associated with PV installations, and implement preventative and remedial measures to ensure personnel safety:</i>		
1.6 Identify and implement appropriate codes and standards concerning installation, operation and maintenance of PV systems and equipment	Cognitive, Psychomotor	Must
1.7 Identify and implement appropriate codes and standards concerning worker and public safety	Cognitive, Psychomotor	Must
1.8 Identify personal safety hazards associated with PV installations, and implement preventative and remedial measures	Cognitive, Psychomotor	Must
1.9 Identify environmental hazards associated with PV installations, and implement preventative and remedial measures	Cognitive, Psychomotor	Must

2. Conducting a Site Assessment		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>In conducting site surveys for PV systems, the installer shall be able to:</i>		
2.1 Identify typical tools and equipment required for conducting site surveys for PV installations, and demonstrate proficiency in their use	Cognitive	Should
2.2 Establish suitable location with proper orientation, sufficient area, adequate solar access and structural integrity for installing PV array	Cognitive	Should
2.3 Establish suitable locations for installing inverters, control, batteries and other balance-of-system components	Cognitive	Should
2.4 Diagram possible layouts and locations for array and equipment, including existing building or site features	Cognitive	Should
2.5 Identify and assess any site-specific safety hazards or other issues associated with installation of system	Cognitive	Should
2.6 Obtain and interpret solar radiation and temperature data for site for purposes of establishing performance expectations and use in electrical system calculations	Cognitive	Should
2.7 Quantify the customer electrical load and energy use through review of utility bills, meter readings, measurements and/or customer interview, as required	Cognitive	Could

2.8	Estimate and/or measure the peak load demand and average daily energy use for all loads directly connected to inverter-battery systems for purposes of sizing equipment, as applicable	Cognitive	Should
2.9	Determine requirements for installing additional subpanels and interfacing PV system with utility service, and/or other generation sources as applicable	Cognitive	Should
2.10	Identify opportunities for the use of energy efficient equipment/appliances, conservation and energy management practices, as applicable	Cognitive	Could

3. Selecting a System Design			
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>	
<i>Based on results from a site survey, customer requirements and expectations, the practitioner shall be able to:</i>			
3.1	Identify appropriate system designs/configurations based on customer needs, expectations and site conditions	Cognitive	Should
3.2	Estimate sizing requirements for major components based on customer load, desired energy or peak power production, autonomy requirement, size and costs as applicable	Cognitive	Must
3.3	Identify and select major components and balance of system equipment required for installation	Cognitive	Should
3.4	Estimate time, materials and equipment required for installation, determine installation sequence to optimize use of time and materials	Cognitive	Could

4. Adapting the Mechanical Design			
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>	
<i>In adapting a PV system mechanical design, the practitioner shall be able to:</i>			
4.1	Identify a mechanical design and installation plan that is consistent with the environmental, architectural, structural, code requirements and other conditions of the site	Cognitive	Must
4.2	Identify appropriate module/array layout, orientation and mounting method for ease of installation, electrical configuration and maintenance at the site	Cognitive	Must

5. Adapting the Electrical Design		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>In adapting a PV system electrical design, the practitioner shall be able to:</i>		
5.1 Determine the design currents for any part of a PV system electrical circuit	Cognitive	Must
5.2 Select appropriate conductor types and ratings for each electrical circuit in the system based on application	Cognitive	Must
5.3 Determine the derated ampacity of system conductors, and select appropriate sizes based on design currents	Cognitive	Must
5.4 Determine appropriate size, ratings and locations for all system overcurrent and disconnect devices	Cognitive	Must
5.5 Determine appropriate size, ratings and locations for grounding, surge suppression and associated equipment	Cognitive	Must
5.6 Determine voltage drop for any electrical circuit based on size and length of conductors	Cognitive	Must
5.7 Verify that the array operating voltage range is within acceptable operating limits for power conditioning equipment, including inverters and controllers	Cognitive	Must
5.8 Select an appropriate utility interconnection point, and determine the size, ratings and locations for overcurrent and disconnect devices as required.	Cognitive	Must

6. Installing Subsystems and Components at the Site		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>As part of the PV system installation process, the practitioner shall be able to:</i>		
6.1 Utilize drawings, schematics, instructions and recommended procedures in installing equipment	Cognitive	Must
6.2 Implement all applicable personnel safety and environmental protection measures	Cognitive	Must
6.3 Visually inspect and quick test PV modules as required	Psychomotor	Could
6.4 Assemble modules, panels and support structures as specified by module manufacturer or design	Psychomotor	Should
6.5 Install module array interconnect wiring as required, implement measures to disable array during installation	Psychomotor	Should
6.6 Complete final assembly, structural attachment and weather sealing of array to building or other support mechanism as required		Should
6.7 Install and label inverters, controls, disconnects and overcurrent devices, surge suppression and grounding equipment, junction boxes, batteries and enclosures, conduit and other electrical hardware as required	Psychomotor	Must
6.8 Label, install and terminate electrical wiring; verify proper connections, voltages and phase/polarity relationships	Psychomotor	Must
6.9 Verify continuity and measure impedance of grounding system as required	Cognitive, Psychomotor	Should
6.10 Program, adjust and/or configure inverters and controls for desired set points and operating modes as required	Cognitive, Psychomotor	Must

7. Performing a System Checkout and Inspection		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>After completing the installation of a PV system, as part of system commissioning, inspections and handoff to the owner/operator, the practitioner shall be able to:</i>		
7.1 Visually inspect entire installation, identifying and resolving any deficiencies in materials or workmanship	Cognitive, Psychomotor	Should
7.2 Check system mechanical installation for structural integrity and weather sealing as required	Cognitive, Psychomotor	Must
7.3 Check electrical installation for proper wiring practice, polarity, grounding and security of terminations	Cognitive, Psychomotor	Must
7.4 Activate system and verify overall system functionality and performance, compare with expectations	Cognitive, Psychomotor	Must
7.5 Demonstrate procedures for connecting and disconnecting the system and equipment from all sources	Cognitive, Psychomotor	Must
7.6 Identify and verify all markings and labels for system and equipment as required	Cognitive	Should
7.7 Identify and explain all safety issues associated with operation and maintenance of system	Cognitive	Should
7.8 Transfer a complete documentation package for the system and equipment to owner/operator	Cognitive	Should

8. Maintaining and Troubleshooting a System		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>In maintaining and troubleshooting PV systems, the practitioner shall be able to:</i>		
8.1 Identify tools and equipment required for maintaining and troubleshooting PV systems; demonstrate proficiency in their use	Cognitive, Psychomotor	Should
8.2 Identify maintenance needs and implement service procedures for modules, arrays, batteries, power conditioning equipment, safety systems, structural and weather sealing systems, and balance of systems equipment	Cognitive, Psychomotor	Should
8.3 Measure system performance and operating parameters, compare with specifications and expectations, and assess operating condition of system and equipment	Cognitive, Psychomotor	Should
8.4 Perform diagnostic procedures and interpret results	Cognitive, Psychomotor	Should
8.5 Identify performance and safety issues, and implement corrective measures	Cognitive, Psychomotor	Must
8.6 Verify and demonstrate complete functionality and performance of system, including start-up, shut-down, normal operation and emergency/bypass operation	Cognitive, Psychomotor	Must
8.7 Compile and maintain records of system operation, performance and maintenance	Cognitive	Should