Objectives and Task Analysis for the Photovoltaic System Installer

Introduction

This document presents an in-depth task analysis (job analysis or key skills 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 organisations, 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 and/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 organisations 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, thus helping to ensure the safety, quality, and consumer acceptance of PV installations.

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 though qualified experience. The tasks are also ranked according to their priority or importance. *Critical* 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. *Very Important* items are medium priority tasks, and are generally expected of all competent installers. *Important* items are considered lower priority tasks, but usually performed or understood 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		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
As part of safety considerations associated with installing and maintaining PV systems, any PV installer must be able to		
1.1 Maintain safe work habits and a clean, orderly work area	Cognitive, Psychomotor	Critical
1.2 Demonstrate safe and proper use of required tools and equipment	Cognitive, Psychomotor	Critical
1.3 Demonstrate safe and accepted practices for personnel protection	Cognitive, Psychomotor	Critical
1.4 Demonstrate awareness of safety hazards and how to avoid them	Cognitive, Psychomotor	Critical
1.5 Demonstrate proficiency in basic first aid and CPR	Cognitive, Psychomotor	Important
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.		
1.6 Identify and implement appropriate codes and standards concerning installation, operation, and maintenance of PV systems and equipment	Cognitive, Psychomotor	Critical
1.7 Identify and implement appropriate codes and standards concerning worker and public safety	Cognitive, Psychomotor	Critical
1.8 Identify personal safety hazards associated with PV installations	Cognitive, Psychomotor	Critical
1.9 Identify environmental hazards associated with PV installations	Cognitive, Psychomotor	Critical

2. Conducting a Site Assessment		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
In conducting site surveys for PV systems, the installer shall be able to		
2.1 Identify typical tools and equipment required for conducting site surveys for PV installations, and demonstrate proficiency in their use	Cognitive	Very Important
2.2 Establish suitable location with proper orientation, sufficient area, adequate solar access, and structural integrity for installing PV array	Cognitive	Very Important

2.3	Establish suitable locations for installing inverters, control, batteries, and other balance-of-system components	Cognitive	Very Important
2.4	Diagram possible layouts and locations for array and equipment, including existing building or site features	Cognitive	Very Important
2.5	Identify and assess any site-specific safety hazards or other issues associated with installation of system	Cognitive	Critical
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	Very Important
2.7	Quantify the customer electrical load and energy use (e.g., through review of utility bills, meter readings, measurements, and/or customer interview)	Cognitive	Important
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	Very Important
2.9	Determine requirements for installing additional subpanels and interfacing PV system with utility service, and/or other generation sources as applicable	Cognitive	Very Important
2.10	Identify opportunities for the use of energy efficient equipment/appliances, conservation and energy management practices, as applicable	Cognitive	Important

3. Selecting a System Design			
Task/Skill:		***Skill Type:***	***Priority/ Importance:***
Based on results from a site survey, customer requirements and expectations, the installer shall be able to			
3.1	Identify appropriate system designs/configurations based on customer needs, expectations and site conditions	Cognitive	Very Important
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	Very Important
3.3	Identify and select major components and balance of system equipment required for installation	Cognitive	Very Important
3.4	Estimate time, materials and equipment required for installation, determine installation sequence to optimise use of time and materials	Cognitive	Important

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

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

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

7. Performing a System Checkout and Inspection		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
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		
7.1 Visually inspect entire installation, identifying and resolving any deficiencies in materials or workmanship	Cognitive, Psychomotor	Very Important

7.2	Check system mechanical installation for structural integrity and weather sealing	Cognitive, Psychomotor	Critical
7.3	Check electrical installation for proper wiring practice, polarity, earthing, and integrity of terminations	Cognitive, Psychomotor	Critical
7.4	Activate system and verify overall system functionality and performance; compare with expectations	Cognitive, Psychomotor	Critical
7.5	Demonstrate procedures for connecting and disconnecting the system and equipment from all sources	Cognitive, Psychomotor	Critical
7.6	Identify and verify all required markings and labels for the system and equipment	Cognitive	Critical
7.7	Identify and explain all safety issues associated with operation and maintenance of system	Cognitive	Critical
7.8	Identify what documentation is required to be provided to the PV system owner/operator by the installer	Cognitive	Very Important

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