

# Objectives and Task Analysis for the Installer of Solar Based Off-Grid Power Systems

## Introduction

This document presents a task analysis (job analysis or key skills analysis) for practitioners who *install* solar based off-grid power systems. This is not to be confused with the role of maintenance/troubleshooting personnel or system designers. For the purpose of this task analysis, a system installer is someone that installs the off-grid system. They will more than likely only interact with the system during the time the system is installed.

Off-grid systems can include the following types of system:

- Small solar home systems comprising one or two solar modules and the loads are only DC
- Stand alone solar systems where the loads can be DC or AC
- Hybrid power systems with a solar array and fuel generator as the energy sources.

The purpose of this task analysis is to define a general set of competencies and/or skills typically required of installers who:

1. Install solar home systems for systems that comprise one or two solar modules, a 12V or 24V battery, small controller and DC appliances. (Installer solar based off-grid power systems level 1)
2. Install stand alone solar systems which include AC loads for a single building or adjacent buildings (Installer solar based off-grid power systems level 2). Level 2 contains the following two options which will be relevant for some installations:
  - a. Option 1: Back-up fuel generator for the system
  - b. Option 2: System is for multiple buildings or small villages
3. Install hybrid power systems comprising a solar array, batteries, inverters and fuel generator as the energy sources (Installer solar based off-grid power systems level 3)

Specifically, the task analysis helps establish the basis for training curricula, and helps define requirements for the assessment and credentialing of installers. These tasks, or modified version thereof, may be used as guidelines for organizations that wish to train, test, certify, or otherwise qualify installers for installing solar based off-grid power 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 solar home system installer; stand alone solar system installer and hybrid (PV and fuel generator) power system installer. The task analysis 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.

A number of task analyses are common to all three installer levels. Under some of the specific tasks, there are tasks that are specified only for the Installer levels 2 and/or 3.

The following table defines the tasks required for the three levels of system designer. All tasks defined for Installer level 1 must be completed by Installer Levels 2 and 3. All tasks defined for Installer Level 2 must be completed by Installer level 3.

<b>Task</b>	<b>PV Off-grid Power systems Installer level 1</b>	<b>PV Off-grid Power systems Installer Level 2</b>	<b>PV Off-grid Power systems Installer Level 3</b>
	<i>Install solar home systems for systems that comprise one or two solar modules, a 12-24V battery, small controller and DC lights.</i>	<i>Install stand alone solar systems which include AC loads</i>	<i>Install hybrid power systems comprising a solar array and fuel generator as the energy sources</i>
	<b>TASKS</b>		
Working safely with PV based off grid power systems	1.1 to 1.8		
Understanding Energy Concepts	2.1 to 2.3	2.4	
Understanding Solar Resources	3.1 to 3.3		
Interpreting System Drawing	4.1 to 4.2		

Demonstrate Installation techniques for system components	5.1 to 5.13	5.14,5.15(optional for level 2) and 5.16	
Understanding system cabling and cable and protection devices	6.1 to 6.6	6.7 to 6.12 6.9 and 6.10 Optional for level 2.	
Demonstrate practical cabling and final system installation	7.1 to 7.9		
Testing and Commissioning	8.1 to 8.9		

Fundamentally, these tasks require that the installer begins with a load system design that is agreed between the energy users and the system designers. Very importantly, the installer must have knowledge of occupational health and safety requirements for the type of system being installed.

Installer level 1 shall then install the PV array and the balance of system equipment required for the system to meet the needs of the customer and in accordance with all relevant standards for that particular country. If no standards exist, the installer must follow installation practices typical for the PV industry in the country or appropriate Sustainable Energy Industry Association of Pacific Islands/Pacific Power Association (SEIAPI/PPA) guidelines. As a minimum, the balance of system will typically include an array frame, some form of charge controller, a battery, appliances and associated cables and circuit protection equipment.

Installer level 2 shall then install the PV array and the balance of system equipment required for the system to meet the needs of the customer and in accordance with all relevant standards for that particular country. If no standards exist, the installer must follow installation practices typical for the PV industry in that country or appropriate Sustainable Energy Industry Association of Pacific Islands/Pacific Power Association (SEIAPI/PPA) guidelines. As a minimum, the balance of system will typically include an array frame, some form of charge controller, an inverter, a battery bank and associated cables and circuit protection equipment. The balance of system equipment could also include a back-up generator, a transfer switch and appliances.

Installer level 3 shall then install the PV array, fuel generator and the balance of system equipment required for the system to meet the needs of the customer and in accordance with all relevant standards for that particular country. If no standards exist, the installer must follow installation practices typical for the PV industry in that country. As a minimum, the balance of system will typically include an

array frame, some form of charge controller, inverter, a battery bank, a transfer switch or system controller and associated cables and circuit protection equipment.

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 recommended installation practice in any manner. As with any developing technology, it is fully expected that the skills required of the installer will develop and change over time, as new materials, techniques, codes, and standards evolve.

## Classifications

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 are more appropriately assessed through qualified experience.

Specific tasks in this document are ranked according to their priority or importance:

*Critical* items are considered high priority tasks, and are expected competencies for all PV and fuel generator installers.

*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 Off grid Installer

The Off-grid installer is required to install an off grid PV based power-system that meets the performance and reliability needs of the customer, and complies with all applicable safety codes and standards by:

1. WORKING SAFELY WITH PV BASED OFF-GRID POWER SYSTEMS .....	6
2. UNDERSTANDING ENERGY CONCEPTS .....	7
3. DETERMINING SOLAR RESOURCES.....	7
4. INTERPRET SYSTEM DRAWINGS .....	8
5. DEMONSTRATING INSTALLATION TECHNIQUES FOR ALL SYSTEM COMPONENTS.....	9
6. UNDERSTANDING SYSTEM CABLING AND CABLE AND SYSTEM PROTECTION DEVICES.....	13
7. DEMONSTRATE PRACTICAL CABLING AND FINAL SYSTEM INSTALLATION .....	14
8. TESTING AND COMMISSIONING .....	15

<b>1. Working Safely with PV Based Off-Grid power Systems</b>		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>As part of normal safety considerations, any PV based off-grid power system installer must be able to:</i>		
1.1 Maintain safe work habits and clean, orderly work area	Cognitive, Psychomotor	Critical
1.2 Demonstrate proper use of 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
<i>The installer must be able to identify electrical and non-electrical hazards associated with PV Based Off-Grid Power system installations, and implement preventative and remedial measures to ensure personnel safety:</i>		
1.5 Implement appropriate codes and standards concerning installation of solar based off-grid power systems and equipment as specified by the designer and or supervisor.	Cognitive, Psychomotor	<i>Critical</i>
1.6 Implement appropriate codes and standards concerning worker and public safety as specified by the designer and or supervisor.	Cognitive, Psychomotor	<i>Critical</i>
1.7 Identify personal safety hazards, both electrical and physical, associated with PV based off-grid power systems installations, and implement preventative and remedial measures	Cognitive, Psychomotor	<i>Critical</i>
1.8 Identify environmental hazards associated with PV based off-grid power systems installations, and implement preventative and remedial measures	Cognitive, Psychomotor	<i>Critical</i>

<b>2. Understanding Energy Concepts</b>		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>In order to design energy based systems, the installers must have understanding and knowledge of the following energy and power concepts</i>		
2.1 Demonstrate knowledge of correct units for, electrical potential, electrical flow, electrical resistance, energy and power	Cognitive,	Critical
2.2 Demonstrate the use of the prefixes k (1000) and M (mega, 10 <sup>6</sup> ) when converting values of units	Cognitive,	Important
2.3 Identify the power rating of DC electrical appliances when presented with this information in different formats. e.g. as W or as A	Cognitive,	Critical
<i>Following are for Designer Level 2 and 3 Only</i>		
2.4 Demonstrate understanding of differences between AC and DC power	Cognitive,	Critical

<b>3. Determining Solar Resources</b>		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>To demonstrate appropriate skills and knowledge of photovoltaic energy resources the installer must be able to:</i>		
3.1 Understand the requirement for proper orientation and inclination of solar array as specified for the system.	Cognitive,	Very Important
3.2 Understand the impact that the sun's movements over the day and the year have on battery charging and hence overall available energy.	Cognitive,	Very Important
3.3 Understand the impact of shading on the effect of charging the batteries and hence overall available energy	Cognitive,	Critical

<b>4. Interpret System Drawings</b>		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
4.1 Identify and describe all system components from those depicted in a system drawing	Cognitive,	Critical
4.2 Identify actual location for all equipment to be installed on site based on the drawing.	Cognitive,	Critical

<b>5. Demonstrating Installation Techniques for all System Components</b>		
<b>Task/Skill:</b>	<b>Skill Type:</b>	<b>Priority/Importance:</b>
To demonstrate that they have appropriate practical skills to carry out the installation of all system components the PV based off-grid power system installer must be able to:		
<b>PV ARRAYS</b>		
5.1 Demonstrate sound mounting design and techniques for attaching modules to the array frame and the array frame to its supporting structure 5.1.1 Use of appropriate bolts or screws, including gauge, penetration 5.1.2 Fixing of external timber or metal battens to the roof sub frame 5.1.3 Weather sealing of array to building or other support mechanism	Cognitive, Psychomotor	Critical
5.2 Demonstrate a working knowledge of the pitch and condition of different roof claddings systems, and install appropriate mounting techniques for the roofs typical within the country of installation as specified by the designer and or supervisor.	Cognitive, Psychomotor	Very Important
5.3 Understand the issue of corrosion problems arising from contacting dissimilar metals in mounting systems / roof claddings and how it can be avoided through: 5.3.1 Use of rubber grommets, non-metallic membranes 5.3.2 Use of appropriate bolts (stainless steel etc.)	Cognitive, Psychomotor	Very Important
5.4 Demonstrate how to fit PV arrays to roofs through 5.4.1 Interpreting layout diagrams for PV array to cater for different shaped roofs 5.4.2 Knowing how to install different methods of fixing PV arrays at optimum pitch and orientation to off roof pitches and orientations	Cognitive, Psychomotor	Very Important

<b>Balance of System Components</b> <b>Batteries</b>		
5.5 Demonstrate the safe handling of batteries	Cognitive, Psychomotor	Critical
5.6 Understand battery bank installation in relation to factors which effect the longevity and performance of the battery bank such as : 5.6.1 positioning the batteries so that they not adversely effected by the harsh environmental condition of the pacific islands(e.g exposed to hot sun)	Cognitive,	Critical
5.7 Demonstrate appropriate placement to optimise inter-cell connections and minimise excessive cable lengths	Cognitive, Psychomotor	Critical
5.8 Understand the different system enclosures and shrouds that are required to meet the climatic conditions in the pacific Islands: 5.8.1 Understand the need for battery enclosures and terminal shrouds 5.8.2 Understand the need for a safe working environment and safe installation of the battery for the system owners	Cognitive, Psychomotor	Critical
5.9 Demonstrate the appropriate placement of inlet and exhaust ventilation apertures	Cognitive, Psychomotor	Critical
<b>Balance of System Components</b> <b>Charge Controllers</b>		
5.10 Demonstrate the positioning and fixing of solar charge controllers to : 5.10.1 minimize cable lengths 5.10.2 position the controller so that it is not adversely effected by the harsh environmental condition of the pacific islands 5.10.3 be installed in accordance with manufacturers specifications 5.10.4 provide a safe working environment and safe installation for the system owners	Cognitive, Psychomotor	Critical
<b>Balance of System Components</b> <b>Appliances e.g lights</b>		
5.11 Demonstrate the positioning and fixing of all appliances in place to: 5.11.1 minimise cable lengths 5.11.2 be installed in accordance with manufacturers specifications 5.11.3 provide a safe working environment and safe installation for the system owners	Cognitive, Psychomotor	Critical

<b>Balance of System Components</b> General		
5.12 Demonstrate the positioning and fixing of all system components in place to: 5.12.1 minimise cable lengths between all components 5.12.2 be installed in accordance with manufacturers specifications 5.12.3 provide a safe working environment and safe installation for the system owners	Cognitive, Psychomotor	Critical
5.13 Layout and secure system components in position 5.13.1 Demonstrate diagrammatically and in practice the layout of system components 5.13.2 Understand the reasons for optimal system component layout 5.13.3 Demonstrate the use of appropriate fixing systems to secure system components in place	Cognitive, Psychomotor	Critical
<i>For Installer/Maintainer level 2 and 3 Only</i>		

<b>Balance of system components</b> <b>Inverter</b>		
5.14 Demonstrate the correct positioning and sound mounting techniques for 5.14.1 securely locking the inverter to its supporting structure 5.14.2 ensuring that the inverter is not adversely effected by the harsh environmental condition of the pacific islands. 5.14.3 providing suitable airflow 5.14.4 meeting the installation requirements specified by the manufacture 5.14.5 providing a safe working environment and safe installation for the system owners	Cognitive, Psychomotor	Critical
<b>Balance of system components</b> <b>Fuel Generator (optional Level 2)</b>		
5.15 Demonstrate the correct positioning and sound mounting techniques for 5.15.1 securely locking the generator plant to its supporting structure 5.15.2 provide suitable sound attenuation 5.15.3 providing vibration isolation, exhaust extraction and cooling ventilation which comply with manufactures specification 5.15.4 allowing adequate access to all plant components for maintenance and fault finding	Cognitive, Psychomotor	Critical
5.16 Demonstrate the position and fixing of fuel storage tanks and fuel lines to comply with relevant standards and 5.16.1 provide a safe working environment and safe installation for the system owners 5.16.2 provide fuel containment systems for environmental protection in case of spillage 5.16.3 minimised fuel line lengths between tank and engine	Cognitive, Psychomotor	Critical

<b>6. Understanding System Cabling and Cable and System Protection Devices</b>		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>To demonstrate that they have a working knowledge of cable specification and cable system protection devices the PV based off-grid power system installer must be able to:</i>		
<b>Cables</b>		
6.1 Understand the variations in different electrical transmission configuration, such as underground or overhead, and why they are applied. (DC cables)	Cognitive	Critical
6.2 Understand the reasons why excessive voltage drop in a cable can be detrimental to system performance and why the installers must install the cable that is specified.	Cognitive	Critical
6.3 Discuss current carrying capacity and the implications for cable installation.	Cognitive	Critical
6.4 Demonstrate the measurement of voltage drop in a conductor	Cognitive	Critical
6.5 Demonstrate the measurement of current through a conductor	Cognitive	Critical
6.6 Demonstrate the installation the protection devices that was provided for all conductors in a circuit	Cognitive	Critical
<i>For Installer level 2 and 3</i>		

AC Cabling		
6.7 Demonstrate the difference installation practices required between AC cables and DC cables		Critical
6.8 Discuss the difference in installation standards and practices for AC cables compared with DC cables.	Cognitive	Critical
Cabling for Multiple buildings and/or village Optional for Level 2		
6.9 Demonstrate the installation of electrical transmission configuration, such as underground or overhead for the AC cables	cognitive	critical
6.10 Demonstrate the installation of protection requirements for the different buildings and the interconnection cabling to the buildings		
Earthing (Grounding)		
6.11 Install earthing (grounding) systems as specified.	Cognitive	Critical
6.12 Install lightning protection as specified.	Cognitive	Critical

<b>7. Demonstrate practical cabling and final system installation</b>		
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>
<i>To demonstrate that they can carry out installation of cabling, the installer must</i>		
7.1 Demonstrate cable termination techniques	Cognitive, Psychomotor	Critical
7.2 Demonstrate the installation and replacement of circuit protection	Cognitive, Psychomotor	Critical
7.3 Demonstrate safe techniques for laying and securing cables in place	Cognitive, Psychomotor	Very Important
7.4 Demonstrate the use of appropriate physical protection for installed cables	Cognitive, Psychomotor	Very Important
<i>To complete the installation the installers must be able to:</i>		
7.5 Complete final assembly, structural attachment, and weather sealing of array to building or other support mechanism	Psychomotor	Critical

7.6	Install and provide required labels on controls, disconnects and over current devices,	Psychomotor	Critical
7.7	Label, install, and terminate electrical wiring; verify proper connections, voltages, and polarity relationships	Psychomotor	Critical
7.8	Install signage requirements that meet relevant local requirements, standards and industry best practice as specified by the designer and or supervisor.	Cognitive,	Critical
7.9	Verify continuity in circuits	Cognitive, Psychomotor	Very Important

<b>8. Testing and Commissioning</b>			
<i>Task/Skill:</i>	<i>Skill Type:</i>	<i>Priority/Importance:</i>	
<i>After completing the installation of a solar home system, as part of system commissioning, inspections and handoff to the owner/operator, the installer of solar home systems shall be able to:</i>			
8.1	Visually inspect entire installation, identifying and resolving any deficiencies in materials or workmanship	Cognitive, Psychomotor	Critical
8.2	Check system mechanical installation for structural integrity and weather sealing as required	Cognitive, Psychomotor	Critical
8.3	Check electrical installation for proper wiring practice, polarity, security of terminations, and grounding when necessary	Cognitive, Psychomotor	Critical
8.4	Activate system and verify overall system functionality and performance, compare with expectations	Cognitive, Psychomotor	Critical
8.5	Demonstrate correct sequence for connecting and disconnecting the system and equipment from all sources	Cognitive, Psychomotor	Critical
8.6	Identify and verify all markings and labels for system and equipment as required	Cognitive	Critical
8.7	Identify and explain all safety issues associated with operation and maintenance of system	Cognitive	Critical
8.8	Transfer a complete documentation package for the system and equipment to owner/operator	Cognitive	Very Important
8.9	Review and cosign final acceptance agreement summarizing safety and maintenance document	Cognitive	Very Important