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

Introduction

This document presents a task analysis (job analysis or key skills analysis) for practitioners who *install and maintain* solar based off-grid power systems. In addition to providing installation, these technicians provide system maintenance and troubleshooting to determine system faults during field visits of PV systems.

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/maintainers who:

1. Install and maintain solar home systems for systems that typically comprise one or two solar modules, a 12V or 24V battery, small controller and DC appliances. (Installer / Maintainer solar based off-grid power systems level 1)
2. Install and maintain stand alone solar systems which include AC and possibly some DC loads for a single building or adjacent buildings (Installer / maintainer 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 and maintain hybrid power systems comprising a solar array, inverter, batteries and fuel generator as the energy sources (Installer /maintainer 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 practitioners. These tasks, or modified version thereof, may be used as guidelines for organizations that wish to train, test, certify, or otherwise qualify existing or new workers to install 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 systems.

Scope

This task analysis is intended to be all-inclusive of the skills expected for any qualified installer/ maintainer of solar home systems, stand alone solar systems and hybrid power systems. 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 levels. Under some of the specific tasks, there are tasks that are specified only for the Installer/maintainer levels 2 and/or 3.

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

Task	**PV Off-grid Power systems level 1 Installation and Maintenance**	**PV Off-grid Power systems Level 2 Installation and Maintenance**	**PV Off-grid Power systems Level 3 Installation and Maintenance**
	Install and Maintain solar home systems for systems that comprise one or two solar modules, a 12V battery, small controller and DC lights.	*Install and Maintain stand alone solar systems which include AC loads*	*Install and Maintain hybrid power systems comprising a solar array and fuel generator as the energy sources*
	TASKS		
Working safely with PV based off grid power systems	1.1 to 1.8		
Understanding Energy Concepts	2.1 to 2.4	2.5 to 2.8	
Understanding Solar Resources	3.1 to 3.3		
Understanding system Components	4.1 to 4.16	4.17 to 4.36 4.23 to 4.32 optional for Level 2	4.37 to 4.39
Interpreting System Drawing	5.1 to 5.3		
Demonstrate Installation	6.1 to 6.13	6.14 , 6.15,6.16	

techniques for system components		6.15 and 6.16 Optional for level 2	
Specify all system cabling and cable and protection devices. (Note: Though these should be specified by a designer a PR actioner who installs/maintains must be able to know how to determine cable sizing and protection)	7.1 to 7.9	7.10 to 7.16 7.12 and 7.13 Optional for level 2	
Demonstrate practical cabling and final system installation	8.1 to 8.9		
Testing and Commissioning	9.1 to 9.9		
Maintenance and Troubleshooting systems	10.1 to 10.8	10.9, 10.10,10.11 10.10 Optional for level 2	

Fundamentally, these tasks require that the installer /maintainer begin with a system design developed by a qualified system designer in consultation with the energy user. Very importantly, the installer/maintainer must have knowledge of occupational health and safety requirements for the type of system being installed.

Installer/maintainer level 1 shall then install the PV array and the balance of system equipment required for the system to meet the needs of the end-user and in accordance with all relevant standards for that particular country. If no standards exist, the installer/maintainer must follow installation practices typical for the PV industry in the country or the 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. The installer/maintainer will also have an understanding of the operations of each system individual components and how they are interconnected to create a system so that they can troubleshoot and provide maintenance for the system.

Installer/maintainer level 2 shall then install the PV array and the balance of system equipment required for the system to meet the needs of the end-user and in accordance with all relevant standards for that particular country. If no standards exist, the installer/maintainer 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, a battery bank , an inverter and associated cables and circuit protection equipment. As an option, the balance of system equipment could also include a back-up generator, a transfer switch and appliances. Another option would be these systems being used to supply multiple buildings and/or villages. The installer/maintainer will also have an understanding of the operations of each system individual components and how they are interconnected to create a system so that they can troubleshoot and provide maintenance for the system.

Installer/maintainer 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/maintainer 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, inverter, a battery bank, a transfer switch or system controller and associated cables and circuit protection equipment. The installer/maintainer will also have an understanding of the operations of each system individual components and how they are interconnected to create a system so that they can troubleshoot and provide maintenance for the system.

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 practitioner 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 though 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 system installers/maintainers
Very Important items are medium priority tasks, and are generally expected of all competent installers/maintainers
Important items are considered lower priority tasks, but usually performed or understood by the quality installers/installers

Primary Objective for the Off grid Installer/maintainer

The Off-grid installer/maintainer is required to install and maintain 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. UNDERSTANDING SOLAR RESOURCES 8
4. UNDERSTANDING SYSTEM COMPONENTS 9
5. INTERPRET SYSTEM DRAWINGS 13
6. DEMONSTRATING INSTALLATION TECHNIQUES FOR ALL SYSTEM COMPONENTS 14
7. SPECIFYING ALL SYSTEM CABLING AND CABLE AND SYSTEM PROTECTION DEVICES 17
8. DEMONSTRATE PRACTICAL CABLING AND FINAL SYSTEM INSTALLATION 20
9. TESTING AND COMMISSIONING 21
10. MAINTAINING AND TROUBLESHOOTING SYSTEMS 22

1. Working Safely with PV Based Off-Grid power Systems		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
As part of normal safety considerations, any PV based off-grid power system installer/maintainer must be able to:		
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
The installer//maintainer 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:		
1.5 Identify and implement appropriate codes and standards concerning installation, operation and maintenance of solar based off-grid power systems and equipment	Cognitive, Psychomotor	*Critical*
1.6 Identify and implement appropriate codes and standards concerning worker and public safety	Cognitive, Psychomotor	*Critical*
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	*Critical*
1.8 Identify environmental hazards associated with PV based off-grid power systems installations, and implement preventative and remedial measures	Cognitive, Psychomotor	*Critical*

2. Understanding Energy Concepts		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
In order to install/maintain energy based systems, the designers must have understanding and knowledge of the following energy and power concepts		
2.1 Demonstrate knowledge of correct units for, electrical potential (voltage), electrical flow(current), electrical resistance, energy and power	Cognitive,	Critical
2.2 Understand Ohm's Law and be able to calculate energy loads given	Cognitive,	important
2.3 Demonstrate the use of the prefixes k (1000) and M (mega, 10^6) when converting values of units	Cognitive,	Important
2.4 Identify the power rating of DC electrical appliances when presented with this information in different formats. e.g. as W or as through calculating based on Amps and Voltage.	Cognitive,	Critical
Following are for Level 2 and 3 Only		
2.5 Demonstrate understanding of differences between AC and DC power	Cognitive,	Critical
2.6 Demonstrate understanding of power factor	Cognitive,	important
2.7 Demonstrate understanding of true power and real power	Cognitive,	important
2.8 Demonstrate understanding of surge power requirements of certain appliances	Cognitive,	critical

3. Understanding Solar Resources		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
To demonstrate appropriate skills and knowledge of photovoltaic energy resources the installer/maintainer must be able to:		
3.1 Understand the requirement for proper orientation and inclination of solar array.	Cognitive,	Important
3.2 Define the term 'peak sun hours' (irradiation) and the impact that the sun's movements over the day and the year have on battery charging and hence overall available energy	Cognitive,	Important
3.3 Quantify the impact of shading on the available irradiation for a sample site and the effect on charging the batteries	Cognitive,	Critical

4. Understanding System Components		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
To Demonstrate that they are familiar with all the components of a system the installer/maintainer of an off grid power system must be able to:		
PV ARRAYS		
4.1 Interpret the technical specifications and output characteristics of photovoltaic modules and understand the terms Isc, Voc, Imp, Vmp, Pmax	Cognitive,	Important
4.2 Define the factors which influence the output characteristics of photovoltaic modules (irradiance, temperature, age)	Cognitive,	Important
4.3 Compare the relative merits of alternative photovoltaic modules for different applications and installation requirements. Compare the generic alternatives of the following classes, and compare different manufacturers' data within the classes, viz: 4.3.1 monocrystalline 4.3.2 polycrystalline 4.3.3 amorphous	Cognitive,	Important
4.4 Demonstrate basic electric circuit theory and be able to identify series and parallel circuits	Cognitive,	Critical
4.5 Demonstrate the effect on array output (current, voltage and power) of connecting modules in series and parallel configurations	Cognitive,	Critical
4.6 Explain the effects of using dissimilar modules in an array	Cognitive,	Very Important
4.7 Demonstrate the use of blocking and bypass diodes with the different classes of PV modules, and make appropriate decisions about their use or otherwise and quantify the effect of diodes on array output.	Cognitive,	Important
4.8 Demonstrate the impact of shading and implement a program to periodically check for shading effects by cleaning panels, removing debris (leaves bird droppings etc.), trimming trees	Cognitive,	Critical

4.9 Explain the design criteria and installation techniques for 4.9.1 Pole mounted panels 4.9.2 Roof mounted panels	Cognitive,	Very Important
Balance of System Components **Battery Bank**		
4.10 Interpret and explain different battery technologies, internal battery design variations and characteristics and make a considered decision to use particular battery types for different system requirements, considering reliability, safety, convenience, life and cost (vented, valve-release, sealed, liquid electrolyte, AGM, Gel, Ni-Cad, 2 volts cells, 4-24 volt batteries)	Cognitive,	important
4.11 Explain the factors and relevant manufacturers' data which relate to battery performance, mode of failure and expected life (viz DOD, discharge and charge currents and voltages, capacity at different discharge rates and temperatures, high and low ambient temperatures, over-discharge, over-charge, gassing, equalisation, sulphation, stratification, plate corrosion, sludge shorting, electrolyte SG and volume	Cognitive,	Very Important
4.12 Demonstrate the different techniques used to measure battery bank capacity, e.g. by the use of specific gravity measurements and charts for the installed batteries or by a measured discharge test.	Cognitive,	Very Important
Balance of Systems **Charge Regulator/System Controllers**		
4.13 Demonstrate the operating principles of alternative types of regulators /controllers (series, shunt, single and multi-stage, phase-width modulation,)	Cognitive,	Important
4.14 Explain the relevance of and demonstrate the proper installation of temperature-correction probes	Cognitive,	Important
4.15 Demonstrate the role of each of the regulator features (low voltage cut-out, temperature compensation, load disconnect)	Cognitive,	Very Important
Balance of Systems **Lights**		
4.16 Demonstrate understanding of the different DC lighting technologies that are available.	Cognitive,	Important
For Level 2 and 3		
Balance of Systems **Inverters**		

4.17 Demonstrate an understanding of the basic operating principles of inverters in converting DC to AC and how this has been achieved for different inverter output waveforms-modified square (or modified sinewave), and sine wave.	Cognitive,	Very Important
4.18 List the factors which affect the efficiency and reliability of inverters, and their minimum location and housing requirements	Cognitive,	critical
4.19 Demonstrate a working knowledge of inverter specifications and features – continuous, and surge power ratings and their temperature dependence, over and under voltage stand-by power consumption, status-indicating, metering, data-logging and programming functions - and understand the use of shunts, audible noise, radio frequency interference	Cognitive,	Very Important Not required
Balance of Systems **Maximum Power Point Trackers (MPPTS)**		
4.20 Explain the operating principles of MPPTs	Cognitive,	Important
4.21 Discuss the efficiency of MPPTs and what factors affect the efficiency	Cognitive,	Important
4.22 Understand the differences between series, switched or parallel systems and the appropriate use of manual or relay-type change-over switches		Very Important
Balance of Systems **Optional for Level 2 : Battery Chargers**		
4.23 Explain the operating principles and demonstrate the characteristics of different battery charger types (ferro-resonant triac, switch-mode)	Cognitive,	Important
4.24 Compare battery charger specifications and maximum continuous charge rates with system requirements	Cognitive,	Important
4.25 Demonstrate an ability to program multi-stage chargers and inverter-chargers in line with battery type and capacity (including awareness of battery manufacturers' recommended parameters), and with seasonal load patterns	Cognitive,	Very Important

Balance of Systems **Optional for Level 2 : Fuel Generators**		
4.26 Demonstrate understanding of different fuel generators available: diesel , petrol(gasoline), LPG and biofeuls	Cognitive,	Important
4.27 Explain the operating principles of different fuel generaors eg diesel internal combustion generator ,	Cognitive,	Important
4.28 Interpret the rating of generators (kVA compared with kW, measuring voltage and frequency stability vs. load)	Cognitive,	Very Important
4.29 Be aware that the cabling from the generator to the inverter/charger or charger is AC and if permanently wired must be carried out by a suitably qualified technician in accordance to the laws of the country	Cognitive,	Very Important
4.30 Discuss different starting systems for generators, and how to set up a programmed relay-controlled start / stop interface	Cognitive,	Very Important
4.31 Demonstrate a knowledge of appropriate siting and segregating of generators (ignition of battery gases, heat, noise, fumes, fuel storage)	Cognitive,	Cognitive,
4.32 Demonstrate an understanding of the multi phase alternator with knowledge of wiring configuration for 3 phase to single phase conversion and the de-rating of outputs due to the reconfiguration	Cognitive,	Very Important
DC-DC Step Down Converters (If required)		
4.33 Explain the operating principles and appropriate uses of DC – DC converters	Cognitive,	Important
Remote Monitoring/Data Logging		
4.34 Explain the operating principles of data logging equipment	Cognitive,	Important
4.35 Calibrate a data logger	Cognitive,	Important

4.36 Explain the use of data transfer interface devices (disc, lap link, modem)	Cognitive,	Important
For Level 3		
Balance of Systems **Grid connect Inverters**		
4.37 List the factors which affect the efficiency and reliability of grid connect inverters, and their minimum location and housing requirements	Cognitive,	Very Important
4.38 Demonstrate an understanding of the Maximum Power Point Tracking feature of grid connect inverters	Cognitive,	Important
4.39 Demonstrate a working knowledge of inverter specifications and features –over and under voltage and frequency controls, harmonic distortion, stand-by power consumption, status-indicating, metering, data-logging and programming functions - and understand the problems associated with audible noise, radio frequency interference	Cognitive,	Very Important

5. Interpret System Drawings		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
5.1 Identify and describe all system components from those depicted in a system drawing	Cognitive,	Critical
5.2 Produce a procurement list of all system components from a system drawing	Cognitive,	Critical
5.3 Identify actual location for all equipment to be installed on site	Cognitive,	Critical

6. Demonstrating Installation Techniques for all System Components		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
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/maintainer must be able to:		
PV ARRAYS		
6.1 Demonstrate sound mounting design and techniques for attaching modules to the array frame and the array frame to its supporting structure 6.1.1 use of appropriate bolts or screws, including gauge, penetration 6.1.2 fixing of external timber or metal battens to the roof sub frame 6.1.3 weather sealing of array to building or other support mechanism	Cognitive, Psychomotor	Critical
6.2 Demonstrate a working knowledge of the pitch and condition of different roof claddings systems, and apply appropriate mounting techniques for the roofs typical within the country of installation	Cognitive, Psychomotor	Very Important
6.3 Explain how to recognise and avoid corrosion problems arising from contacting dissimilar metals in mounting systems / roof claddings 6.3.1 use of rubber grommets, non-metallic membranes 6.3.2 use of appropriate bolts (stainless steel etc.)	Cognitive, Psychomotor	Very Important
6.4 Demonstrate how to fit PV arrays to roofs 6.4.1 Interpret layout diagrams for PV array to cater for different shaped roofs 6.4.2 Know different methods of fixing PV arrays at optimum pitch and orientation to off roof pitches and orientations	Cognitive, Psychomotor	Very Important

Balance of System Components **Batteries**		
6.5 Demonstrate the safe handling of batteries	Cognitive, Psychomotor	Critical
6.6 Discuss battery bank installation in relation to factors which effect the longevity and performance of the battery bank 6.6.1 are installed in accordance with manufacturers specifications 6.6.2 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
6.7 Demonstrate appropriate placement to optimise inter-cell connections and minimise excessive cable lengths	Cognitive, Psychomotor	Critical
6.8 Specify appropriate system enclosures and shrouds in particular for the climatic conditions in the pacific Islands: 6.8.1 Discuss the need for battery enclosures and terminal shrouds 6.8.2 Discuss any relevant Standard requirements for battery enclosures and terminal shrouds 6.8.3 Discuss alternate methods of providing appropriate battery enclosures and terminal shrouds 6.8.4 provide a safe working environment and safe installation for the system owners	Cognitive, Psychomotor	Critical
6.9 Demonstrate the appropriate placement of inlet and exhaust ventilation apertures	Cognitive, Psychomotor	Critical
Balance of System Components Charge Controllers		
6.10 Demonstrate the positioning and fixing of solar charge controllers: 6.10.1 minimise cable lengths 6.10.2 positioning the charge controller so that it is not adversely effected by the harsh environmental condition of the pacific islands 6.10.3 are installed in accordance with manufacturers specifications 6.10.4 provide a safe working environment and safe installation for the system owners	Cognitive, Psychomotor	Critical
Balance of System Components Appliances e.g lights		

6.11 Demonstrate the positioning and fixing of all appliances in place to: 6.11.1 minimise cable lengths 6.11.2 in accordance with manufacturers specifications 6.11.3 provide a safe working environment and safe installation for the system owners	Cognitive, Psychomotor	Critical
Balance of System Components General		
6.12 Demonstrate the positioning and fixing of all system components in place to: 6.12.1 minimise cable lengths between all components 6.12.2 in accordance with manufacturers specifications 6.12.3 provide a safe working environment and safe installation for the system owners	Cognitive, Psychomotor	Critical
6.13 Layout and secure system components in position 6.13.1 Demonstrate diagrammatically and in practice the layout of system components 6.13.2 Discuss the reasons for optimal system component layout 6.13.3 Demonstrate the use of appropriate fixing systems to secure system components in place	Cognitive, Psychomotor	Critical
For Installer/Maintainer level 2 and 3 Only		

Balance of system components **Inverter**		
6.14 Demonstrate the correct positioning and sound mounting techniques for 6.14.1 securely locking the inverter to its supporting structure 6.14.2 ensuring that he inverter is not adversely effected by the harsh environmental condition of the pacific islands. 6.14.3 providing suitable airflow 6.14.4 Meeting the installation requirements specified by the manufacture 6.14.5 providing a safe working environment and safe installation for the system owners	Cognitive, Psychomotor	Critical
Balance of system components **Fuel Generator (optional Level 2)**		
6.15 Demonstrate the correct positioning and sound mounting techniques for 6.15.1 securely locking the generator plant to its supporting structure 6.15.2 provide suitable sound attenuation 6.15.3 providing vibration isolation, exhaust extraction and cooling ventilation which comply with manufactures specification 6.15.4 allowing adequate access to all plant components for maintenance and fault finding	Cognitive, Psychomotor	Critical
6.16 Demonstrate the position and fixing of fuel storage tanks and fuel lines to comply with relevant standards and 6.16.1 provide a safe working environment and safe installation for the system owners 6.16.2 provide fuel containment systems for environmental protection in case of spillage 6.16.3 minimised fuel line lengths between tank and engine	Cognitive, Psychomotor	Critical

7. Specifying All System Cabling and Cable and System Protection Devices		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
To demonstrate that they have a working knowledge of cable specification and cable system protection devices the PV based off-grid power system installer .maintainer ***must be able to:***		
Cables		

7.1 Determine the type of electrical transmission configuration, such as underground or overhead, according to distances, topology and local regulations and environmental issues. (Though common for all three levels this will cover more issues for level 2 and 3 then covered for level 1)	Cognitive	Critical
7.2 Explain the reasons why excessive voltage drop can be detrimental to system performance	Cognitive	Critical
7.3 Discuss current carrying capacity and the implications for cable selection .	Cognitive	Critical
7.4 Demonstrate the calculation and measurement of voltage drop in a conductor	Cognitive	Critical
7.5 Demonstrate the measurement of current through a conductor	Cognitive	Critical
7.6 Demonstrate the use of tables to determine the current carrying capacity of a conductor and the factors which influence CCC	Cognitive	Critical
7.7 Apply voltage drop and current carrying capacity calculation to select cables for all applications in a PV based off-grid power system	Cognitive	Critical
7.8 Specify appropriate protection for all conductors in a circuit	Cognitive	Critical
7.9 Demonstrate ability to design lighting and load circuits to ensure voltage drop is minimized.	Cognitive	Very Important
For Installer level 2 and 3		
AC Cabling		
7.10 Discuss the difference between AC cables and DC cables	Cognitive	Critical
7.11 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**		

7.12 Determine the type of electrical transmission configuration, such as underground or overhead, according to distances, topology and local regulations and environmental issues	cognitive	critical
7.13 Determine protection requirements for the different buildings and the interconnection cabling to the builidngc		
Earthing (Grounding)		
7.14 Discuss the need for an appropriate earthling system	Cognitive	Critical
7.15 Demonstrate ways of earthing all system components	Cognitive	Critical
7.16 Discuss the need for lightening protection, the advantages and disadvantages and the types of protection available	Cognitive	Critical

8. Demonstrate practical cabling and final system installation		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
To demonstrate that they can carry out installation of cabling, the installer/maintainer must (Note the level of competency and required knowledge will be different for the level 2 and 3 compared to the Level 1 who just does DC installation at 12V or 24V.)		
8.1 Demonstrate cable termination techniques	Cognitive, Psychomotor	Critical
8.2 Demonstrate the installation and replacement of circuit protection	Cognitive, Psychomotor	Critical
8.3 Demonstrate safe techniques for laying and securing cables in place	Cognitive, Psychomotor	Very Important
8.4 Demonstrate the use of appropriate physical protection for installed cables	Cognitive, Psychomotor	Very Important
To complete the installation the installer/maintainers must be able to:		
8.5 Complete final assembly, structural attachment, and weather sealing of array to building or other support mechanism	Psychomotor	Critical
8.6 Install and provide required labels on controls, disconnects and over current devices,	Psychomotor	Critical
8.7 Label, install, and terminate electrical wiring; verify proper connections, voltages, and polarity relationships	Psychomotor	Critical
8.8 Discuss signage requirements to meet relevant local requirements, standards and industry best practice	Cognitive,	Critical
8.9 Verify continuity in circuits	Cognitive, Psychomotor	Very Important

9. Testing and Commissioning		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
After completing the installation of a PV based off-grid system, as part of system commissioning, inspections and handoff to the owner/operator, the installer/maintainer of PV based off-grid system shall be able to:		
9.1 Visually inspect entire installation, identifying and resolving any deficiencies in materials or workmanship	Cognitive, Psychomotor	Critical
9.2 Check system mechanical installation for structural integrity and weather sealing as required	Cognitive, Psychomotor	Critical
9.3 Check electrical installation for proper wiring practice, polarity, security of terminations, and grounding when necessary	Cognitive, Psychomotor	Critical
9.4 Activate system and verify overall system functionality and performance, compare with expectations	Cognitive, Psychomotor	Critical
9.5 Demonstrate correct sequence for connecting and disconnecting the system and equipment from all sources	Cognitive, Psychomotor	Critical
9.6 Identify and verify all markings and labels for system and equipment as required	Cognitive	Critical
9.7 Identify and explain all safety issues associated with operation and maintenance of system	Cognitive	Critical
9.8 Transfer a complete documentation package for the system and equipment to owner/operator	Cognitive	Very Important
9.9 Review and cosign final acceptance agreement summarizing safety and maintenance document	Cognitive	Very Important

10. Maintaining and Troubleshooting Systems		
Task/Skill:	***Skill Type:***	***Priority/ Importance:***
To demonstrate that they have a working knowledge of how to maintain and trouble shoot any system the PV based off-grid power system installer/maintainer must be able to: (Note Different levels of complexity for eachtecinstaller/maintainer level)		
10.1 Identify tools and equipment required for maintaining and troubleshooting PV based off-grid power systems; demonstrate proficiency in their use	Cognitive, Psychomotor	Critical
10.2 Identify maintenance needs and implement service procedures for modules, arrays, batteries, controllers, safety systems, structural and weather sealing systems,	Cognitive, Psychomotor	Critical
10.3 Measure system performance and operating parameters; compare with specifications and expectations, and assess operating condition of system and equipment	Cognitive, Psychomotor	Critical
10.4 Perform diagnostic procedures and interpret results	Cognitive, Psychomotor	Critical
10.5 Identify performance and safety issues, and implement corrective measures	Cognitive, Psychomotor	Critical
10.6 Verify and demonstrate complete functionality and performance of system, including start-up, shut-down, normal operation,	Cognitive Psychomotor	Critical
10.7 Compile and maintain records of system operation, performance, and maintenance	Cognitive	Very Important
10.8 State the system documentation that should be provided to the system owners	Cognitive	Very Important
For Level 2 and 3		
10.9 Identify maintenance needs and service procedures for inverters	Cognitive, Psychomotor	Critical
10.10 Implement service procedures for fuel generating plant, including engine, alternator, start/stop controls, and engine protecting systems and fuel delivery and storage systems. (optional for level 2)	Cognitive, Psychomotor	Critical
10.11 Implement service procedures for the transmissions lines between multiple building. (optional for level 2)	Cognitive, Psychomotor	Critical