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

Introduction

This document presents a task analysis (job analysis or key skills analysis) for practitioners who design solar based Off-Grid power systems.

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

- Small solar home systems comprising one or two solar modules and the load 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 practitioners who:

1. Design solar home systems for systems that comprise one or two solar modules, a 12V battery, small controller and DC lights. (Designer Solar based Off-Grid power systems level 1)
2. Design stand alone solar systems which include AC loads (Designer Solar based Off-Grid power level systems 2)
3. Design hybrid power systems comprising a solar array and fuel generator as the energy sources (Designer 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 design 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 designer; stand alone solar system designer and hybrid power system designer. 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 design levels. Under some of the specific tasks, there are tasks that are specified only for the Designer levels 2 and/or 3.

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

Task	**Designer Solar Based Off Grid Power Systems level 1**	**Designer Solar Based Off Grid Power Systems level 2**	**Designer Solar Based Off Grid Power Systems level 3**
	Design solar home systems for systems that comprise one or two solar modules, a 12V battery, small controller and DC lights.	*Design stand alone solar systems which include AC loads*	*Design hybrid power systems comprising a solar array and fuel generator as the energy sources*
	TASKS		
Understanding Energy Concepts	1.1 to 1.6	1.7 to 1.13	
Understanding energy Assessment and Load Analysis		2.1 to 2.4	
Determining Solar Resources	3.1 to 3.4		
Conducting a site assessment	4.1 to 4.8	4.9	4.10
Understanding system Components	5.1 to 5.31	5.32 to 5.43	5.44 to 5.69
Understanding system Design	6.1 to 6.5	6.6 to 6.11	6.12 to 6.21
Interpreting Technical Standards	7.1 to 7.2		
Understanding Economic Analysis	8.1 to 8.2		8.3
Interpreting Regulatory Requirements	9.1 to 9.2		
Knowledge of occupational	10.1 to 10.3		

health and safety			
Development of Documentation	11.1 to 11.2		11.3

For designer level 1 generally solar home systems are between 20W and 100W (sometimes higher) and are sold as packages where the number of lights and maximum operation time of the lights is defined. As part of the education of the customer it is important that a solar home system designer is fully aware of the energy limitations of a solar home system and can undertake an energy (load) assessment of a household and therefore it is expected that a designer can design a DC solar system based on any load. Fundamentally, these tasks require that the designer begins with a load assessment and a solar resource assessment for the proposed site. The designer shall then determine the size of the PV array, the most suitable array frame (pole or roof mounted) the capacity of the battery ,the rating of the controller and associated cables and circuit protection equipment. Other skills required to design a system include some knowledge local regulatory requirements and standards; ability to do economic analysis of systems capital and operating costs,; production of documentation for the customer and very importantly a knowledge of occupational health and safety requirements.

For designer level 2 the system is larger and there will be an inverter to provide AC loads. Fundamentally, these tasks require that the designer begins with a load assessment and a solar resource assessment for the proposed site. The designer shall then determine the size of the PV array, and the type and size of balance of system equipment required for the system to meet the needs of the customer who will use the system. As a minimum, the balance of system will typically include an array frame, some form of charge controller, a battery bank and associated cables and circuit protection equipment. Other skills required to design a system include some knowledge of monitoring and data logging; local regulatory requirements and standards; ability to do economic analysis of systems capital and operating costs; production of documentation for the customer; and very importantly, a knowledge of occupational health and safety requirements.

For designer level 3 the system includes a fuel generator and these tasks require that the designer begins with a load assessment and a solar resource assessment for the proposed site. The designer shall then determine the size of the PV array, the diesel generator and the type and size of balance of system equipment required for the system to meet the needs of the customer who will use the system. As a minimum, the balance of system will typically include an array frame, some form of charge controller, a battery bank and associated cables and circuit protection equipment. Therefore, a final system design will include a PV array with a diesel generator operating at various times. Other skills required to design a system include some knowledge of monitoring and data logging; local regulatory requirements and standards; ability to do economic analysis of systems capital and operating costs; production of documentation for the customer; and very importantly, a knowledge of occupational health and safety requirements.

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.

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 designers. These include items involving determining number of and type of equipment to meet the customers needs. *Very Important* items are medium priority tasks, and are generally expected of all competent designers. *Important* items are considered lower priority tasks, but usually performed or understood by the quality designer.

Primary Objective for the Off grid Designer

The Off-grid designer is required to specify and design 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. Understanding Energy Concepts	
Task/Skill:	***Priority/ Importance:***
In order to design energy based systems, the designers must have understanding and knowledge of the following energy and power concepts	
1.1 Demonstrate knowledge of correct units for energy and power	Critical
1.2 Demonstrate how to convert from one unit to another	Critical
1.3 Demonstrate the use of the prefixes k (1000) and M (mega, 10^6) when converting units	Important
1.4 Identify the power rating of DC electrical appliances when presented with this information in different formats. e.g. as W or as A	Critical
1.5 Identify all factors which contribute to the overall power rating of an appliance	Very Important
1.6 Calculate energy consumption from power ratings and operating times,	Critical
Following are for Designer Level 2 and 3 Only	
1.7 Demonstrate understanding of differences between AC and DC power	Critical
1.8 Demonstrate understanding of power factor	Critical
1.9 Demonstrate understanding of true power and real power	Critical
1.10 Identify the power rating of AC electrical appliances when presented with this information in different formats. e.g. as W or as A	Critical

1.11 Calculate energy consumption from power ratings and operating times, including programmable or thermostatically-controlled appliances such as washing machines, refrigerators, irons, bread makers, computers	Critical
1.12 Discuss energy conservation in the context of typical off-grid system design	Very Important
1.13 Demonstrate understanding of surge power requirements of certain appliances	Very Important

2. Undertaking Energy Assessment and Load Analysis	
Following are for Designer Level 2 and 3 Only	
Task/Skill:	***Priority/ Importance:***
In determining the electrical requirements of the site, the designer shall be able to:	
2.1 Analyse all the energy needs of the site and recommend what energy source (e.g., electricity directly from the diesel generator set, or electricity from PV system) is best suited to the application	Critical
In undertaking the load analysis of a site, the designer shall be able to:	
2.2 Determine the average weekly and daily energy consumption of a site and if appropriate for two seasons either summer/winter or wet/dry	Critical
2.3 Identify and account for maximum power demand with respect to typical operation of the various loads identified at the site	Critical
2.4 Demonstrate understanding of what the surge factor is for an appliance/load and demonstrate an understanding of typical surge factors for common appliances; how to determine it from manufacturers' data sheets and how to determine maximum surge demand for a site.	Very Important

3. Determining Solar Resources	
Task/Skill:	***Priority/ Importance:***
To demonstrate appropriate skills and knowledge of photovoltaic energy resources the designer must be able to:	
3.1 Access and interpret solar radiation data available from different sources	Very Important
3.2 Define the term 'peak sun hours' (irradiation) and be able to quantify the daily total peak sun hours to array orientation, inclination and time of the year	Very Important
3.3 Quantify the impact of shading on the available peak sun hours for a sample site	Critical

4. Conducting a Site Assessment	
Task/Skill:	***Priority/ Importance:***
In conducting site surveys for off grid power the designer must be able to:	Important
4.1 Identify typical tools and equipment required for conducting site surveys for PV installations, and demonstrate proficiency in their use	Important
4.2 Establish suitable location with proper orientation, sufficient area, adequate solar access and structural integrity for installing PV array	Very Important
4.3 Assess a site in relation to information from manufacturers on the suitability of the array frame and mounting techniques to meet wind loading requirements	Very Important
4.4 Establish suitable locations for installing, controller ; batteries ; lights and associated cabling	Important
4.5 Diagram possible layouts and locations for PV Modules and equipment, including existing building or site features	Very Important
4.6 Identify and assess any site-specific safety hazards or other issues associated with installation of system	Critical
4.7 Obtain and interpret solar radiation and temperature data for site for purposes of establishing performance expectations and use in electrical system calculations	Important
4.8 If required: quantify the customer electrical load and energy use and if appropriate for two seasons- either summer/winter or wet/dry . If package system: explain the performance of the SHS being offered including the limitations.	Critical
For Designer Level 2 and 3	
4.9 Establish suitable locations for installing, inverter or inverters	
For Designer Level 3	
4.10 Establish suitable locations for installing, generator	

5. Understanding System Components	
Task/Skill:	***Priority/ Importance:***
To Demonstrate that they are familiar with all the components of a system the designer of an off grid power system must be able to:	
PV ARRAYS	
5.1 Interpret the technical specifications and output characteristics of photovoltaic modules and understand the terms Isc, Voc, Imp, Vmp, Pmax	Very Important
5.2 Define the factors which influence the output characteristics of photovoltaic modules (irradiance, temperature, age)	Important
5.3 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: 5.3.1 monocrystalline 5.3.2 polycrystalline 5.3.3 amorphous	Important
5.4 Demonstrate basic electric circuit theory and be able to identify series and parallel circuits	Very Important
5.5 Demonstrate the effect on array output (current, voltage and power) of connecting modules in series and parallel configurations	Very Important
5.6 Explain the effects of using dissimilar modules in an array	Very Important
5.7 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.	Very Important
5.8 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	Critical

5.9 Explain the design criteria and installation techniques for 5.9.1 Pole mounted frames 5.9.2 Roof mounted	Very Important
5.10 Demonstrate understanding of how to select optimum tilt angle and orientation of the array	Very Important
5.11 Demonstrate sound mounting design and techniques for attaching modules to the array frame and the array frame to its supporting structure 5.11.1 use of appropriate bolts or screws, including gauge, penetration 5.11.2 fixing of external timber or metal battens to the roof sub frame	Critical
5.12 Explain how to recognise and avoid the corrosion problems arising from contacting dissimilar metals in mounting systems / roof claddings 5.12.1 use of rubber grommets, non-metallic membranes 5.12.2 use of appropriate bolts (stainless steel etc.)	Very Important
5.13 Demonstrate by the use of diagrams the layout of a PV array to cater for different shaped roofs	Very Important
Balance of System Components **Battery Bank**	
5.14 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)	important
5.15 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	Very Important
5.16 Appreciate and be able to list the installation requirements for safety and performance	Critical
5.17 Interpret commercially available battery specifications including warranty conditions	Important
5.18 Demonstrate the different techniques used to measure battery bank capacity, e.g. by the use of specific gravity measurements and charts or by a measured discharge test.	Very Important
Balance of Systems **Charge Regulator/System Controllers**	

5.19 Demonstrate the operating principles of alternative types of regulators /controllers (series, shunt, single and multi-stage, phase-width modulation,)	Important
5.20 Explain the relevance of and demonstrate the use of temperature-correction probes	Important
5.21 Demonstrate the role of each of the regulator features (low voltage cut-out, temperature compensation, load disconnect)	Very Important
5.22 Demonstrate familiarity with commercially available regulators / controllers	Important
Balance of Systems **Lights**	
5.23 Demonstrate understanding of the different DC lights available	Important
Balance of Systems **System Cabling and Circuit Protection**	
5.24 Demonstrate the ability to calculate voltage drop for a cable.	Critical
5.25 Explain the reasons why excessive voltage drop can be detrimental to system performance	Critical
5.26 Discuss current carrying capacity and the implications for cable selection	Critical
5.27 Demonstrate the use of tables to calculate the current carrying capacity of a conductor and the factors which influence CCC	Critical
5.28 Specify appropriate protection for all conductors in a circuit	Critical
5.29 Demonstrate ability to design lighting and load circuits to ensure voltage drop is minimized.	Very Important
Battery Enclosures	
5.30 Discuss the need for battery enclosures and terminal shrouds	Critical
5.31 Discuss the need for battery ventilation	Critical
For Designer Level 2 and 3	

Balance of Systems **Array**	
5.32 Explain the design criteria and installation techniques for ground mounted arrays	Very Important
Balance of Systems **Inverters**	
5.33 Demonstrate an understanding of the basic operating principles of inverters	Very Important
5.34 List the differences between series, switched or parallel system design, and the appropriate use of manual or relay-type change-over switches	Very Important
5.35 Identify inverter components and be able to replace defined components in the field	Very Important
5.36 List the factors which affect the efficiency and reliability of inverters, and their minimum location and housing requirements	Critical
5.37 Demonstrate a working knowledge of inverter specifications and features – continuous, half-hour and surge power ratings and their temperature dependence, over and under voltage and frequency controls, harmonic distortion, stand-by power consumption, status-indicating, metering, data-logging and programming functions - and understand the use of shunts, audible noise, radio frequency interference	Critical
5.38 Demonstrate the effect of power factor correction on inverter and system performance	Very Important
5.39 Demonstrate with a working knowledge of the specifications, installation requirements and controls for a range of commercially available inverters	Very Important
Balance of Systems **Maximum Power Point Trackers (MPPTS)**	
5.40 Explain the operating principles of MPPTs	Important

5.41 Discuss the efficiency of MPPTs and what factors affect the efficiency	Very Important
5.42 Appreciate and estimate the seasonal effectiveness of MPPTs in different climatic zones (relationship between ambient temperatures, clouds, haze) compared with conventional regulators, and calculate the cost effectiveness of MPPTs compared with extra modules (including generator times)	Very Important
5.43 Demonstrate familiarity with commercially available MPPTS	Very Important
For Designer Level 3	

Balance of Systems **Battery Chargers**	
5.44 Explain the operating principles and demonstrate the characteristics of different battery charger types (ferro-resonant triac, switch-mode)	Important
5.45 Compare battery charger specifications and maximum continuous charge rates with system requirements	Critical
5.46 Appreciate the reasons for inefficiencies of chargers and account for inefficiencies when determining the specifications for dependent system components	Critical
5.47 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	Critical
5.48 Demonstrate an understanding of a range of commercially available chargers and inverter-chargers	Very Important
Balance of Systems **Fuel Generators**	
5.49 Demonstrate understanding of different fuel generators available: diesel , petrol(gasoline), LPG and biofeuls	Important
5.50 Explain the operating principles of a diesel fuel internal combustion generator	Important
5.51 Interpret the rating of generators (kVA compared with kW, measuring voltage and frequency stability vs. load)	Critical
5.52 Be aware that the cabling from the generator to the inverter/charger or charger is at a dangerous voltage and if permanently wired must be carried out by a suitably qualified technician in accordance to the laws of the country	Critical

5.53 Discuss different starting systems for generators, and how to set up a programmed relay-controlled start / stop interface	Very Important
5.54 Demonstrate a knowledge of appropriate siting and segregating of generators (ignition of battery gases, heat, noise, fumes, fuel storage)	Critical
5.55 Demonstrate a knowledge of commercially available package generator sets and exhaust, silencing and fuel tank options	Very Important
5.56 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	Critical
5.57 Equate generator efficiency to fuel consumption and discuss generator efficiency as related to series and parallel inverter configurations	Very Important
DC-DC Step Down Converters (If required)	
5.58 Explain the operating principles and appropriate uses of DC – DC converters	Important
5.59 Account for energy loss/efficiency of converters	Important
5.60 Interpret the specifications of converters and select a converter (or MPPT / converter) to meet system requirements	Important
Remote Monitoring/Data Logging	
5.61 Explain the operating principles of data logging equipment	Important
5.62 Calibrate a data logger	Important
5.63 Explain the use of data transfer interface devices (disc, lap link, modem)	Important

5.64	Appreciate and explain the effect on the accuracy of data when collected over different sampling periods and the ease with which data is processed at different sampling rates	Important
5.65	Demonstrate a working knowledge of commercial software used for presenting tabular and graphical data, e.g. spreadsheets.	Important
Balance of Systems	**Grid connect Inverters**	
5.66	List the factors which affect the efficiency and reliability of grid connect inverters, and their minimum location and housing requirements	Very Important
5.67	Demonstrate an understanding of the Maximum Power Point Tracking feature of grid connect inverters	Important
5.68	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	Very Important
5.69	Demonstrate with a working knowledge of the specifications, installation requirements and controls for a range of commercially available inverters	Very Important

6. Understanding System Design	
Task/Skill:	***Priority/ Importance:***
To Demonstrate that they are familiar with the design process and all factors which influence the designer of an off grid power system must be able to:	
PV ARRAYS	
6.1 Quantify load requirements and the effect of system inefficiencies (battery) on the array size required to meet the load for Standard (switched) Controllers: apply output current at nominated voltage and temperature, manufacturers tolerance and dirt derating for the array; battery bank coulombic efficiency factors	Critical
Balance of System Components **Battery Bank**	
6.2 Define the term "days of autonomy" and explain the statistical relationship between days of autonomy and other system parameters such as published solar radiation data	Very Important
6.3 Determine required battery bank capacity to meet the required daily energy consumption allowing for days of autonomy to a maximum depth of discharge.	Critical
Balance of Systems **Charge Regulator/System Controllers**	
6.4 Match controllers specifications with system parameters (voltage, current)	Critical
6.5 Select an appropriate controller / regulator for the system	Critical
For Designer Level 2 and 3	
PV ARRAYS	
6.6 Quantify load requirements and the effect of inverter inefficiencies on the array size for standard controllers and MPPTS	Critical
6.7 Match array configuration to specifications of the MPPT	Critical
Balance of System Components **Battery Bank**	

6.8 Determine required battery bank capacity to meet the required daily energy consumption allowing for days of autonomy to a maximum depth of discharge and allowing for inverter efficiency.	Critical
Balance of Systems **MPPTS**	
6.9 Match MPPT specifications with system parameters (voltage, current)	Critical
6.10 Select an appropriate MPPT for the system	Critical
Balance of Systems **Inverters**	
6.11 Determine required inverter specifications from load analysis	Critical
For Designer Level 3	
6.12 Demonstrate knowledge of AC and DC bus systems	Critical
6.13 For DC bus systems demonstrate knowledge of series, switched and parallel generator systems	Critical
6.14 Calculate the quantity of daily load which is met by each of the energy sources for DC or AC bus systems such as: • Generator directly • PV array directly • Battery being charged by generator • Battery being charged by PV array	Critical
PV ARRAYS	
6.15 Calculate the array size required to meet loads directly either with an AC bus or DC bus system.	Critical
6.16 Calculate the array size required to meet loads via the battery bank for an AC bus system.	Critical
6.17 Match array configuration to specifications of the grid connect inverter (or inverters) for AC bus systems	Critical
Balance of System Components **Battery Bank**	

6.18 Determine required battery bank capacity to meet the required energy consumption being supplied by the battery bank for AC and DC bus systems, allowing for days of autonomy to a maximum depth of discharge and allowing for inverter efficiency.	Critical
Balance of Systems **Inverter**	
6.19 Calculate the maximum real power (in VA) and surge power (VA) required of the Inverter or Inverters for the AC or DC bus system.	Critical
Balance of Systems **Fuel Generators**	
6.20 Calculate the maximum real power (in VA) and surge power (VA) required of the generator	Critical
Balance of Systems **Grid connect inverters**	
6.21 Determine the size of the grid connect inverter or inverters for the AC bus system	Critical

7. Interpreting Technical Standards

Task/Skill:	***Priority/ Importance:***
To demonstrate that they are familiar with relevant standards (if applicable) the designer must be able to:	
7.1 Apply all relevant standards applicable for that country.	Very Important
7.2 Own or have reasonable access to relevant Standards and country guidelines including: SEIAPI Guidelines: • Design of Grid Connect PV Systems • Installation of Grid Connect PV systems • Design of off-grid power systems • Installation of off-grid power systems **Note: All standards and guidelines available within the country should also be listed.**	Very Important

8. Undertaking Economic Analysis	
Task/Skill:	***Priority/ Importance:***
To demonstrate that they can carry out an economic analysis of the system design and its projected performance the designer must be able to:	
8.1 Calculate the capital costs of the system equipment and installation.	Critical
8.2 Calculate expected replacement costs and a timetable for replacement of all system components	Important
For Designer Level 3	
8.3 Calculate expected running costs of the system	Important

9. Interpreting Regulatory Requirements	
Task/Skill:	***Priority/ Importance:***
To demonstrate that they have a working knowledge of regulatory requirements the designer must be able to	
9.1 Demonstrate awareness of the range of government planning or other requirements which may impact on the viability of a planned system **Note: This should contain the relevant requirements for the country**	Very Important
9.2 Demonstrate and awareness of the requirements for doing electrical work in that country **Note: Only if relevant in the country**	Critical

10. Knowledge of Occupational Health and Safety	
Task/Skill:	***Priority/ Importance:***
To demonstrate that they are familiar with and can apply occupational health and safety requirements the designers must be able to	
10.1 Carry out a Job Safety analysis:- 10.1.1 Identify job tasks 10.1.2 Identify hazards 10.1.3 Identify the risk class 10.1.4 Nominate risk control measures 10.1.5 Nominate a person responsible for carrying out each measure	Critical
10.2 Be aware of any local OHS legislation (if relevant) and its application to the sustainable energy industry	Critical
10.3 Use defined safe working practices (particularly relating to the hazards of height, heavy weights, explosive gases, electric shock and burns)	Critical

11. Developing Documentation	
Task/Skill:	***Priority/ Importance:***
To Demonstrate that they are familiar with system documentation the designer must be able to	
11.1 State the system documentation that should be provided to the system owners	important
11.2 Demonstrate the completion of a battery record log book	important
For Designer Level 3	
11.3 Demonstrate the completion of a generating set service log book	