REGISTERED
NATIONAL STANDARD

UNIT OF COMPETENCY

Title:	**Determine sizing and installation of off-grid PV systems (SHS and stand-alone PV systems)**[1]				
TQF Level:	4	**Credits:**	12	**Version:**	1
National standard code:	**NS120-04**				
Associated qualification (and code):	National Certificate in Sustainable Energy (Solar) Level 4				
Approval date:	10th June 2026	**Review date:**	10th June 2031		
Purpose:	This unit standard involves the sizing and installation of off-grid Photovoltaic (PV) Power systems specifically, solar home systems and stand-alone PV systems (dc and ac loads). Persons credited with this unit standard are able to: • Undertake site assessments. • Determine the d.c. and a.c. load requirements. • Size off-grid PV systems (SHS and stand-alone PV systems) • Determine the system cost • Plan safe installation • Install off-grid PV power system (SHS and stand-alone PV systems) • Test and commission				

[1] Notes:

1) Due to safety issues inherent in working with electricity, all training and assessment activities must be in accordance with local industry and regulatory requirements;

2) This unit of competency has been adapted the EQAP micro qualifications (micro credentials):

- *PPAOG 101 Designer of Off-Grid PV Power Systems (DC Load SHS)*
- *PPAOG 102 Designer of Off-Grid PV Power Systems (Stand-alone Solar systems)*
- *PPAOG 201 Installer of Off-Grid PV Power Systems (DC Load SHS)*
- *PPAOG 202 Installer of Off-Grid PV Power Systems (Stand-alone Solar systems)*

Learning Outcome 1 (LO1)	Understand ***Occupational Health*** and ***Safety***
Performance standards	1.1 Carry out a job safety analysis (or risk assessment) with off-grid PV systems including: • Identify job tasks • Identify hazards • Identify the risk class • Nominate risk control measures • Nominate a person responsible for carrying out each measure 1.2 Demonstrate knowledge on Occupational Safety & Health legislation and its application to the sustainable energy industry that may influence the design and installation; 1.3 Apply defined safe working practices (particularly relating to the hazards of height, heavy weights, explosive gases, electric shock and burns) and identify personal protective equipment for usage; 1.4 Identify the PPE equipment for installation.
Learning Outcome 2 (LO2)	Determine ***Solar*** resources
Performance Standards	2.1 Access and interpret solar radiation data available from different sources and equipment; 2.2 Quantify the daily total peak sun hours affected by array orientation, inclination and time of the year; 2.3 Quantify the impact of shading on the available peak sun hours for a sample site; 2.4 Demonstrate understanding on the sun's position and the orientation including tilt of a solar module for optimum output.
Learning Outcome 3 (LO3)	Undertake site assessment
Performance Standards	3.1 Analyse all the energy needs of the site and recommend what energy source is best suited to the application; 3.2 Identify the tools and equipment required for conducting site surveys for PV installations including demonstrate proficiency in their use; 3.3 Explain the term ''energy efficiency'' and the benefits of implementing energy efficiency considerations in system sizing. (Specify energy efficiency measures such as use of LED lights, using passive design for heating and cooling, insulating cooling spaces and using energy rated

	appliances. Emphasize on energy saving measures in commonly used electrical appliances such as refrigerator, television, computers/laptops, etc.); 3.4 Determine the daily energy consumption (kWh) for a site and if appropriate for two seasons either summer/winter or wet/dry. (Include both SHS dc loads only and stand-alone PV systems and ensure energy efficiency considerations); 3.5 Calculate maximum power demand with respect to typical operation of the various loads identified at the site; 3.6 Determine surge factor for relevant appliance/load and calculate surge demand for a site; 3.7 Discuss typical surge factors for common appliances, demonstrate how to locate it from manufacturers' data sheets; 3.8 Assess a site in relation to information from manufacturers on the suitability of the array frame and mounting techniques to meet wind loading requirements; 3.9 Determine suitable locations for installing the, modules, PV inverter (a.c. coupled) controller (d.c coupled), batteries, battery inverter and associated cabling; 3.10 Draw possible layouts and locations for off-grid PV power system equipment, including existing building or site features; 3.11Identify and assess any site-specific safety hazards, environmental and social concerns or other issues associated with installation of off-grid PV power system.
Learning Outcome 4 (LO4)	Understand system components
Performance standards	**PV Arrays** 4.1 Understand the basic operation of silicone-based PV cells and gain knowledge on various other common types of solar cell technology available including thin-film, multi-junction, etc.; 4.2 Compare the following PV cell technology, and compare different manufacturers' data within the classes, viz: • monocrystalline • polycrystalline • amorphous (thin film) • PERC (Passivated Emitter and Rear Cell) • TOPCon (Tunnel Oxide Passivated Contact) • Heterojunction Technology (HJT)

- Multi-junction

4.3 Interpret the technical specifications and output characteristics of photovoltaic modules and understand the terms I_{sc}, V_{oc}, I_{mp}, V_{mp}, P_{max} along with the temperature coefficients;

4.4 Define the factors which influence the output characteristics of photovoltaic modules (irradiance, temperature, dirt, manufactures tolerance and age);

4.5 Demonstrate the selection of the optimum tilt angle and orientation for system design;

4.6 Demonstrate the mounting design and techniques for attaching modules to the array frame and the array frame to its supporting structure, especially show the use of appropriate bolts or screws, including gauge and penetration and fixing of external timber or metal battens to the roof sub frame;

4.7 Explain techniques to avoid corrosion problems arising from contacting dissimilar metals in mounting systems;

4.8 Explain the design criteria and installation techniques for pole mounting, ground mounting and roof mounting systems;

4.9 Demonstrate by the use of diagrams the layout of the PV array to cater for different shaped roofs.

Battery Bank

4.10 Explain different battery technologies, internal battery design variations and characteristics;

4.11 Explain the factors and relevant manufacturers' data which relate to battery performance;

4.12 Interpret commercially available battery specifications including warranty conditions;

4.13 Demonstrate the different techniques used to measure battery bank capacity.

Standard Solar Controllers/(Charge Regulators)

4.14 Explain the operating principles of different types of solar controllers or regulators (series, shunt, single and multi-stage pulse-width modulation (PWM), etc.), include the demonstration of temperature correction probes.

Maximum Power Point Tracker (MPPT) Solar Controller

4.15 Explain the operating principles of MPPT solar controller;
4.16 Discuss the efficiency of MPPTs and the factors that affect the output;
4.17 Discuss the seasonal effects on 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.

Battery Inverters/Hybrid Inverters

4.18 Explain the basic operating principles of battery inverters and hybrid inverters;
4.19 Discuss battery inverter and hybrid inverter components;
4.20Identify the factors which affect the efficiency and reliability of inverters including their minimum location and housing requirements;
4.21 Elaborate on 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, etc.);
4.22 Discuss the effect of power factor correction on inverter and system performance;
4.23 Compare the specifications, installation requirements and controls for a range of commercially available inverters.

PV (Grid Connect) Inverters

4.24 Discuss the operating principles of different types of PV (grid-connect) inverters available;
4.25 Determine required inverter specifications for PV array matching;
4.26 Identify the factors which affect the efficiency and reliability of inverters, and their minimum location and housing requirements;
4.27 Describe the Maximum Power Point Tracking feature of PV (grid connect) inverters;

	4.28 Discuss inverter specifications and features (over and under voltage and frequency controls, harmonic distortion, status-indicating, metering, data-logging and programming functions - and understand the problems associated with audible noise, radio frequency interference, etc.); 4.29 Explain the effect of inverter efficiency on energy output of the system; 4.30 Identify the specifications, installation requirements and controls for a range of commercially available PV (grid connect) inverters. **Balance of Systems** **System Cabling, Disconnection and Circuit Protection** 4.31 Explain and calculate voltage drop for a cable in an off-grid PV power system; 4.32 Demonstrate the use of tables to find the current carrying capacity of a conductor and discuss factors which influence it; 4.33 Determine minimum cable size based on voltage drop and current carrying capacity; 4.34 Specify appropriate disconnection and protection for all conductors in a circuit for an off-grid PV power system and calculate protection device rating.
Learning Outcome 5 (LO5)	Carry out sizing of off-grid PV system (SHS & stand-alone PV systems)
Performance standards	5.1 Apply relevant IEC, AS/NZS standards, international best practice and SEIAPI Technical guidelines in sizing system components; 5.2 Explain configuration of a.c. and d.c coupled systems; 5.3 Analyse monthly ''peak sun hours'' for the site and determine the design month (worst month). **PV Arrays - d.c coupled** 5.4 Quantify array size based on load requirements. (Considering the effect of system losses (battery efficiency) for standard (switched) controllers using module output current at nominated voltage and temperature and allowing for manufacturers tolerance

and dirt derating for the array. Also discuss array over-sizing according to AS/NZS standards and technical guidelines.);

5.5 Quantify array size based on load requirements. (Considering the effect of system losses (inverter losses, transmission losses, MPPT losses) on the array size for MPPT solar controllers using module output power at nominated temperature and allowing for manufacturers tolerance and dirt derating for the array. Also discuss array over-sizing according to AS/NZS standards and technical guidelines.);

5.6 Calculate the array size required to meet loads directly from the PV array;

5.7 Calculate the array size required to meet loads from the PV array via the battery bank;

5.8 Determine array configuration by matching specifications to the MPPT.

PV Arrays - a.c coupled

5.9 Quantify array size based on load requirements. (Considering the effect of system losses (inverter losses, transmission losses, PV inverter losses) on the array size for a.c bus using module output power at nominated temperature and allowing for manufacturer's tolerance and dirt derating for the array. Also discuss array over-sizing according to AS/NZS standards and guidelines.);

5.10 Calculate the array size required to meet loads directly from the PV array;

5.11 Calculate the array size required to meet loads from the PV array via the battery bank;

5.12 Determine array configuration by matching specifications to the PV (grid connect) inverter.

Battery Bank

5.13 Determine required battery bank capacity to meet the required daily energy consumption. (Considering days of

	autonomy, maximum depth of discharge allowing for inverter efficiency and matching the capacity to the available charging and required discharge currents including continuous and surge demands.) **Standard Solar Controllers/Regulators** 5.14 Match solar controller's specifications with system parameters (voltage and current of the array); 5.15 Select an appropriate controller / regulator for the system. **MPPT Solar Controller** 5.16 Match MPPT specifications with system parameters (voltage, current and power of the array); 5.17 Select an appropriate MPPT for the system. **PV (Grid Connect) Inverters** 5.18 Match PV (Grid Connect) Inverter specifications with system parameters (voltage, current and power of the array); 5.19 Select an appropriate PV (Grid Connect) inverter for the system. **Battery Inverters/Hybrid Inverters** 5.20 Determine required battery inverter/hybrid inverter specifications from load analysis considering appropriate over-sizing and future considerations; 5.21 Determine required battery inverter specifications in an a.c coupled system considering the size of the PV inverter(s) or determine required hybrid inverter specifications. **System Costs and Documentation**

	5.22 Calculate the capital costs of the system equipment and installation costs for typical off-Grid PV power systems. (discuss the system economics including the levelized cost of energy (LCOE); 5.23 Calculate expected replacement costs and establish a timetable for replacement of all system components in an off-grid PV power system; 5.24 State the system documentation that should be provided to the installer and the system owner.
Learning Outcome 6 (LO6)	Demonstrate installation procedures
Performance standards	6.1 Interpret commonly used symbols and typical wiring and single line diagrams for off-grid PV systems; **PV Arrays** 6.2 Demonstrate the installation of PV arrays on roofs in an off-grid PV power system. (Upon interpreting layout diagrams for PV array to cater for different shaped roofs and practicing to install different methods of fixing PV arrays at optimum pitch and orientation to off roof pitches and orientations.); 6.3 Demonstrate the installation of PV array on ground for an off-grid PV power system. (Upon interpreting layout diagrams for ground-mount systems and practicing to install and secure the PV array at optimum tilt and orientation for the site ensuring adequate spacing to avoid shading.) **Batteries** 6.4 Explain battery bank installation in an off-grid PV power system in relation to factors which affect the longevity and performance of the battery bank. (such as positioning the batteries so that they do not get adversely affected by the harsh environmental condition of the pacific islands (e.g. exposure to hot sun));

6.5 Demonstrate appropriate placement to optimize inter-cell connections and minimize excessive cable lengths;

6.6 Demonstrate the appropriate placement of inlet and exhaust ventilation apertures (lead acid batteries);

Solar Controllers (Standard/MPPT Controller)

6.7 Demonstrate the positioning and fixing of solar charge controllers to:

- minimize cable lengths
- securely lock the solar controller to its supporting structure
- position the controller so that it is not adversely affected by the harsh environmental condition of the pacific islands
- be installed in accordance with manufacturers specifications
- provide a safe working environment and safe installation for the system owners

PV Inverter (Grid connect)

6.8 Demonstrate the correct positioning and sound mounting techniques to:

- minimize cable lengths
- securely lock the PV inverter to its supporting structure
- ensure that the PV inverter is not adversely affected by the harsh environmental condition of the pacific islands.
- provide suitable airflow
- meet the installation requirements specified by the manufacturer
- provide a safe working environment and safe installation for the system owners

Battery Inverter/Hybrid Inverter

6.9 Demonstrate the correct positioning and sound mounting techniques to:

- minimize cable lengths
- securely lock the battery inverter to its supporting structure
- ensure that the battery inverter is not adversely affected by the harsh environmental condition of the pacific islands.
- provide suitable airflow
- meet the installation requirements specified by the manufacturer
- provide a safe working environment and safe installation for the system owners

Balance of System Components

General

6.10 Confirm permissible voltage drop in a circuit for an off-grid PV power system;

6.11 Confirm current carrying capacity from tables or through calculations for cables;

6.12 Demonstrate the measurement of voltage/voltage drop in a conductor (a.c and d.c cables);

6.13 Demonstrate the measurement of current through a conductor (a.c and d.c cables);

6.14 Demonstrate the installation of protection devices for all conductors in an off-grid PV power system.

AC Cabling

6.15 Discuss the difference in installation standards and practices required between a.c. cables and d.c cables.

Earthing (Grounding)

	6.16 Install earthing (grounding) systems as specified and required for off-grid PV power systems; 6.17 Install lightning protection systems as specified for the off-grid PV power system.
Learning Outcome 7 (LO7)	Carry out system installation of SHS and stand-alone PV systems
Performance standards	7.1 Apply all relevant AS/NZS standards and SEIAPI technical guidelines for system installation; 7.2 Demonstrate safe techniques for laying and securing cables in place in an off-grid PV power system; 7.3 Demonstrate the use of appropriate physical protection for installed cables; 7.4 Complete final assembly, structural attachment, and weather sealing of array to building or other support mechanism of the off-grid PV power system; 7.5 Install and provide required labels on controls, disconnects and over current devices for the off-grid PV power system; 7.6 Label, install, and terminate electrical wiring, verify proper connections, voltages, and polarity relationships; 7.7 Install signage requirements that meet relevant local requirements, AS/NZS standards and industry best practice as specified by the designer and or supervisor; 7.8 Verify continuity in circuits.
Learning Outcome 8 (LO8)	Carry out ***testing*** and ***commissioning***
Performance standards	8.1 Conduct visual inspection of the entire installation, identifying and resolving any deficiencies in materials or workmanship for the off-grid PV power system; 8.2 Check system mechanical installation for structural integrity and weather sealing as required; 8.3 Check electrical installation for proper wiring practice. (Polarity, security of terminations, and grounding when necessary); 8.4 Activate system and verify overall system functionality and performance, compare with expectations; 8.5 Demonstrate correct sequence for connecting and disconnecting the system and equipment from all sources;

	8.6 Identify and verify all markings and labels for system and equipment as required; 8.7 Identify and explain all safety issues associated with operation and maintenance of system; 8.8 Specify complete documentation package for the system and equipment to owner/operator.
Pre-requisites	• Electricians Qualification accredited Level 4 or equivalent OR • Passed the NS 118-04 Demonstrate electrical installation technology
Co-requisites	N/A
Underpinning skill and knowledge	The following knowledge and skills underpin this unit standard: **Knowledge:** 1. Safety of solar PV systems 2. Knowledge of safe-handling techniques for moving, hoisting, lifting, etc. of heavy structures; 3. Knowledge of tools and equipment for solar installation; 4. Knowledge of basic functions and components of solar PV systems; 5. Basic knowledge of electrical wiring **Skills** 6. Safe working principles and equipment handling skills 7. Installing electrical wiring systems
Assessment requirements	**Methods of assessment:** A range of assessment methods should be used to assess students' knowledge and application of skills. These shall include but not restricted to the following: a) Direct observation of students performing certain tasks stated under context of assessment; b) Oral questions to test relevant skills and knowledge during observation (e.g., Interviews) c) Written assessment such as: i) Tutorial exercises on important topics in preparation for the final examination ii) Design task for sizing a small-scale stand-alone PV system to denote competency in sizing components

	iii) Final examination d) Practical assessment: Assessment of install skills to denote competency in off-grid PV system installations ***The student needs to be competent in the final exam and the practical assessment to be classified as ''competent'' overall for the unit.***
Moderation arrangements	1. Training providers must have their own moderation system approved by TNQAB before accreditation is granted: a) Relevant internal moderation processes are documented; b) Assessment is planned for each unit, and moderation processes are integrated into such plan 2. External moderation is conducted by the National Qualifications unit of TNQAB for all unit components of national qualifications; a. Samples of assessed activities are submitted for moderation; b. Moderation (external) forms are available on request from the National Qualifications unit of TNQAB.
Resource requirements	1. 4-8 sets solar home system including all major equipment (battery, array and controller); d.c lights and associated fittings and switches and all associated equipment (cabling, protection and isolating devices etc.). The system should reflect current industry practices in relation to installing and setting up solar home systems 2. A small-scale off-grid PV power system including all major equipment (battery, array, inverter and controller) and all associated equipment (cabling, protection and isolating devices etc.). The system should reflect current industry practices in relation to installing and setting up stand-alone PV systems. Both ac coupled and dc coupled configuration off-grid PV system need to be covered. 3. Worker's tools for undertaking installation • Insulated screw-drivers • Insulated pliers • Cordless drill set with drill bits • MC4 crimping tool • Torque wrench

	• Wire stripper • Measuring tape • Termination tools • Heat gun • Conduit bender • Rachet and socket set 4. Testing equipment • DC multimeter • Clamp meter (up to 20A d.c) • Insulation resistance tester • IV curve tracer • Compass, irradiance meter, inclinometer • IR camera 5. Personal Protection Equipment • Harness • Eye protection • Apron • Helmet • Safety glasses • Hand gloves 6. Recommended textbook: i) GSES, Stand Alone Power Systems: Design and Installation (8th ed.), Global Sustainable Energy Solutions Pty Ltd ii) Australia and New Zealand standards: AS/NZS 3000 iii) Relevant national or regional technical guidelines including the Pacific Power Association/ Sustainable Energy Industry Association of Pacific Islands regional guideline: Design of Off-grid PV Systems and Installation of Off-grid PV systems iv) Relevant documentation comprising of manufacturer's technical information such as data sheets, installation manual and user guides.
Requirements to complete this unit	To demonstrate competence, the person studying this unit is: 1. Required to demonstrate all LOs to the expected standards of performance;

	2. Required to attain an Achieved Grade (Competent) to fulfil the requirements of the Unit Standard. The person is required to be competent in the final exam and practical assessment to attain a pass grade in this unit. 3. Eligible to three (3) attempts in the final exam/practical assessment to achieve the required competency within 14 days of the first attempt. Failure to achieve the required competency level after three (3) attempts of the exam or specific part of the assessment will require the person studying this Unit to re-enrol for the same Unit.
Important notes and definitions	**Notes:** 1. All activities associated with this unit standard must comply with the requirements of national codes of practice, regulations and legislation for workplace health, safety, and environmental protection and any subsequent amendments. 2. Assessors must comply with Tonga national assessment and moderation requirements. 3. The delivery of all units of competencies must be in sequential order and ensure that the pre-requisites requirements are met. **Definitions:** 1. ***AS/NZS (Australia/New Zealand) standards*** dictate the mandatory safety, manufacturing, and operational rules for electricity, appliances and installations. They ensure a baseline of protection against fire, electrocution, and damage to property across the country. 2. ***Grid connected PV systems (also known as on-grid)*** is a solar power setup that operates in direct parallel with your local utility electricity network. 3. ***Hazards*** refer to any situation or dangerous condition where contact with electrical systems or exposed conductors can cause harm, injury, or property damage. 4. ***LCOE (Levelized Cost of Energy)*** is the average total cost to build and operate a power plant per unit of electricity generated over its entire lifetime. It is the minimum price the electricity must be sold at for the project to break even.

	5. ***MPPT (Maximum Power Point Tracker)*** is an electronic technique and algorithm used in electrical systems – most commonly in solar power setups – to extract the maximum possible energy from a power source as environmental conditions change. 6. ***Occupational Health and Safety*** refers to the policies, procedures and standards designed to protect workers from electrical hazards like shocks, electrocution, fires and arc flashes. It mandates safe work practices, proper equipment maintenance, and the use of personal protective equipment (PPE). 7. ***Pulse Width Modulation (PWM)*** is a technique used in electricity to reduce the average power delivered by an electrical signal. 8. ***Off-grid PV systems*** is a standalone solar setup that generates and stores its own electricity without connecting to the public power grid. It relies entirely on solar panels to capture sunlight, batteries to store energy for use at night or on cloudy days, and an inverter to convert the power into usable.
Public comments on unit	Please contact TNQAB National Qualifications Unit (email EnquireNQ@tnqab.to or Telephone 28136) if you like to discuss or suggest changes to the details of this unit.