1. Module details

Module name

Photovoltaic Power Systems

Module duration

It is expected that students with the appropriate entry knowledge and skills will successfully complete this module in 60 hours.

Module code

NUER02

Discipline code

1105

2. Module purpose

This module provides knowledge and skills in the design, installation, commissioning and maintenance of photovoltaic (PV) power systems, both stand-alone and grid connected. Stand-alone systems using parallel configuration, or where automatic genset control is used, are not covered.

3. Prerequisites

NUER04 – Standalone Power System Components

EA903 – Industrial Computer Systems or equivalent

4. Relationship to competency standards

This module provides part of the underpinning knowledge and skills identified in the 'Evidence Guide' of specific units in the National Electrotechnology Competency Standards, namely NES112, NES113, NES114, NES219, NES305, NES412, NES506, NES709, NES710.

5. Content

Daily irradiation

angles, tables, maps
collector positioning
calculations

PV modules

terminology
technology types, structure and manufacture
operating principles, spectral response, efficiency and cost
module features for long life

Module characteristics

terminology
equivalent circuit
I-V curves, load lines, operating point, effect of temperature and irradiance
shading and bypass diodes
ratings and standards
power output under MPP and standard battery charging conditions
Advantages and disadvantages of MPPTs for water

pumping and battery charging
daily energy output, de-rating factors

PV powered water pumping systems

selection and sizing of pumps, pipes and fittings
power requirements
motors, mechanical transmissions
array size
selection of complete systems

Stand-alone PV system design

system voltage selection
rules of thumb; component sizing
detailed load assessment, load management
selection and sizing of PV array
selection and sizing of all components
battery accommodation
complete system design, system operation
capital, operation and maintenance and life cycle costs
cost comparison of options
use of computer-based design tools
system manual

Grid connected PV systems

operation of grid connected PV systems
PV array sizing for grid connected systems
technical requirements for grid connection – AS 4777
system types and circuit configurations, schematic and wiring diagrams
BOS selection and sizing
non-technical considerations impacting on grid PV
estimation of greenhouse gas reductions

System installation and commissioning

site locations: array, batteries, components
installation requirements: all components
start-up, shut down and commissioning procedures
installation and commissioning practice

Maintenance and troubleshooting

Safety hazards (esp batteries, gensets)
Safe work practices
Periodic maintenance
lubrication, filters
Test for correct operation
start, stop
speed, voltage, waveform
protection system

testing, location and rectification of faults
battery maintenance requirements
maintenance schedule
maintenance practice

6. Assessment strategy

Assessment methods

Assessment should encompass both progressive and holistic elements in recognition of the interdependence between learning outcomes and to ensure the module purpose is met. To assist in ensuring validity, reliability and fairness, assessment instruments should include both practical exercises and written exercises consisting of a number of item types, such as multiple choice, short answer and problem solving. A system design project is strongly recommended as the major assessment item, which may encompass holistic assessment of a number of assessment criteria across several learning outcomes.

Conditions of assessment

Normally learning and assessment will take place in a classroom/ laboratory environment, or in simulated or actual workplace conditions during installation, commissioning and maintenance work.

7. Learning outcome details

Learning outcome 1

Determine the average daily irradiation for each month, adjusted for shading from obstacles, falling on the plane of a collector given irradiation data tables, sun path diagrams and appropriate computer software.

Assessment criteria

1.1 Define the terms:
- declination angle
- reflectance
- sunshine hours
- extraterrestrial irradiation

1.2 Interpret solar radiation data tables and contour maps.

1.3 Determine, using field measurements and a sun path diagram, the times and dates when a PV array will be shaded by obstacles at a particular site.

1.4 Calculate the daily average irradiation on a horizontal plane given extraterrestrial irradiation, location constants and sunshine hour data.

1.5 Calculate the monthly mean daily irradiation falling on a PV array for each month of the year, adjusted for the effects of shading, using irradiance and irradiation data tables and a sun path diagram and/or appropriate software.

Learning outcome 2

Describe the structure, manufacture and principles of operation of each of the main types of photovoltaic (PV) modules, and the impact of these on efficiency and cost.

Assessment criteria

2.1 Define these terms:
- mono-crystalline
- poly-crystalline
- amorphous
- band gap energy
- semi-conductor

2.2 Draw a diagram of a basic crystalline silicon PV cell, showing its physical structure, with at least five major features labelled.

2.3 Briefly describe the major steps in the production of PV modules based on bulk silicon cells, in comparison with the production of thin film PV modules.

2.4 Describe the basic physical principles of PV cell operation for the main types of commercially available PV modules.

2.5 Compare the efficiency, spectral response, cost and typical applications of the main types of commercially available PV modules.

2.6 List at least two new photovoltaic technologies currently being developed towards commercialisation, and their major features.

2.7 Describe the mechanical and electrical features necessary for the long life of a PV module under a wide range of operating conditions.

Learning outcome 3

Determine the operating point, power and daily energy output of a PV array under a given set of operating and environmental conditions.

Assessment criteria

3.1 Define these terms:

- I-V curve
- fill factor
- operating point
- maximum power point (MPP)
- cell temperature co-efficient
- nominal operating cell temperature (NOCT)
- current, voltage and power output co-efficients

3.2 Draw an equivalent circuit for a PV cell, labelling each of the elements and the polarity of the terminals.

3.3 Draw and label a family of I-V curves for a PV module, labelling major points and showing the effects of variation in irradiance and variation in cell temperature.

3.4 Determine the major ratings of a PV module from manufacturer's information or nameplate data.

3.5 Determine the operating point of a PV module with a resistive load, a constant voltage source or any other load with known I-V characteristics, using the load line method.

3.6 Describe the configuration of a typical PV array, including the function, placement and ratings of blocking and bypass diodes.

3.7 Describe the effect of partial shading of a PV module or array, the impact of bypass diodes and the significance of their configuration on output current in typical operating conditions.

3.8 Calculate the power at MPP, and the power under typical battery charging conditions, of a PV module, given irradiance and ambient air temperature.

3.9 Calculate the daily energy output of a PV array in accordance with AS 4509.2, and by using “rule of thumb” de-rating factors.

3.10 Outline the advantages and disadvantages of MPPTs in water pumping applications and in battery charging applications.

3.11 Briefly outline the scope and content of Australian or international standards relevant to the performance of PV modules.

3.12 Determine the electrical characteristics of a PV module according to relevant Australian or international standards, using an outdoor test method.

Learning outcome 4

Write specifications for the design of a PV powered water pumping system, given daily water requirement, head and site details

Assessment criteria

4.1 Select a pump type appropriate for a given pumping application.

4.2 Select and size pipes and fittings for a given pumping application.

4.3 Calculate the mechanical power required to pump the peak flow rate.

4.4 Select and size the motor and mechanical transmission.

4.5 Draw and label a circuit schematic of a typical PV water pumping system showing all components.

4.6 Calculate the required size of a fixed array.

4.7 Select a commercially available water pumping system for a particular application.

Learning outcome 5

Design a stand-alone PV power system for a homestead, providing documentation of the entire system including components, selection and sizing process, installation details, operation and maintenance requirements and costing, in accordance with relevant standards.

Assessment criteria	5.1	Perform detailed load assessment including the assessment of total daily energy, maximum demand, surge demand and load management requirements, consistent with AS 4509.2.
	5.2	Determine an appropriate system voltage and the size of major components in the system using appropriate calculations.
	5.3	Select and size a PV array, given load and solar radiation data and using a method consistent with AS 4509.2.
	5.4	Select and size suitable regulators, inverter, battery, battery charger and backup generator for a given load and PV array size, in accordance with AS 4509.2.
	5.5	Select and size suitable metering, switches, cabling, cabling hardware, protection and isolation devices and electrical enclosures for a PV RAPS system in accordance with AS 4509 and AS/NZS 3000.
	5.6	Select a suitable material and design for a PV array mounting frame in a given application in accordance with AS 4509.
	5.7	Design battery accommodation in accordance with AS 4086.2, AS 4509.1 and AS 4509.2.
	5.8	Carry out a complete design of PV power system using a series or switched configuration, consistent with the guidelines set out in AS 4509.2.
	5.10	Estimate the capital cost and running costs for the PV system, accounting for government rebates or other incentives.
	5.11	Determine the following using computer based tools: Load assessment Selection and sizing of components Life cycle costing
	5.12	Compare the capital cost, simple pay back time and life cycle cost of a PV power system with another power supply option.
	5.13	Produce a System Manual according to AS 4509.2 and AS 4509.3.
Learning outcome 6		**Design a household scale grid connected PV system.**

Assessment criteria

6.1 Describe the operation of grid interactive PV systems including synchronisation, safety features, power flow control and metered energy for systems with and without energy storage.

6.2 Select and size a PV array for a grid connected inverter system, based on any of:

annual energy demand,
budget constraints,
architectural constraints or
limitations on available inverter sizes.

6.3 Draw schematic diagrams of common grid connected inverter circuit configurations with or without energy storage including metering arrangements, isolation and connection with respect to RCDs.

6.4 Specify major installation details for a proposed grid connected inverter system, based on the requirements set out in AS 4777 Parts 1 to 3.

6.5 Select and size an inverter and balance of system components including cabling, circuit protection and isolation equipment for a grid connected PV system with or without energy storage.

6.6 Outline the major non-technical considerations impacting on the design, installation and operation of grid connected PV systems including economic, financial, contractual, institutional, legislative and regulatory.

6.7 Estimate the annual reduction in greenhouse gas emissions achieved by a given PV power system at a given location.

Learning outcome 7

Perform installation and commissioning work on a PV system in accordance with relevant standards and OH & S guidelines.

7.1 Choose a suitable location for the PV array, batteries and other components at a given installation site in accordance with AS 4509 and AS 4086.2.

7.2 Specify the major installation requirements for all system components which will ensure correct operation, long life, safety and ease of maintenance consistent with AS 4509, AS 4086.2, AS/NZS 3000 and relevant OH&S guidelines.

7.3 Specify start-up and shut-down procedures as well as a commissioning procedure for a PV power system in accordance with AS 4509.

7.4 Test all components of a PV system for correct operation.

7.5 Perform installation and commissioning work on a PV power system in accordance with AS 4509, AS 4086.2, AS/NZS 3000 and AS 3010.1.

Learning outcome 8

Perform basic maintenance and troubleshooting on a PV power system in accordance with relevant standards and OH & S guidelines.

Assessment Criteria

8.1 Identify the safety hazards associated with gensets.

8.2 Carry out installation and maintenance procedures on gensets using safe work practices in accordance with OH&S guidelines.

8.3 Perform basic periodic servicing requirements for a genset.

8.4 Test a genset for correct operation.

8.5 Locate and rectify an electrical fault within a PV array, or in any other part of the system.

8.6 Specify the maintenance requirements for a commercially available stand-alone power system battery, in accordance with AS 4086.2 and AS 4509.3 and manufacturer's specifications.

8.7 Devise a maintenance schedule for a stand-alone PV power system.

8.8 Carry out testing and maintenance tasks required for stand-alone PV systems in accordance with AS 4086.2 and AS 4509 and relevant OH&S regulations.

8. Delivery of the module

Delivery strategy

Delivery strategies must be suitable for learning both theoretical and practical aspects described in the module purpose. It is considered that the most effective way to achieve this is by the integration of theory and practice where students learn by experimentation and through practical experience in working with real systems.

It is recommended that learning and assessment be facilitated in a holistic manner. System design projects may serve as the major assessment items on which a large part of the teaching and learning will focus. This may also facilitate the integration of learning about individual system components. The learning outcome sequence may be other than that indicated in the module.

Resource requirements

Resources should be sufficient for students to carry out experiments in pairs. This will require a range of commercially available system components, tools, experimental devices and measuring instruments, as well as access to sites or training facilities for system installation and maintenance.
A computer laboratory, system design software and copies of all relevant standards are required.

Occupational health and safety requirements

A safe and healthy environment will be provided for students and teachers as well as safety procedures with regard to learning / teaching activity according to local OH&S regulations.

The following OH&S issues are to be addressed in the appropriate learning outcome(s):

General:

- lifting and carrying
- eye/skin/ear protection
- use of power tools
- working on roofs
- keeping work areas tidy

Electrical:

- use of measuring instruments
- isolation procedures
- use of ladders
- work with battery installations (Eg. hydrogen explosion, acid spillage, ventilation, short circuits)

Minimum physical resources

PV modules and frame sufficient for array of at least 300 W rating

All other components of a small stand-alone PV system including vented lead acid batteries

Grid interactive inverter

Access to an installation site (may be simulated)

Solarimeter, multimeters, oscilloscope and other test equipment.

Hand and power tools for system installation and maintenance

Hydrometer

Glass thermometers

Safety equipment e.g., rubber gloves, rubber boots, plastic/rubber apron, face shield.

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