1. Module details

Module name

Grid Connected Inverter Systems

Module duration

It is expected that students with the appropriate entry knowledge and skills will successfully complete this module in 40 hours.

Module code

NUER19

Discipline code

1105

2. Module purpose

This module provides knowledge and skills in the installation, commissioning and maintenance of grid connected inverter systems, typically supplied with power from a PV array. The focus is on residential or small commercial scale systems.

3. Prerequisites

NUE058 Electrical concepts and applications;
NE174 Electrical Wiring and Equipment 3.

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 NES115 - Install and maintain a grid connected inverter system.

5. Content

Inverters

basic function, types, output waveforms
simple block diagram structure
Inverter bridge and half bridge; FETS, (operation, cct symbol, major device ratings)
Use of PWM techniques;
Special requirements for grid connect application
Block diagram structure for grid connect inverters
Operation of grid connected inverters

Solar radiation resource

terminology
units, symbols
sun position, sun path diagrams
solar radiation on fixed collectors
Selection of array tilt angle
Shading assessment

Photovoltaic arrays

terminology
modules: types, efficiency, applications
IV curves, irradiance and temperature effects
major ratings

array configurations, blocking and bypass diodes
Shading and bypass diodes
Calculation of array power
Calculation of daily array energy

Installation requirements

site locations: array, inverter, batteries
commissioning, start up and shut down
connection to switchboards
signage requirements
grid protection
additional requirements for UPS systems
D.C. side issues
PV arrays wiring for minimisation of shading losses
schematic diagrams including metering

System installation, commissioning and maintenance

safe work practices
test an inverter system for correct operation
locate and rectify faults
maintenance schedule

Non-technical issues

Non-technical considerations
Greenhouse gas reduction

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.

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

Describe the structure and operation of inverters suitable for grid connected operation.

Assessment criteria

1.1 Describe the basic function of an inverter, including the output waveforms of different types.

1.2 Describe, with the aid of a circuit diagram, the operation of an inverter bridge and half-bridge.

1.3 Describe, with the aid of waveform diagrams, the function of PWM techniques in modified square wave and synthesised sine wave inverters.

1.4 List the characteristics which distinguish inverters suitable for grid connected photovoltaic array application from standard inverters.

1.5 Describe the operation of grid interactive PV systems including synchronisation, power flow control, passive and active anti-islanding, and metered energy for systems with and without energy storage.

Learning outcome 2

Determine the daily average solar irradiation for each month falling on a collector at an appropriate tilt angle for a grid connected PV array.

Assessment Criteria

2.1 Define these terms:

- irradiation
- latitude
- direct and diffuse radiation
- azimuth and altitude angles
- rradiance
- solar window
- tilt angle
- solstice
- equinox

2.2 Write the units and symbols for irradiation and irradiance.

2.3 Measure solar irradiance with a solarimeter.

2.5 Describe how radiation varies throughout the year on the surface of a fixed collector.

2.6 Select an appropriate tilt angle for fixed and seasonally-adjustable PV arrays at a given latitude.

	2.7	Interpret solar radiation data tables and solar contour maps.
	2.8	Estimate the shading on a PV array in terms of reduction in annual irradiation through appropriate observation and measurement.
Learning outcome 3	**Describe the operation and performance of a photovoltaic (PV) array.**	
Assessment criteria	3.1	Define these terms: cell, module and array I-V curve operating point maximum power point (MPP)
	3.2	Distinguish between the types of commercially available PV modules, their efficiency and typical applications.
	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 insolation and variation in cell temperature.
	3.4	Determine the major ratings of a PV module from manufacturer's information or nameplate data.
	3.5	Describe the configuration of a typical PV array, including the function, placement and ratings of blocking and bypass diodes.
	3.6	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.
	3.7	Calculate the power at MPP of an array, given module specifications, irradiance and ambient air temperature.
	3.8	Calculate the daily energy output of a PV array given module specifications, daily irradiation and using "rule of thumb" de-rating factors.
Learning outcome 4	**Specify the installation requirements for a domestic or small commercial grid connected PV system.**	
Assessment criteria	4.1	Choose a suitable location for the PV array, inverter and batteries if any, at a given installation site in accordance with AS2676.2 and AS3011.2, and the considerations given in AS4509.

	4.2	Specify commissioning procedures, including start-up and shut-down procedures for a grid connected PV power system.
	4.3	Outline the labelling and signage requirements for switchboards supplied with power from grid connected inverters, as set out in AS 4777.1.
	4.4	Outline the function and operation of a "grid protection device" as specified in AS4777.
	4.5	Outline the additional requirements for UPS systems as specified in AS4777.1.
	4.6	Outline the major d.c. side issues in grid connected inverter systems.
	4.7	Draw schematic diagrams of common grid connected inverter circuit configurations with or without energy storage including metering arrangements, isolation and connection with respect to switchboards and RCDs in accordance with AS 4777.1.
	4.8	Specify an array wiring plan for series connected modules to minimise power loss due to shading at a particular site.
Learning outcome 5	**Perform installation, commissioning, basic maintenance and troubleshooting on a grid connected PV power system in accordance with relevant standards and OH & S guidelines.**	
Assessment Criteria	5.1	Install a PV array on a roof in accordance with OH&S guidelines.
	5.2	Carry out all relevant installation, commissioning and maintenance procedures on grid connected inverter systems using safe work practices in accordance with OH&S guidelines.
	5.3	Test a grid connected inverter for correct operation.
	5.4	Locate and rectify an electrical fault within a PV array or wiring.
	5.5	Devise a maintenance schedule for a grid connected PV power system.

Learning outcome 6	**Outline the major non-technical considerations impacting on the design, installation and operation of grid connected PV systems.**
Assessment Criteria	6.1 List at least 5 non-technical considerations impacting on the design, installation and operation of grid connected PV systems.
	6.2 Estimate the annual reduction in greenhouse gas emissions achieved by a given PV power system in a given location.

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. 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. Some activities may require careful programming to provide access to expensive equipment in turn. Practical activities 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. 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 meters
- 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
Grid interactive inverter
Access to an installation site

	Multimeters, oscilloscope and other test equipment. Hand and power tools for system installation and maintenance
Recommended References	AS/NZS 3000:2000 *Wiring Rules*
	AS 4777 (Proposed new standard)
	Archer, M and Hill, R (editors), (2001) "*Clean Electricity from Photovoltaics*". Imperial College Press, London.
	Monsour P.M., Burton R. (2002) *Photovoltaic Power Systems - Learning Guide.* Renewable Energy Centre - Brisbane Institute of TAFE, Brisbane.
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	Twidell, J.W., Weir, A.D. (1986). *Renewable Energy Sources*. E. & F. Spon, London.
	Wenham, S.R. et al (1994). *Applied Photovoltaics***.** University of New South Wales, Sydney.
	Zweibel, K, (1990) "*Harnessing Solar Power. The Photovoltaics Challenge".* Plenum Press, London.