1. Module details

Module name

Fuel Cells and Advanced Energy Storage Technology

Module duration

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

Module code

NUER07

Discipline code

1105

2. Module purpose

This module provides knowledge relating to the structure, operation, selection and sizing, installation, commissioning and maintenance of fuel cell systems and advanced energy storage systems, in particular as they relate to stand-alone stationary or mobile power systems.

3. Prerequisites

NUER02 – Photovoltaic Power Systems

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 NES219, NES305, NES412, NES506, NES710.

5. Content

Fuel Cells - general

technology types, fuels
fuel cell structure and operation
Polymer Electrolyte Fuel Cell (PEFC or PEMFC) and Solid Oxide Fuel Cell (SOFC)
electrical characteristics
effect of operating conditions
fuel processing requirements
renewable and non-renewable fuels
fuel cell systems and Balance of Plant
commercially available fuel cells, major specifications
production of hydrogen from renewable sources

Fuel Cells - Selection and Sizing

Stand-alone power system application
function, configuration, operation
required ratings - power and energy requirements for an application
Selection and sizing for application
fuel usage calculations

Fuel Cells - installation and commissioning

safety hazards
installation and commissioning requirements
start-up, shut down and commissioning procedures
maintenance requirements
relevant standards
involvement of other qualified personnel

New energy storage technologies

Power and energy requirements
Overview of new technologies: batteries including flow batteries; flywheels; super-capacitors
major features, cost, current status, and their suitability for standalone power systems

Flow batteries - general

technology types and structure
cell structure and operating principles
Zinc Bromine (ZBB) and Vanadium Redox (VRB)
electrical characteristics
effect of temperature
advantages and disadvantages compared to lead acid batteries for standalone power systems
limitations on life
commercially available devices, specifications

Flow batteries - Selection and Sizing

Stand-alone power system application
function, configuration, operation
required ratings - power and energy requirements for an application
Selection and sizing for application

Flow batteries - installation and commissioning

safety hazards
installation and commissioning requirements
maintenance requirements
relevant standards
involvement of other qualified personnel

6. Assessment strategy

Assessment methods	Assessment should encompass both progressive and holistic elements in recognition of the interdependence between learning outcomes. To assist in ensuring validity, reliability and fairness, assessment instruments should include written exercises consisting of a number of item types, such as multiple choice, short answer and problem solving. It should be noted that new technologies may emerge over the lifetime of this module, which are of more commercial significance than those mentioned in the assessment criteria. These may be substituted in keeping with the module purpose.
Conditions of assessment	Normally learning and assessment will take place in a classroom/ laboratory environment.

7. Learning outcome details

Learning outcome 1

Describe the structure, operating principles and major features of each of the main types of fuel cells suitable for small scale stationary or mobile power applications.

Assessment criteria

1.1 Compare the major types of fuel cell technology in terms of typical applications, size range, fuel type, efficiency and status of the technology.

1.2 Describe, with the aid of a diagram, the basic structure and operation of a Polymer Electrolyte Fuel Cell (PEFC or PEMFC) and a Solid Oxide Fuel Cell (SOFC).

1.3 Describe the electrical characteristics of a fuel cell stack in terms of typical variation in voltage vs. load current.

1.4 Describe in qualitative terms the effect of temperature, pressure, fuel utilisation and gas composition on the operating characteristics of PEFC and SOFC fuel cells.

1.5 Outline the fuel processing requirements for hydrocarbon fuels for use in PEFC and SOFC fuel cells.

1.6 Distinguish between renewable and non-renewable fuels for fuel cells.

1.7 Outline the function of the major balance of plant (BoP) components required for PEFC and SOFC fuel cell systems, with reference to a commercially available unit of each type.

1.8 Compare the major specifications of 2 different commercially available fuel cells.

1.9 Briefly describe methods for the production and use of hydrogen from renewable energy sources.

Learning outcome 2

Select and size a fuel cell system for a stand-alone power system application.

2.1 Describe the use of fuel cells in domestic or small commercial scale stand-alone power systems, including function, power system configurations, and operational strategies.

2.2 Calculate the required ratings for a fuel cell for a domestic or small commercial stand-alone power system.

	2.3	Select a fuel cell and type of fuel suitable for a domestic or small commercial stand-alone power system.
	2.4	Calculate daily, monthly or annual fuel usage for a fuel cell in a stand-alone power system application.
Learning outcome 3	**Specify installation, commissioning and maintenance requirements for a fuel cell system in accordance with relevant standards.**	
Assessment Criteria	3.1	Identify the safety hazards associated with fuel cells.
	3.2	Specify the major installation and commissioning requirements for a PEFC or SOFC fuel cell.
	3.3	Specify the major maintenance requirements for a PEFC or SOFC fuel cell.
	3.4	List the standards relevant to the installation, commissioning and maintenance of PEFC and SOFC fuel cells.
	3.5	Identify where other suitably qualified personnel are required to complete the installation of a fuel cell.
Learning outcome 4	**Compare the major types of new energy storage technology.**	
Assessment Criteria	4.1	Distinguish between power and energy requirements in the application of energy storage devices.
	4.2	Compare the major types of new energy storage technology in terms of their major features, cost, current status, and their suitability for standalone power systems applications.
Learning outcome 5	**Describe the structure, operating principles and major features of flow batteries suitable for small scale stationary or mobile power applications.**	
Assessment Criteria	5.1	List the major types of flow batteries currently at or near commercial production.
	5.2	Describe, with the aid of a diagram, the basic structure and operation of a Vanadium Redox cell and a Zinc Bromine cell.
	5.3	Describe, with the aid of a diagram, the basic structure and operation of either a complete Zinc Bromine Battery (ZBB) and Vanadium Redox Battery (VRB) including balance of plant.

	5.4	Describe the electrical characteristics of either a ZBB or VRB in terms of typical variation in voltage vs. state of charge.
	5.5	Describe the effect of temperature on the operating characteristics of either a ZBB or a VRB.
	5.6	List the advantages and disadvantages of Zinc Bromine Batteries and Vanadium Redox Batteries in comparison with lead acid batteries for use in standalone power systems and mobile applications.
	5.7	Outline the limitations on the life of a ZBB or a VRB.
	5.8	Compare the major specifications of 2 different commercially available flow batteries.
Learning outcome 6	**Select and size a flow battery system for a stand-alone power system application.**	
Assessment Criteria	6.1	Describe the use of either Vanadium Redox or Zinc Bromine batteries in domestic or small commercial scale stand-alone power systems, including function, power system configurations, and operational strategies.
	6.2	Select and size a Zinc Bromine or a Vanadium Redox battery for a domestic or small commercial stand-alone power system.
Learning outcome 7	**Specify installation, commissioning and maintenance requirements for a flow battery system in accordance with relevant standards.**	
Assessment Criteria	7.1	Identify the safety hazards associated with either Zinc Bromine or Vanadium Redox batteries.
	7.2	Specify the major installation and commissioning requirements for either Zinc Bromine or Vanadium Redox batteries.
	7.3	Specify the major maintenance requirements for either Zinc Bromine or Vanadium Redox batteries.
	7.4	List the standards relevant to the installation, commissioning and maintenance of either Zinc Bromine or Vanadium Redox batteries.
	7.5	Identify where other suitably qualified personnel are required to complete the installation of a fuel cell.

8. Delivery of the module

Delivery strategy	Special consideration should be made in the delivery of this module to account for the emerging nature of the technologies presented. Where possible, theoretical learnings should be supported by experimentation on educational equipment, where commercial equipment is unavailable or too costly. The use of case studies or field trips where possible, is also recommended to assist in the grounding of theoretical knowledge. 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 groups of 3 or less. This will require a range of experimental devices and measuring instruments, or commercially available system components, where possible. Equipment availability may necessitate programming of activities to allow access to costly equipment in turn. 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.
Minimum physical resources	Educational fuel cell Fittings and fuel handling equipment as required for the fuel cell Multimeters and other electrical test equipment.
Recommended References	EG&G Services, Parsons, Inc. and Science Applications International Corporation (2000) *Fuel Cell Handbook (5th Ed).* U.S. Department of Energy, Morgantown, West Virginia. (Available on the internet). www.fuelcells.org