1. Module details

Module name

Alternating Current Machines

Module duration

It is expected that a student possessing the prerequisite skills and knowledge will achieve the module purpose in 72 to 80 hours.

Module code

NUE046

Discipline code

0703110

2. Module purpose

This module provides Learners with knowledge of the operation, application and control of single phase and three phase induction motors and synchronous machines.

Learners will determine power, torque, frequency and speed relationships of various single and three phase motors and select and connect a motor starter to suit given load conditions and local requirements. Also, they will be able to apply the Wiring Rules' requirements regarding motors and conduct test to determine causes of malfunctions in single and three phase motors circuits and starters.

3. Learning pathway

Intended use in the structured learning program

This module is intended to supplement exposure to electrical installation work. In particular it applies to the installation, maintenance, testing, commissioning, fault finding and repair of electrical motor circuits and equipment.
Therefore before undertaking this module a student should have a clear understanding and experience of electrical installation in general and how the fundamental principles for safety apply.

Recommended prerequisites

For the most effective learning this module should be undertaken only after modules in three-phase systems, electrical wiring and equipment and protection methods and devices have been completed.

4. Relationship to competency standards

This module provides part of the underpinning knowledge and skills in the 'Evidence Guide' of specific units of competency in the National Electrotechnology Training Package and provides similar support, where mapped, to equivalent units in the National Metals and Engineering Competency Standards. For details refer to the module to unit maps, available from EEQSBA.

This module supports the development of essential capabilities

5. Content

required for electrical licensing.

1. Three phase motors
   - construction
   - operation principles
     - rotating magnetic fields
     - startors
     - poles
     - rotors – squirrel cage and wound
     - torque and R_{rotor} : X_{Lrotor} relationship
   - performance characteristics
     - normal squirrel cage
     - double cage
     - wound rotor
2. Motor protection
   - short duration overloads
   - sustained overloads
   - locked rotor
   - undervoltage supply
   - overvoltage supply
   - repetitive starting or reversing
   - high operating temperature
   - high humidity or moisture
   - enclosures
   - protection devices
     - microtherm devices
     - thermal overload
     - magnetic dashpots
     - current controlled relay
     - fuses
     - circuit breakers
3. Purpose of limiting starting current of machines
   - requirements of the Wiring Rules and local authorities
   - three phase starter operation and application
     - direct on line
     - start delta
     - auto transformer
     - soft start (electronic)
     - primary resistance
     - secondary resistance

- Motor vs load: speed torque relationships

4. Connection methods of three phase starters
   - methods of braking AC motors
   - reversal of rotation of AC motors
5. Wiring Rules and service rule requirements
   - connection
   - control switches
   - isolating switches
   - limitation of transient current
   - automatic starting
   - protection against over-temperature
6. Single phase motor principles and characteristics
   - "rotating" magnetic field
   - production of torque
   - split phase motor
   - shaded-pole motor
   - capacitor types
   - universal motor
   - characteristics curves
   - reversal of rotation
7. Construction
   - windings, stators and rotors
   - starting current devices
   - protection devices
8. Applications
   - comparison of torque/power/speed characteristic
   - calculation of power, torque, speed and efficiency
   - applications
9. Fault testing
   - balanced line current
   - terminal voltage
   - insulation resistance
   - winding resistance/continuity
   - control and power circuit testing
   - procedures
10. Three-phase synchronous machines
    - operating principles
    - construction feature
    - application

11. Three-phase synchronous machines
    - effects of load changes
    - effects of excitation change
    - load/current characteristics
12. Single phase synchronous machines
    - alternators
    - motors
    - applications

6. Assessment strategy

Assessment methods

Assessment should be progressive reflecting a holistic approach to ensure the module purpose is met. To assist in ensuring validity, reliability and fairness assessment instruments should include practical exercises, assignments and written tests 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 formal learning environment.

7. Learning outcome details

Learning outcome 1

Describe the operating principles and characteristics of three phase induction motors

Assessment criteria

1.1 Explain the principles of operation.

1.2 Describe the construction features of various induction motor types.

1.3 Show the relationship between torque, speed, and power in an induction motor.

1.4 State the conditions necessary for an induction motor to produce maximum torque.

1.5 Determine the operating characteristics of an induction motor from name plate information and by measurement.

1.6 Determine the full load efficiency and power factor of induction motors.

Learning outcome 2	Describe methods of protecting motors against over-temperature	
Assessment criteria	2.1	Describe the conditions that cause motors to overheat.
	2.2	List methods of protecting motors against overcurrent and undervoltage.
	2.3	Explain the operating principles of microtherm devices, thermal and magnetic overloads and current control relays.
	2.4	Select HRC fuses/circuit breakers to protect a motor circuit.
	2.5	Select an overload device for a given motor and load condition.
Learning outcome 3	Select starters for given three phase induction motors, load conditions and local requirements	
Assessment criteria	3.1	Describe the operating characteristics and applications of DOL, star-delta, auto transformer, soft start, primary resistance and secondary resistance starters.
	3.2	Determine the relative starting torque produced by a motor using each type of starter.
	3.3	Describe the components and operating sequence of each type of starter.
	3.4	State conditions necessary for a motor to accelerate when coupled to a load.
	3.5	Determine the effects on motor performance when a load variation occurs.
Learning outcome 4	Connect three phase induction motors to a range of starters utilising local and remote stop-start	
Assessment criteria	4.1	Interpret motor starter wiring diagrams.
	4.2	Connect motor starters with local or remote stop-start stations.

Learning outcome 5	Determine the Wiring Rules and local requirements with regards to motors
Assessment criteria	5.1 Explain how the Wiring Rules' requirements relating to motors, their protection and control can be met.
	5.2 State local Supply Authorities' requirements for the limitation of starting current, connection and controls of electric motors.
Learning outcome 6	Describe the operating principles and characteristics of split-phase, shaded-pole and universal single phase motors
Assessment criteria	6.1 Explain how a 'rotating' magnetic field is produced in split-phase and shaded-pole motors.
	6.2 Explain the relative difference in torque produced by various types of 'phase-splitting' motors using a phasor diagram.
	6.3 Describe the torque/speed characteristics of single phase motors.
	6.4 Draw circuit diagrams of split-phase, capacitor start, capacitor start-run motors, shaded-pole motor and universal motor.
	6.5 Demonstrate the method of reversing the direction of rotation of single phase motors.
Learning outcome 7	Identify the components of single phase motors and their controls and describe the purpose of each component
Assessment criteria	7.1 Identify the run winding and the start/auxiliary winding in a split-phase motor by resistance measurement at the motor terminals.
	7.2 Identify starting circuits switching devices and explain how they operate.
	7.3 Identify components in single phase motors and explain their purpose.
	7.4 Identify devices used with single phase motors to provide overload protection, over-temperature protection, automatic or remote starting and speed control.

Learning outcome 8	Determine the suitability of various types of single phase motors for particular applications
Assessment criteria	8.1 Compare power, torque and speed characteristics of various types of single phase motors.
	8.2 Calculate power, torque, speed and efficiency of single-phase motors.
	8.3 List typical applications for various types of single-phase motors.
Learning outcome 9	Describe possible causes of malfunction of three phase and single phase induction motors and demonstrate the tests required for diagnosing faults
Assessment criteria	9.1 State the common causes of motor malfunction.
	9.2 Conduct a load test on a motor to determine whether the terminal voltage is correct, line current is balanced and the motor operates within rated speed.
	9.3 Determine the fault in various motor windings for various winding conditions.
	9.4 Conduct tests on motors and circuits to locate faults.
Learning outcome 10	Describe the operating principles and constructional details of three-phase synchronous machines
Assessment criteria	10.1 Outline the constructional details of three-phase alternators and synchronous motors.
	10.2 Explain the theory of operation of three-phase alternators and synchronous motors.
	10.3 List applications of three-phase synchronous motors.
	10.4 Interpret given nameplate data.
	10.5 Calculate full load current ratings of given synchronous machines given their ratings.
Learning outcome 11	Predict the effect of (a) load and (b) change in excitation on the operating characteristics of three-phase synchronous machines
Assessment criteria	11.1 Predict the effect of a given load on the output characteristics of a three-phase alternator.

	11.2 Predict the effect of excitation variation on a given operating condition of a three-phase alternator. 11.3 Explain the effect of load on a three-phase synchronous motor. 11.4 Predict the effect of excitation variation in relation to a three-phase synchronous motor.
Learning outcome 12	Outline the construction details characteristics and application of common single-phase synchronous machines
Assessment criteria	12.1 Outline the constructional details of common single-phase portable alternator. 12.2 Outline the operating characteristics of common single-phase alternators. 12.3 Recognise the type of common single-phase synchronous motor given constructional details. 12.4 Identify an appropriate application of each type of motor identified.

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 method to achieve this is by integration of theory and practice where students learn by experimentation, research and reports. It is recommended that learning and assessment be facilitated in a holistic manner that may require a learning outcome sequence other than that indicated in the module.
Resource requirements	Resources should be sufficient for students to carry out exercises on an individual basis. Useful references include: Jenneson, J. R. 1996, *Electrical Principles for Electrical Trades,* 4th Ed., McGraw Hill, Sydney Van den Bergen, B. 1996, *Mathematics for the Electrical Trades*. TAFE Publications, RMIT, Melbourne Traiter, John E. 1984, *Handbook of Electric Motor Use and Repair,* Prentice-Hall Rosenberg, Robert etal 1987, *Electric Motor Repair,* Molt, Rinchart and Winstor.

	Standards Australia, Standards New Zealand *AS/NZS 3000:2000 Wiring rules* *AS/NZS 4836 Safe working practice on low-voltage electrical installations* WorkCover Codes of Practice Local electricity distributor and authority regulations Where this module is used in an approved Traineeship or Apprenticeship program learners should be advised to obtain, where available, respective EEQSBA [1] *User Guide*s (*these outline in detail what training and work performance the Learner is required to undertake for the program).*
Occupational health and safety requirements	A safe and healthy environment will be provided for learners and teachers. Safety procedures for the particular learning facilities shall be followed as part of the learning / teaching activity and assessment.

[1] EEQSBA – ElctroComms and EnergyUtilities Qualifications standards Body of Australia Ltd.