

34.3.0 MACHINES AND UTILIZATION

34.3.01 Introduction

The module unit is designed to equip the trainee with knowledge, skills and attitudes necessary to understand machine design, construction, installation, maintenance and their applications.

34.3.02 General Objectives

At the end of this Module Unit, the trainee should be able to:

- a) Understand the principles of operation of various electric machine
- b) Maintain and repair electrical machines and machine controls
- c) Install electrical machines
- d) Observe safety standards when installing electric machines
- e) Analyse electrical machine systems
- f) Select and use/recommend ac and dc Machines for various purposes
- g) Understand the concepts of refrigeration and air conditioning
- h) Outline the operational principles of electric traction

34.3.03 Module Unit Summary and Time Allocation

Machines and Utilization

Code	Sub-Module Unit	Content	Time
34.3.1	Induction Machines	<ul style="list-style-type: none">• Construction of induction motors• Equivalent circuit for induction motors• Operation• Circle diagram• Speed control• Application	14
34.3.2	Synchronous Machines	<ul style="list-style-type: none">• Construction• Equivalent circuit• Operation• Circle diagram• Applications	14
34.3.3	Direct Current Machines	<ul style="list-style-type: none">• Construction• Operation• Speed control• Application	10

34.3.4	Special Machines	<ul style="list-style-type: none"> • Types • Construction • Operation 	12
34.3.5	Electric Drives	<ul style="list-style-type: none"> • Choice of motor • Heating and cooling curves • Power rating • Application 	12
34.3.6	Refrigeration And Air-conditioning	<ul style="list-style-type: none"> • Operation • Construction • Layout of plant 	14
34.3.7	Electric Traction	<ul style="list-style-type: none"> • Introduction • Mechanics of train movement • Starting and speed control • Braking • Construction control and distribution systems 	12
Total Time			88

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<p>34.3.1 INDUCTION MACHINES</p> <p>Theory</p> <p>34.3.1T0 <i>Specific Objectives</i> By the end of the sub-module unit, the trainee should be able to:</p> <ol style="list-style-type: none"> a) describe the construction of induction machine b) analyse an equivalent circuit of the induction machine c) describe the operation of the induction machine d) explain the application of circle diagram to determine various machine parameters e) describe the speed control methods of the induction machine f) state the application of induction machines <p><i>Content</i></p> <p>34.3.1T1 Description of the construction of induction machines</p> <ol style="list-style-type: none"> i) Stator ii) Rotor <p>34.3.1T2 Analysis of an equivalent circuit diagram</p> <ol style="list-style-type: none"> i) Ideal equivalent circuit ii) Equivalent circuit at no-load iii) Equivalent circuit at load 	<p>34.3.1T3 Description of the operation of the induction machines</p> <ol style="list-style-type: none"> i) Phasor diagrams at: ii) No load iii) On-load iv) Primary and secondary v) Derive expressions for machine parameters vi) Torque vii) Current viii) Output power ix) Slip x) Power factor <p>34.3.1T4 Explanation of the application of the circle diagram</p> <ol style="list-style-type: none"> i) Locus diagrams ii) Open-circuit current iii) Iron and copper losses iv) Air gap power v) Mechanical power output vi) Electrical torque vii) Rotor current viii) Characteristics ix) Torque/slips characteristics x) Acceleration, deceleration and stopping times <p>34.3.1T5 Description of the speed control methods of the induction machines</p> <ol style="list-style-type: none"> i) Frequency variation ii) Pole changing iii) Voltage variation iv) Cascade connection <p>34.3.1T6 Application of induction machines</p> <p>Practice</p> <p>34.3.1T0 <i>Specific Objectives</i></p>
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By the end of the sub-module unit, the trainee should be able to:

- a) connect and measure torque of an induction machine
- b) measure speed of an induction machine
- c) perform tests to plot circle diagrams
- d) connect and measure the efficiency of induction machines
- e) apply various methods to control the speed of an induction machine

Content

- 34.3.1P1 Connection and measurement of torque
- 34.3.1P2 Measurement of speed of an induction machine
- 34.3.1P3 Testing of induction machine to plot the circle diagram
- 34.3.1P4 connection and measure of the efficiency of the induction machine
- 34.3.1P5 Application of various methods to control the speed of induction machine
- i) Frequency variation
 - ii) Voltage variation
 - iii) Cascade connection

34.3.1C

Competence

The trainee should have the ability to:

- i) Control induction motor speeds
- ii) Apply circle diagram parameters to obtain induction machine output characteristics

- iii) Interpret measurement to determine induction machine equivalent circuit
- iv) Determine efficiency of induction machines

Teaching / Learning Resources

- i) Induction machines
- ii) Measuring instruments
- iii) Connecting cables

Suggested teaching/Learning Activities

- Discussion
- Illustration
- Demonstration
- Note taking
- Practical exercise
- Calculations

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments
- Timed practical tests

34.3.2 SYNCHRONOUS MACHINES

Theory

34.3.2T0 Specific Objectives

By the end of the sub-module unit, the trainee should be able to:

- a) describe the construction of synchronous machine
- b) analyse the equivalent circuit of the synchronous machine
- c) explain the operation of synchronous machine connected to an infinite busbar

- d) describe the application of circle diagram to determine machine parameters
- e) state the application of the synchronous machine

Content

- 34.3.2T1 Description of the construction of the synchronous machine
 - i) Field windings
 - ii) Armature windings
 - iii) Salient and cylindrical motors
- 34.3.2T2 Analysis of the equivalent circuit of synchronous machine
 - i) Ideal equivalent circuit
 - ii) Equivalent circuit at no-load
 - iii) Equivalent circuit at load
- 34.3.2T3 Describe the operation of the synchronous machine connected to
 - i) Infinite bus-bars
 - ii) Connection to bus-bars
 - iii) Synchronizing
 - iv) Switching
- 34.3.2T4 Application of circle diagram to derive operation parameters
 - i) Locus diagrams
 - ii) Open circuit current
 - iii) Iron and copper losses
 - iv) Air gap power
 - v) Air gap power
 - vi) Mechanical power output
 - vii) Electric torque
 - viii) Rotor torque
 - ix) Rotor current

- x) Machine characteristics
- 34.3.2T5 Starting the application of the synchronous machine
- i) Constant speed drivers
 - ii) Power factor correction

Practice

- 34.3.2P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- a) connect synchronous machines using various starting methods
 - b) synchronise the machine for parallel operation
 - c) connect the machine for power factor correction and determination of V-curves
 - d) locate faults in machines

Content

- 34.3.2P1 Connection of synchronous machines using various starting machines
 - i) Induction motor
- 34.3.2P2 Synchronization of machine for parallel operation
 - ii) Lamps dark method
 - iii) Lamps bright method
 - iv) Synchroscope
- 34.3.2P3 Connection of the machine for power factor correction and determination of the V-curves

- i) Synchronous phase modifier
 - ii) Plot of V-curves
- 34.3.2P4 Location of faults in synchronous machines
- i) Open circuit
 - ii) Short circuit
 - iii) Earth fault
 - iv) Phase failure
- 34.3.2C **Competence**
- The trainee should have the ability to ability to:
- i) Synchronise machines to infinite bus-bars
 - ii) Operate synchronous machines in parallel
 - iii) Locate faults and perform repair
 - iv) Run synchronous machines

Suggested Teaching / Learning resources

- Lamps
- Synchronous machines
- Teaching aids
- Measuring instruments

Suggested teaching/Learning Activities

- Discussion
- Illustration
- Demonstration
- Note taking
- Practical exercise
- Calculations

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments
- Timed practical tests

34.3.3 **DIRECT CURRENT MACHINES**

Theory

- 34.3.3T0 *Specific Objectives*
- By the end of the sub-module unit, the trainee should be able to:
- a) describe the construction of the synchronous machine
 - b) explain the operation of the synchronous machine
 - c) describe the speed control methods used in DC machines
 - d) state the application of dc machines

Content

- 34.3.3T1 Description of the construction of the synchronous machine
- i) Armature
 - ii) Field
 - iii) Commutator
 - iv) Shaft and bearings
 - v) Orientation of the field with respect to brushes
- 34.3.3T2 Explanation of the operation of synchronous machine
- i) Derivation of the machine parameters
 - ii) E.m.f. equation
 - iii) Power equation
 - iv) Torque equation
 - v) Analysis of circuits
 - vi) Field circuit
 - vii) Armature current
 - viii) Characteristics
 - ix) E.m.f / speed
 - x) Torque/speed

	xi) Magnetization curves		e) correct dc machines for speed control
	xii) Excitation		
34.3. T3	Explanation of speed control		
	i) General speed equation	34.3.3P1	<i>Content</i> Drawing and connecting of dc machines for starting
	ii) Base speed control		i) Manual starting methods
	iii) SCR speed control		ii) Automatic starting methods
	iv) Dynamic behaviours during speed adjustment	34.3.3P2	Connection of different types of dc machines
	v) Armature control		i) Series
	vi) Shunt field control		ii) Shunt
	vii) Precautions when increasing speed through field weakening	34.3.3P3	Measuring of the parameters of dc machines
	viii) Speed changes should be made slowly to avoid damage to commutators and brushes		i) Effect of Armature inductance on commutation
			ii) Mechanical power and developed torque
34.3.3T4	Application of dc machines		iii) Losses and efficiency
			iv) Torque / speed characteristics
			v) Field current and armature current
	Practice	34.3.3P4	Connection of dc machines for braking Regenerative braking
34.3.3P0	<i>Specific Objectives</i> By the end of the sub-module unit, the trainee should be able to:	34.3.3P5	vi) Equipment for braking Connection of dc machines for speed control
	a) draw circuit diagrams for starting dc machines and demonstrate the connection of starters		i) Rheostatic control
	b) connect different types of dc machines		ii) Thyristor control
	c) measure the parameters of dc machines to plot machine characteristics		iii) Ward Leonard speed control
	d) connect dc machines for braking	34.3.3C	Competence The trainee should have the ability to:
			i) Connect and operate dc machines

- ii) Measure and interpret dc machine parameters for particular application
- iii) Test dc machines to ascertain operational status
- iv) Determine losses and calculate efficiency for given dc machines
- v) Perform braking
- vi) operations for dc machines

Teaching / learning Resources

- i) Dc machines (series, shunt and compound)
- ii) Measuring instruments
- iii) Starters
- iv) Rheostats
- v) Ward Leonard dc/ac
- vi) motors

Suggested teaching/Learning Activities

- Discussion
- Illustration
- Demonstration
- Note taking
- Practical exercise
- Calculations

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments
- Timed practical tests

34.3.4 SPECIAL MACHINES

Theory

- 34.3.4T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- a) identify the types of special machines

- b) describe the construction of the special machines
- c) explain the principles of operation of special machines

Content

34.3.4T1 Identification of the types of special machines

- i) Reluctance motors
- ii) Hysteresis motors
- iii) Stepper motors
- iv) Stepper motors
- v) Variable-reluctance stepper motor
- vi) Linear induction motor
- vii) Universal motor
- viii) Universal motor

34.3.4T2 Description of the construction of special machines

- i) Rotor limitations
- ii) Permanent magnet alloy material
- iii) Non-magnetic supports
- iv) Toothed stator
- v) Toothed rotor
- vi) Stator

34.3.4T3 Principles of operation of special machines

- i) Reluctance motors
- ii) Hysteresis motors
- iii) Stepper motors
- iv) Variable – reluctance stepper motor
- v) Linear induction motor
- vi) Universal motor

	Practice	Special machines
34.3.4P0	<i>Specific Objectives</i> By the end of the sub-module unit, the trainee should be able to:	i) Routine maintenance ii) Locate faults diagnose and repair iii) Test motor for operation
	a) operate the types of special machines b) draw the construction details of special machines c) perform experiments to verify the characteristics of the special machines d) maintain special machines	34.3.4C Competence The trainee should be able to apply special machines in production systems
	<i>Content</i>	<i>Suggested Teaching / Learning Resources</i>
34.3.4P1	Operation of the types special machines i) Reluctance motors ii) Hysteresis motors iii) Stepper motors iv) Variable – reactance stepper motors v) Linear induction motor vi) Universal	- Different types of laboratory simulators - Measuring instruments
34.3.4P2	Drawing the constructional details of special machines i) Reluctance motors ii) Hysteresis motors iii) Stepper motors iv) Variable – reactance stepper motors v) Linear induction motors vi) Universal motor	<i>Suggested teaching/Learning Activities</i> - Discussion - Illustration - Demonstration - Note taking - Practical exercise
34.3.4P3	Experiments to verify the characteristic of special machines	<i>Suggested Evaluation Methods</i> - Oral tests - Timed written tests - Assignments - Timed practical tests
34.3.4P4	Maintenance of	34.3.5 ELECTRIC DRIVES
		Theory
		34.3.5T0 <i>Specific Objectives</i> By the end of the sub-module unit, the trainee should be able to:
		a) explain the factors that affect the choice of motor for a particular drive

- b) explain the application of various drives
- c) derive the expressions for the heating and cooling curves
- d) explain the motor power rating

types of electric drives

- b) connect motor enclosures

Content

- 34.3.5T1 *Content*
Explanation of the factors that affect the choice of motor for a
 - i) particular drive
 - ii) Supply available
 - iii) Load characteristics
 - iv) Cost
 - v) Efficiency
 - vi) Enclosure
 - vii) Braking
- 34.3.5T2 Explanation of the application of various motor drives
 - i) Individual drives
 - ii) Group drives
- 34.3.5T3 Derivation of the expressions for the heating and cooling curves
 - i) Heating curves
 - ii) Cooling curves

- 34.3.5P1 Dismantling and assembling different types of electric drives
 - i) Linear
 - ii) Rotary
- 34.3.5P2 Connection of motor enclosures
 - i) Open type
 - ii) Totally enclosed
 - iii) Air cooled
 - iv) Water cooled

Suggested teaching/Learning Activities

- Discussion
- Illustration
- Demonstration
- Note taking
- Practical exercise

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments
- Timed practical tests

- 34.3.5T4 Explanation of power rating
 - i) Continuous rating
 - ii) Intermediate rating

34.3.6 REFRIGERATION AND AIR CONDITIONING

Theory

Practice

- 34.3.5P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
 - a) dismantle and assemble different

- 34.3.6T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
 - a) explain the principle of operation of the refrigeration and air conditioning

- b) describe the construction of the refrigeration and air conditioning units
 - c) state common refrigerants
 - d) describe the layout of typical refrigeration and air conditioning plant
- should be able install, test, trouble shoot and repair refrigeration and air conditioning plants

Content

34.3.6P1 Installation, testing, trouble shooting and repair refrigeration and air conditioning plants

Content

34.3.6T1 Principles of operation of:

- i) Air conditioning and refrigeration
- ii) Refrigeration cycle
- iii) insulating materials
- iv) Refrigeration load
- v) Refrigeration capacity control
- vi) Air – circulation
- vii) Control of temperature and humidity
- viii) Humidification
- ix) Temperature and humidity transducers
- x) Psychrometry mixtures

Suggested teaching/Learning Activities

- Discussion
- Illustration
- Demonstration
- Note taking
- Practical exercise

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments
- Timed practical tests

34.3.6T2 Description of the of refrigeration and air conditioning units

- i) Compressors
- ii) Condensers
- iii) Evaporators
- iv) Valves
- v) Transducers

34.3.6T4 Refrigeration and air conditioning plants layout

- i) Use of block diagrams
- ii) Use of layout drawings

Practice

34.3.6P0 *Specific Objectives*
By the end of the sub-module unit, the trainee

34.3.7 ELECTRIC TRACTION

Theory

- 34.3.7T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- a) explain the fundamental concepts of the electric traction
 - b) analyse the mechanics of train movement
 - c) outline the starting and speed control systems of traction motors

- d) explain the principles of braking of electric traction
- e) describe the construction, control and distribution of traction systems

- ii) Double – series – parallel
- iii) Control of series motors
- iv) Accomplishing control by shunt transition and bridge transition

Content

- 34.3.7T1 Fundamental concepts of the electric traction
- i) Systems of operation for Tram cars, Trolley buses comparison of tramways, trolley buses, steam and diesel railway system
 - ii) Methods of supplying power to railway train's
 - Overhead systems
 - Conductor rail systems
 - Dc systems
 - Ac single phase and ac three-phase systems
- 34.3.7T2 Analysis of the mechanics of train movement
- i) Speed-time curves for urban, suburban and main line service trains
 - ii) Energy required for propulsion
 - iii) Tractive forces for acceleration, gravitational effect and resistance to motion
 - iv) Total tractive effort for propulsion of train
- 34.3.7T3 Outlining the stating and speed control systems of electric traction
- i) Series – parallel

34.3.7T4 Explanation of the principles of braking of electric traction

- i) Regenerative braking with three-phase motors, and single phase motors
- ii) Equipment for braking

34.3.7T5 Construction, control and distribution of traction systems

- i) Control and auxiliary equipment
- ii) Contractors, relays, circuit breakers
- iii) Starting resistors, compressors, exhausters
- iv) Train heating overhead and conductor rail collection systems
- v) Overhead construction
- vi) Trolley wires
- vii) Support for trolley wires
- viii) Construction at curves
- ix) Special fittings and poles
- x) Feeding and distribution systems
- xi) Traction distribution systems
- xii) Length of trolley wire between feeding points, feeders
- xiii) Negative feeding and distributing systems

Practice

- 34.3.7P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- simulate train movements
 - perform experiments to indicate starting and speed control systems of electric traction

Content

- 34.3.7P1 Simulation of train movements
- Propulsion
 - Braking
 - Acceleration
- 34.3.7P2 Performing experiments to indicate starting and speed control systems
- Series – parallel
 - Double-series-parallel
 - Control of series motors
 - Control by shunt transition
 - Control by bridge transition

34.3.7C Competence

The trainee should have the ability to:

- Simulate train movements
- Start and control speed of traction drives

Suggested Teaching / Learning Resources

- Simulators for electric traction
- Measuring instruments

Suggested teaching/Learning Activities

- Discussion
- Illustration
- Demonstration
- Note taking
- Practical exercise

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments
- Timed practical tests