



Government of Karnataka
DEPARTMENT OF COLLEGIATE AND TECHNICAL EDUCATION

Programme	Electrical and Electronics Engineering	Semester	IV
Course Code	20EE41P	Type of Course	Programme Core
Course Name	Electric Motors	Contact Hours	8 hours/week 104 hours/semester
Teaching Scheme	L:T:P :: 3:1:4	Credits	6
CIE Marks	60	SEE Marks	40

1. Rationale:

Electric motors impact almost every aspect of modern living through the use of various Appliances. They are used at some point in the manufacturing process of nearly every conceivable product that is produced in modern factories and has nearly unlimited number of applications. An Electrical Technician is expected to Analyse the performance and select a particular motor for an application followed by testing, troubleshooting and maintenance of the same.

2. Course Outcomes/Skill Sets:

On successful completion of the course, the students will be able to

CO-01	Conduct performance analysis of a given electrical motor, draw its characteristics and determine the right motor for a specific application.
CO-02	Select, Install and test the motor to be used for a specific application.
CO-03	Describe test parameters, testing procedures and demonstrate the troubleshooting of a given electric motor to ensure it performs optimally.
CO-04	Construct power circuit and control circuits using appropriate components /devices to control the given electric motor.

3. Course Content

Week	CO	PO*	Lecture (Knowledge Criteria)	Tutorial (Activity Criteria)	Practice (Performance Criteria)
			3 hours/week	1 hour /week	4 hours/week (2 hours/batch twice in a week)
1	1	1,4	1. DC Motors: Working principle, back emf & voltage equation- simple problems.	Refer Table1	Follow Safety rules and Safe working practices (Demo) 1. Identify the terminals, and test the field and armature windings of a DC machine for open circuit, short circuit and ground faults using test lamp /megger, check the insulation resistance, identify and locate the possible faults.
			2. Types of motor-circuit diagram with voltage equation. -meaning of Torque -torque developed by D.C motors, torque equation [no derivation] - torque- speed relationship		2. Control the Speed of the DC shunt motor by Armature voltage control. Plot the graph.
			3a. Characteristics of D.C. Motors -Torque – Speed, Speed – Load and Torque – Load Characteristics. 3b. Methods of speed control: - shunt field control -Armature or Rheostatic control		

			-Voltage control		
2	1	1,2,4	<p>1. Induction Motors: Working principle of induction motor. Rotating magnetic field produced by polyphase supply.</p> <p>2. Construction of stator, squirrel cage rotor and phase wound rotor. Slip, frequency of rotor current. Problems.</p> <p>3. Starting torques of squirrel cage and slip ring induction motor with expression. Condition for max starting torque. Effect of change in supply voltage on starting torque.</p>	Refer Table1	<p>Follow Safety rules and Safe working practices</p> <p>1a. Identify the parts of the 3-phase squirrel cage induction motor, test it for open circuit, short circuit and ground faults using a test lamp / megger, check the insulation resistance, identify and locate the possible faults. Suggest remedies.</p> <p>1b. Connect forward & reverse a 3-phase squirrel cage induction motor.</p> <p>2a. Identify the parts of 3 phase slip ring induction motor, test it for open circuit, short circuit and ground faults using test lamp/megger, check the insulation resistance, identify and locate the possible faults. Suggest remedies.</p> <p>Ref.7(5)</p> <p>2b. Connect forward & reverse a 3-phase slip ring induction motor.</p>
3	1	1,4	<p>1. Equation for torque under running conditions. -Draw torque - slip curves. -Relationship between full load torque and maximum torque, starting torque and maximum torque</p> <p>2. Explain Equivalent circuit of an induction motor.</p> <p>3. Relationship between rotor power input, rotor copper loss, and Mechanical power developed and slip. -Problems on the above.</p>	Refer Table1	<p>Follow Safety rules and Safe working practices</p> <p>1. Plot the Speed-Torque (Slip Vs Torque) Characteristics of 3-Phase Induction motor by mechanical loading (Brake-drum apparatus). Use Power Quality Analyzer & Motor Analyzer to measure various parameters. Ref.7(6)</p> <p>2. Determine the efficiency of 3-phase squirrel cage induction motor by no load test/ blocked rotor test and brake test. Use Power Quality Analyzer & Motor Analyzer to measure various parameters.</p>
4	1	1,4	<p>1. Starters: Necessity of starters and list the various types of starters. Main criteria for the selection of the starting method.</p>	Refer Table1	<p>1a. Identify the parts of a DOL starter, test its parts, locate faults if any. Suggest remedies.</p>

			<p>2a. Construction, working and troubleshooting of D.O.L. Starter. 2b. Construction, working and troubleshooting of star-delta Starter.</p>		<p>1b. Connect, Start, Run and Reverse the direction of rotation of 3-phase Induction Motor using DOL starter. Ref.7(7)</p> <p>Follow Safety rules and Safe working practices.</p> <p>2a. Identify the parts of a Star-Delta starter, test its parts and locate faults if any. Suggest remedies Trace the start terminals and end terminals of three-phase windings and mark the terminals u1,v1,w1 and u2,v2,w2 Connect, Start, Run and Reverse the direction of rotation of 3-phase Induction Motor using star delta starter. 2b. Maintain, service and troubleshoot the AC motor starter</p>
5	1,3	2,4	<p>1. Speed Control of induction motor: - Change of applied voltage method. - Change of number of poles.</p> <p>2. Speed Control of induction motor: - Change of frequency - Rheostat control method.</p> <p>3. Testing and troubleshooting procedure of three-phase Induction motor. -General preventive maintenance procedure of three-phase Induction motors.</p>	Refer Table1	<p>Follow Safety rules and Safe working practices.</p> <p>1. Speed control of IM using any one method, Use of Power Quality Analyzer & Motor Analyzer to measure various parameters.</p> <p>2a. Testing, troubleshooting and Servicing of three-phase Induction motors. 2b. Perform general preventive maintenance on 3-ph Induction motor. Ref.7(8,9,10,11)</p>
6	1	1,4	<p>1. Synchronous Motors: Working principle, construction, and method of starting of synchronous motor. -Compare the synchronous motor with the induction motor.</p> <p>2.Effect of increased load with constant excitation. - Effect of change in excitation at constant load.</p> <p>3. Effect of excitation on armature current & power factor.</p>	Refer Table1	<p>Follow Safety rules and Safe working practices</p> <p>1. Start, Run and Reverse the direction of rotation of the synchronous motor.</p> <p>2. Plot V and inverted V curves for synchronous motor, Use Power Quality Analyzer & Motor Analyzer.</p>

7	1	1,2,4	1. Effect of excitation on leading, lagging and zero power factor.	Refer Table1	1. Demonstrate troubleshooting of synchronous motors.
			2. Synchronous condenser and its application. Ref.7(19).		2. Case study of Synchronous condenser.
			3. Hunting and phase swinging, losses and methods of starting of synchronous motors.		
8	1,2	1,4	1. IEC/ NEMA motors, Enclosure protection classes available protection classes are IP23, IP44, IP54 -IEC 60034-4-1:2018 standard for synchronous motors.	Refer Table1	1. Demonstrate different protection classes.
			2. Synchronous reluctance motors. Ref.7(22).		2a. Demonstrate Installation of synchronous motor and Induction motor. 2b. Perform general preventive maintenance of sync motors. Ref.7(20,21)
			3. Procedure for Installation and Maintenance of sync motors and Induction motor.		
9	1	1,4	1. Single-phase motors: Working principle, construction and characteristics. Ref.7(28).	Refer Table1	1a. Identify and connect the starting winding, running winding, capacitor centrifugal switch terminals rotation of 1-ph capacitor start Induction Motor. 1b. Start, Run and Reverse the direction of rotation.
			2. Resistance Split phase motor -Capacitor Start Induction motor.		2. Perform general preventive maintenance of 1-ph Induction Motors.
			3. Working Principle & characteristics of Induction Generators and its applications.		
10	1	1,4	1. Special Machines: Servo motor: Working, construction and applications, types, speed-torque characteristics, specifications, control mechanism. Ref.7(29). Working, construction and applications of Stepper motor and Torque motor and spindle motor.	Refer Table1	1.Identify the parts of special machines: Servo motor, universal motor, stepper motor and brushless DC Motor, and test the coils and windings for its working condition.
			2. Working, construction and applications of Universal motor, Reluctance Motor, Permanent Magnet Synchronous Motor (PMSM).		
			3. Working, construction and applications of Two phase Four Pole Permanent magnet motor, Brushless D.C. Motors, specification for EV motors. Ref.7(31)		2. Demonstrate applications of special machines.
11	2,4	2,3	1. Industrial application of motors.	Refer Table1	1. Calculate the total system efficiency by combining the four key components of a motor

			<p>-Select a motor for a given industrial application. Ref.7(12,13,14)</p> <p>2 Motor testing tool for energy efficiency. Ref.7(25,26,27)</p> <p>3. Draw the standard symbols of control components Different types of push button switches- single element and two element ON/OFF switches, mushroom head emergency stop switch, illuminated type, key lock type, selector switches and limit switches.</p>	<p>system: the motor, drive, transmission and load (e.g., pump, fan, compressor, etc.) by using a motor testing tool(software). Ref.7(15,16,17,18)</p> <p>2.Identify different types of push button switches- single element and two element ON/OFF switches, mushroom head emergency stop switch, illuminated type, key lock type, selector switches and limit switches.</p>
12	4	3,4	<p>1. Working principle of Bi-metallic Overload Relay, Time Delay Relays - Electronic timer and electro-mechanical Pneumatic timer and Single-Phase preventer. Ref 7(32)</p> <p>2.Parts of a contactor, number of NOs, NCs, nature of coil supply AC/DC, voltage ratings and current ratings.</p> <p>3.Draw a control circuit for DOL starter and control circuit for forward and reverse operation of a motor with interlocking function using auxiliary contact.</p>	<p>1a. Identify Bi-metallic Over Load Relay, Time Delay Relays - Electronic timer and Electro-mechanical Pneumatic timer and Single-Phase preventer. 1b. Identify the parts of a contactor, number of NOs, NCs, nature of coil supply AC/DC, voltage ratings and current ratings. Note down the technical specifications and terminal identification number</p> <p>2a. Rig up and test the following applications of logic gates using push button switches, contactor and indicators. a) Starting from two different locations (OR Function) b) Stopping from one position (NOT Function) c) Two hand operation (AND Function) d) Stopping from two different locations (NOT+OR or NOR Functions) e) Stopping if both signals are given (NOT+AND or NAND functions) f) Memory function (Signal is maintained or holding). h. XOR and XNOR operation. 2b. Rig up and test Direct On Line Starter. Ref 7(33)</p>
13	4	3,4	<p>1.Draw a control circuit for forward and reverse operation of a motor with interlocking function using combined auxiliary contact and push buttons.</p>	<p>1.Rig up and test the control circuit for forward and reverse operation of a motor with interlocking function using combined auxiliary contact and push buttons.</p>

		2.Draw a control circuit for a semi-automatic star delta starter. 3.Draw a control circuit for a fully automatic star delta starter.		2.Rig up and test the control circuit for a fully automatic star delta starter. Ref 7(34)
Total in hours		39	13	52

*PO= Program Outcome as listed and defined in year 1 curriculum and CO-PO mapping with strength (Low/Medium/High) has to be mapped by the course coordinator. (Above only suggestive).

Table 1: Suggestive Activities for Tutorials: (The List is only shared as an example and not inclusive of all possible activities of the course. Students and Faculty are encouraged to choose activities that are relevant to the topic and on the availability of such resources at their institution).

Sl No	Week	Activity
1	1	Study the construction of a given DC motor and identify material presently used for construction of YOKE, poles and field winding, armature winding and brushes.
2	2	Compare and contrast Induction motor with Transformer.
3	3	Study Low voltage General performance cast iron motors and 1. Explain IEC 60034-30-1:2014 standard 2. List the motors covered in IEC 60034-30-1:2014 standard 3. List the motors excluded from IEC 60034-30-1:2014 standard 4. Explain the four International Efficiency (IE) classes 5. Explain mounting and cooling arrangements 6. Degrees of protection: IP code 7. Explain thermal classes (B, F and H) and insulation class 8. Tabulate and present Minimum 50 Hz efficiency values defined in IEC/EN 60034-30-1:2014 (based on test methods specified in IEC 60034-2-1:2014)
4	4	Study soft starter 1. Explain how soft starter improves performance in Pumps, fans, conveyors and compressors 2. Compare different starting methods (DOL, Star Delta and Soft starters) and explain problems which are prevented using soft starters. 4. Explain the selection process involved in selecting the right soft starters for a given application. 5. Explain the benefits of soft starters. 6. Typical Technical specification of soft starter. 7. Explain Circuit diagram of any soft starter.
5	5	Study V/f method of speed control and 1. Explain V/f method of speed control 2. List Advantages of V/f method
6	6	Compare synchronous motor with Induction motor
7	7 & 8	Study given synchronous motor 1. List applications of synchronous motor 2. Explain fixed speed and variable speed Synchronous motors 3. List applications of fixed speed and variable speed Synchronous motors 4. Explain Methods of cooling

		5. Explain the Excitation method for a given application.
8	9	<p>Study Totally enclosed squirrel cage single-phase low voltage motors, Sizes 56 - 100, 0.065 to 2.2 kW.</p> <ol style="list-style-type: none"> 1. Explain CSR (capacitor start and run), PSC (run capacitor) and PSC-regulation 2. Typical Specification of PSC motor, CSR and PSC -regulation 3. Explain Cooling system, insulation class and mounting arrangements
9	10	<p>Study electric motors used in Electric vehicles.</p> <ol style="list-style-type: none"> 1. List the motors used in Electric vehicles 2. Explain speed -torque characteristics of Each motor. 3. Explain Electrical specifications of each motor 4. List the company's manufacturing Four-wheeler and Two-wheeler EV
10	11	<p>Study the case "World's largest multi-stage water pumping stations project designed to bring much needed water to the Indian state of Telangana."</p> <ol style="list-style-type: none"> 1. List Type and size of motors used in the project 2. Quantity of water lifted daily in TMC 3. Size of pumps used to lift water 4. Total power required for the project <p>https://new.abb.com/drives/media/kaleshwaram-lift-irrigation-system-abb-success-story https://www.youtube.com/watch?v=5wXOSVCHf38</p>
11	12	<p>Study the case "Mahatma Gandhi Kalwakurthy Lift Irrigation Scheme"</p> <ol style="list-style-type: none"> 1. List Type and size of motors used in the project 2. Quantity of water lifted daily in TMC 3. Size of pumps used to lift water 4. Total power required for the project <p>https://new.abb.com/news/detail/4291/abb-pumping-technology-helps-rescue-parched-farms-and-villages-in-india</p>
12	13	Study the latest technological changes in this course and present the impact of these changes on industry.

4. CIE and SEE Assessment Methodologies

Sl. No	Assessment	Test Week	Duration In minutes	Max marks	Conversion
1.	CIE-1 Written Test	5	80	30	Average of three tests 30
2.	CIE-2 Written Test	9	80	30	
3	CIE-3 Written Test	13	80	30	
4.	CIE-4 Skill Test-Practice	6	180	100	Average of two skill test reduced to 20
5	CIE-5 Skill Test-Practice	12	180	100	
6	CIE-6 Portfolio continuous evaluation of Tutorial sessions through Rubrics	1-13		10	10
Total CIE Marks					60
Semester End Examination (Practice)			180	100	40
Total Marks					100

5. Format for CIE written Test

Course Name	Electric Motors	Test	I/II/III	Sem	III/IV
Course Code	20EE41P	Duration	80 Min	Marks	30

Note: Answer any one full question from each section. Each full question carries 10 marks.

Section	Assessment Questions	Cognitive Levels	Course Outcome	Marks
I	1			
	2			
II	3			
	4			
III	5			
	6			

Note for the Course coordinator: Each question may have one, two or three subdivisions. Optional questions in each section carry the same weightage of marks, Cognitive level and course outcomes.

6. Rubrics for Assessment of Activity (Qualitative Assessment)

Sl. No.	Dimension	Beginner	Intermediate	Good	Advanced	Expert	Students Score
		2	4	6	8	10	
1	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	8
2	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	6
3	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	2
4	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	2
Average Marks= (8+6+2+2)/4=4.5							5

Note: Dimension and Descriptor shall be defined by the respective course coordinator as per the activities

7. Reference:

Sl. No.	Description
1	Electrical Technology volume 2 - BL Theraja & A.K.Theraja S.Chand publication.
2	Principles of Electrical Machines by V.K.Mehtha.S.Chand publication.
3	Electrical machines - Theory and Practice by M.N. Bandyopadhyay PHI publication.
4	Electrical Machines by Bhattacharya. Tata McGraw Hill Co. 5. Electrical Machines - J.B.Gupta Kataria & Sons Publications
5	https://search.abb.com/library/Download.aspx?DocumentID=9AKK107991A3212&LanguageCode=en&DocumentPartId=&Action=Launch

6	https://search.abb.com/library/Download.aspx?DocumentID=B5.0205&DocumentPartID=&Action=Launch
7	https://new.abb.com/docs/librariesprovider53/about-downloads/low-voltage-motor-guide.pdf
8	https://assets.new.siemens.com/siemens/assets/api/uuid:8e9204f9-1860-4720-9d6b-2be548d915d0/version:1560800077/troubleshooting-induction-motors.pdf
9	https://www.youtube.com/watch?v=390nOrLHAaw&t=3176s
10	https://www.youtube.com/watch?v=BoFToRcfL0k
11	https://www.youtube.com/watch?v=VCtiehg2pZc
12	https://motors-pumps.gainesvilleindustrial.com/category/all-categories-electric-motor
13	https://www.controleng.com/online-courses/how-to-specify-motors-for-more-efficient-hvac-systems/
14	https://www.controleng.com/articles/how-to-select-a-motor-for-an-industrial-application/#:~:text=There%20are%20many%20aspects%20to,or%20a%20servo%2Fstepper%20motor.&text=Requirements%20for%20controlling%20motor%20speed%20and%20position%20also%20need%20to%20be%20considered.
15	https://www.iea-4e.org/wp-content/uploads/publications/2015/09/1 emsa pb 20150917.pdf
16	https://www.iea-4e.org/emsatools/
17	https://www.iea-4e.org/wp-content/uploads/2020/11/quickguide-mst-tool 1.2.pdf
18	https://www.iea-4e.org/wp-content/uploads/2020/11/webinar-2-motor-systems-tool 20151015.pdf
19	https://search.abb.com/library/Download.aspx?DocumentID=9AKK107991A6324&LanguageCode=en&DocumentPartId=&Action=Launch
20	https://search.abb.com/library/Download.aspx?DocumentID=SM103&LanguageCode=en&DocumentPartId=&Action=Launch
21	https://search.abb.com/library/Download.aspx?DocumentID=3BSM900636&LanguageCode=en&DocumentPartId=&Action=Launch
22	https://library.e.abb.com/public/58b63ea623ddaf9c125786800278df5/56-61%201m103 ENG 72dpi.pdf
23	https://www.youtube.com/watch?v=mgoZSL2u6Jw
24	https://www.se.com/in/en/work/solutions/motor-control-protection/
25	https://www.iea-4e.org/wp-content/uploads/2020/11/MST Example I - anno 2017.pdf

26	https://www.iea-4e.org/wp-content/uploads/2020/11/MST Example II - anno 2017.pdf
27	https://www.iea-4e.org/wp-content/uploads/2020/11/MST Example II - anno 2017 Solution.pdf
28	https://search.abb.com/library/Download.aspx?DocumentID=B5.0205&DocumentPartID=&Action=Launch
29	https://www.motioncontrolonline.org/blog-article.cfm/What-is-a-Brushless-DC-Motor-and-How-Does-It-Work/57
30	https://www.motioncontrolonline.org/blog-article.cfm/What-is-a-Brushless-DC-Motor-and-How-Does-It-Work/57
31	https://circuitdigest.com/article/different-types-of-motors-used-in-electric-vehicles-ev
32	https://www.youtube.com/watch?v=2hsHoMEuS-0
33	https://www.youtube.com/watch?v=AhJRHFfXkdg
34	https://www.youtube.com/watch?v=OtydNtCxYQI

8.1 CIE-4 Skill Test Scheme of Evaluation

SL. No.	Particulars/Dimension	CO	Marks
1	Portfolio evaluation of Practice Sessions (week1-week6)		10
2	List the standard safety norms related to electrical motors.	1	10
3	Building and Demonstration of the working Circuit including; i. Drawing of circuit diagram using right symbols ii. Build the circuit as per the circuit diagram iii. Demonstrate the performance/operation of a motor iv. Document the necessary readings of the expected outcome	10 10 25 05	50
4	Identify the problem and demonstrate the troubleshooting method used to rectify that problem in a motor.	3	20
5	Viva-voce		10
Total Marks			100

8.2 CIE-5 Skill Test Scheme of Evaluation

SL. No.	Particulars/Dimension	CO	Marks
1	Portfolio evaluation of Practice Sessions (week7-week12)		10
2	List the standard safety norms related to electrical motors.	1	10
3	Building and Demonstration of the working Circuit including; i. Drawing of circuit diagram using right symbols ii. Build the circuit as per the circuit diagram iii. Demonstrate the performance/operation of a motor iv. Document the necessary readings of the expected outcome	05 10 15 05	35
4	Explain the criteria for selection, the process of installation and the importance of timely maintenance and consequences for a motor.	2	15
5	Identify the problem and demonstrate the troubleshooting method used to rectify that problem in a motor.	3	20
6	Viva-voce		10

	Total Marks	100
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8.3 SEE Scheme of Evaluation

SL. No.	Particulars/Dimension	CO	Marks
1	Portfolio evaluation of Practice Sessions (week7-week12)		10
2	Building and Demonstration of the working Circuit including; i. Drawing of circuit diagram using right symbols ii. Build the circuit as per the circuit diagram iii. Demonstrate the performance/operation of a motor iv. Document the necessary readings of the expected outcome v. Comply with standard safety norms related to electrical motors	10 10 20 05 05	1 / 4 50
3	Identify the problem in given motor and demonstrate the troubleshooting method used to rectify that problem in a motor.	3	20
4	Viva-voce		20
	Total Marks		100

9. Equipment/software list with Specification for a batch of 20 students

Sl. No.	Particulars	Specification	Quantity
1.	Central distribution board with control gear and power supply panel for all M/C.		One
2.	Static converter Input-3phase, 440V,50Hz. Output -15kW,0-220V Continuously variable.		One set
3.	DC Shunt Motor with mechanical loading (a brake drum) apparatus		One Set
4	3-Phase Squirrel Cage Induction motor with mechanical loading (a break drum) apparatus		Two set
5	Synchronous motor		One set
6	1-phase Capacitor start Induction motor		One set each
7.	F.HP-motors Universal/hysteresis stepper motor, brushless DC motor, stepper motor, spindle motor , Permanent magnet synchronous motor, Reluctance motor		One each
8	1-Phase Variacs	220V,5A	2
9	3-Phase Variacs	440V,15A	3
10	Single-phase IM Various types one in each type		One each
11	Voltmeters	0-300/600 VAC	
12	Ammeters	0-5/10a AC	
13	Power Quality Analyser and Motor analyser		1
14	Motor Testing Tool free software (https://www.iea-4e.org/emsa/our-work/emsa-tools/)		
15	Contactor - 16A, 4POLE, Coil Voltage 220volts/50 hz AC With 2 NO + 2 NC		20
16	Timer (Electronic) 10 NO		10
17	Push button (ON) 2 element type (1 NO + 1 NC)		20
18	Push button (OFF) 2 element type (1 NO + 1 NC)		20
19	Different types of Push button Switches (key type, Illuminated type, Emergency trip mushroom head type		5 Each
20	Limit Switches		20
21	Selector Switches		20
22	Thermal Over load relays (0-16A,415V with 1NO+1NC)		20
23	MCB 16A, 415V, 4pol		10