Program Name : **Electrical Engineering Program Group**

Program Code : **EE/EP/EU**

Semester : **Sixth**

Course Title : **Maintenance of Electrical Equipment**

Course Code : **22625**

1. RATIONALE

The electrical engineering technologist is required to carry out the maintenance of the electrical machines and equipment, which includes installation and testing. S/he is thus expected to use the relevant skill-sets while working in the industry, commercial establishments, and public utility departments such as PWD, irrigation, electricity supply agencies, water supply and sewage board. This course arms the student with the skills to inspect various types of installations and test electrical machines as per prevailing standards. S/he will also be able to carry out different types of maintenances of electrical equipment. S/he will follow the relevant safety practices during such activities.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain different types of electrical equipment following safe practices.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following ***industry oriented*** COs associated with the above mentioned competency:

a) Follow safe practices to prevent accidents while using electrical equipment.
b) Prepare maintenance schedules for electrical equipment.
c) Maintain rotating electrical machines.
d) Maintain single phase and three phase transformers.
e) Maintain insulation systems of electrical equipment.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme													
				Theory							Practical						
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total		
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	
3	-	2	5	3	70	28	30*	00	100	40	25#	10	25	10	50	20	

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

Legends: ***L****-Lecture;* ***T*** *– Tutorial/Teacher Guided Theory Practice;* ***P*** *-Practical;* ***C*** *– Credit,* ***ESE*** *-End Semester Examination;* ***PA*** *- Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs,UOs,ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

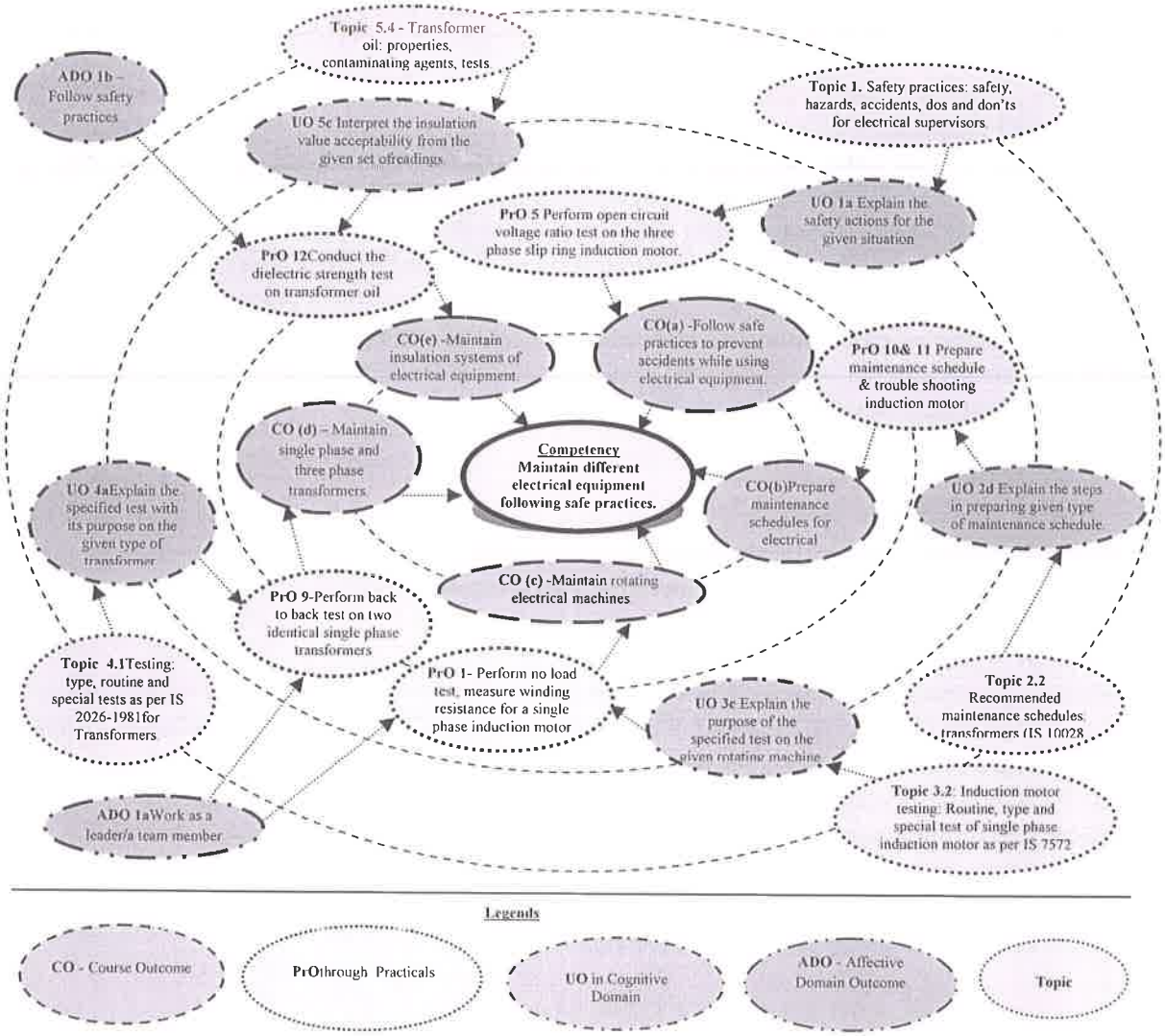

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Perform the no load test, measure winding resistance for a single phase induction motor and determine its performance. (as per relevant IS)	III	02*
2	Perform no load and blocked rotor test on three phase induction motor to determine the equivalent circuit. (as per relevant IS)	III	02*
3	For the motor tested in practical at S. no. 2 plot the circle diagram and judge its performance. (as per relevant IS)	III	02*
4	Perform the brake load test on the three phase Induction motor	III	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	to plot the following operating characteristics, [(1) torque versus speed, (2) current drawn versus output and (3) power factor versus output] (as per relevant IS)		
5	Perform open circuit voltage ratio test on the three phase slip ring induction motor. (as per relevant IS)	III	02*
6	Perform the phasing out and polarity tests on the three phase transformer. (as per relevant IS)	IV	02*
7	Perform the open circuit and short circuit tests on the single phase transformer and determine its performance (regulation and efficiency). (as per relevant IS)	IV	02#
8	Perform the open circuit and short circuit tests on the three phase transformer and determine its performance (regulation and efficiency). (as per relevant IS)	IV	02#
9	Perform back to back test on two identical single phase transformers and determine their efficiencies and regulations.	IV	02*
10	Prepare the maintenance schedule for trouble shooting chart for the single phase induction motor. (as per relevant IS)	II/III	02^
11	Prepare the maintenance schedule for trouble shooting chart for the three phase induction motor. (as per relevant IS)	II/III	02^
12	Prepare maintenance schedule for trouble shooting chart for 3ph Transformers. (as per relevant IS)	II/IV	02*
13	Conduct the dielectric strength test on transformer oil (sample 1). (as per relevant IS)	V	02 &
14	Conduct the dielectric strength test on transformer oil (sample 2). (as per relevant IS)	V	02 &
15	HV test on three phase induction motor (as per relevant IS)	III/V	02%
16	HV test on single phase induction motor. (as per relevant IS)	III/V	02%
	Total		**32**

Legend: #: any one to be performed; &: any one to be performed, %: any one to be performed, ^: any one to be performed,

Note

i. *A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practicals need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. *The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:*

S. No.	Performance Indicators	Weightage in %
1	Preparation of experimental set up	20
2	Setting and operation	20
3	Safety measures	10
4	Observations and Recording	10
5	Interpretation of result and conclusion	20
6	Answer to sample questions	10
7	Submission of report in time	10

S. No.	Performance Indicators	Weightage in %
	Total	100

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a) Follow safety practices.
b) Practice good housekeeping.
c) Practice energy conservation.
d) Work as a leader/a team member.
e) Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organisation Level' in 2nd year
- 'Characterisation Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by administrators.

S. No.	Equipment Name with Broad Specifications	PrO.No.
1	230 V, 50 Hz, single phase capacitor start cage type induction motor (suitable available HP)	1
2	3-phase 5 HP, 400 V, 50 Hz, 1500 RPM squirrel cage induction motor with brake load arrangement as required.	2, 3, 4
3	400V/230V, 50 Hz, 3-phase transformer with all phase winding terminals brought out for connections (suitable output in range of 2 kVA to 4 kVA)	8
4	3-phase 400V, 50 Hz, 1500 RPM slip ring induction motor about 5 HP.	5
5	At least two identical 230 V/115 V or 400 V/ 230 V 50 Hz, 1 or 2 kVA single phase transformers.	6, 7, 9
6	Dielectric oil testing kit (with input at 230 V)	12, 13
7	HV test kits for motors up-to 400 V.	14, 15, 16
8	AC Ammeter range (0-2.5-5-10A), Portable analog MI type as per relevant BIS standard	1, 2, 4, 5, 7, 8, 9
9	AC Voltmeter Range (0-75/150/300V, 0 - 300V /600 V), Portable analog MI type as per relevant BIS standard.	1, 2, 4, 5, 7, 8, 9
10	Tachometers 0-5000 RPM minimum	1, 2, 4
11	Single phase auto transformer 0-270 V, 15 A, input single phase, 230 V.	1, 6, 7, 9
12	Three phase auto transformer 0-450 V, 15 A, input 3 phase, 400 V.	2, 4, 5, 8
13	A. C Watt meters: 0-300/600 V, 5/10 A or 10/20 A as needed.	1,2,4,7, 8, 9
14	LPF Wattmeter, 0-300/600 V, 1A to 2A.	1, 2, 7, 8, 9

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (in cognitive domain)	Topics and Sub-topics
Unit – I Safety and prevention of accidents	1a. Explain the safety actions for the given situation. 1b. Explain the hazards involved for the given situation and action. 1c. Explain the responsibilities of the supervisor in the given hazardous or accident situation. 1d. Explain the level of accountability of the supervisor in the given hazardous or accident situation 1e. Explain the monitoring actions to be taken by the supervisor while working in the given hazardous or accident situation 1f. State the principal characteristics and related precautions for safety of equipment earthed by the specified class.	1.1 Safety practices: safety, hazards, accidents, dos and don'ts for electrical supervisors. 1.2 Electric shock: factors influencing severity of shock, rescuing persons, procedures for artificial respiration. 1.3 Precautions against electric fires, use of fire extinguishers, actions in case of such fires, types and operation of fire extinguishers. 1.4 Earthing of electrical equipment {refer IS code IS 3043-1987):Objectives, classification of electrical equipment with regard to protection against electric shock: class 0 to III.
Unit – II Maintenance schedules	2a. Explain the need for maintenance for the given type of electrical equipment. 2b. Explain the relevant type of maintenances required for the given type of electrical equipment. 2c. Explain the advantages of the given type of maintenance. 2d. Explain the steps in preparing given type of maintenance schedule.	2.1 Maintenance: routine, breakdown, preventive and predictive maintenance, factors affecting preventive maintenance schedules. 2.2 Recommended maintenance schedules: transformers (IS 10028, part III – 1981);single phase and three phase induction motors (IS 900 – 1992); three phase alternators and synchronous motors.
Unit- III Testing and Maintenance of rotating machines	3a. Explain the objectives of testing the given type of electrical machine. 3b. Explain the need for the given type of test/s on the specified machine. 3c. Explain the purpose of the specified test on the given type of rotating machine. 3d. Explain the steps in preparing trouble shooting chart for the given type of rotating machine. 3e. Explain the steps in preparing foundation for the given type of rotating machine. 3f. Explain with sketch the foundation for the given type of rotating machine.	3.1 Testing: Need and standards, tolerance, types: routine, type, special and supplementary tests, Methods of testing: direct, indirect and regenerative with advantages and applications. 3.2 Induction motor testing: Routine, type and special test of single phase induction motor as per IS 7572 – 1974 (re-affirmed in 2002) and three phase induction motor as per IS4029 -2010. 3.3 Alternator and synchronous motor testing: Routine, type and special test of three phase alternator and synchronous motor as per IS 7132 1973 (reaffirmed in 2002).

	3g. Suggest the tools for the given operation under maintenance of the rotating machine.	3.4 Trouble shooting chart for single phase and three induction motor (IS 900 – 1992). 3.5 Foundations: Requirements and factors affecting rotating machine foundation. 3.6 Tools/instruments: Bearing puller, filler gauge, dial indicator, spirit level, megger, earth tester, growler, test lamps, multimeter, spanner sets, and screwdrivers.
Unit– IV Testing and trouble shooting of Transformers	4a. Explain the specified test with its purpose on the given type of transformer. 4b. Explain the causes of failure of the specified type of transformer from the given symptoms. 4c. Explain the steps in preparing trouble shooting chart for the given type of transformer. 4d. Explain the remedies for the specified fault in the given transformer. 4e. Suggest the foundation with sketch for the given type of transformer.	4.1 Testing: type, routine and special tests as per IS 2026-1981 for Distribution and Power transformers. 4.2 Causes of failure: internal and external, types of faults: mechanical. electrical and magnetic 4.3 Trouble-shooting and remedies: trouble shooting charts for single phase and three phase transformers, 4.4 Foundations: requirements for static machine foundations, factors governing them.
Unit– V Maintenance of Electrical Machine Insulation	5a. Suggest the insulation material for the given application. 5b. Explain with sketch the procedure to measure the insulation resistance of the given type of machine. 5c. Interpret the insulation value acceptability from the given set of readings. 5d. Explain the reasons for weakening of given type of insulation. 5e. Explain with sketch the procedure to strengthen the given insulation. 5f. Describe the procedure to maintain the insulation of the specified electrical machine in healthy condition. 5g. Prepare the sample history for the specified electrical machine.	5.1 Classification of insulating materials as per IS 8504- 1994, 5.2 Factors affecting life of insulating materials. 5.3 Measurement of insulation resistance and interpretation of condition of insulation. 5.4 Transformer oil: properties, contaminating agents, tests. 5.5 Strengthening insulations: weakening agents, cleaning, drying, re-varnishing, baking, impregnation, filtration. 5.6 Measures to be taken to maintain the insulation resistance of electrical machines to healthy levels. 5.7 History sheets of transformers and induction motors: [Part A: machine specifications with component specifications (installation information, bearings, oil type, core weight etc. as applicable). Part B: date wise: observations of parameters such as voltage,

		current, temperature etc., symptoms, works carried out under maintenance)

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Safety and prevention of accidents	06	02	04	04	10
II	Maintenance schedules	10	02	02	06	10
III	Testing and maintenance of rotating machines	12	04	06	10	20
IV	Testing and trouble shooting of Transformers	12	04	06	10	20
V	Maintenance of electrical machine insulation.	08	02	02	06	10
Total		**48**	**14**	**20**	**36**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare report for step by step procedure to be followed for artificial respiration to be given to shock affected person.
b) Carry out preventive maintenance on any one machine in lab and prepare report on it.
c) Prepare power point presentation on testing of Induction motor as per IS.
d) Prepare power point presentation related to foundation of transformers.
e) Collect sample of various class of insulating materials and prepare a chart of it.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).

d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Use Flash/Animations to explain various theorems in circuit analysis
f) Guide student(s) in undertaking micro-projects.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

Suggestive lists of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a) Collect information on safety signs used for electrically hazardous areas.
b) Prepare a case study report on faulty electrical machine in institute campus through inspection, conduction of tests, troubleshoot and remedial actions needed.
c) Visit electrical machine manufacturing unit and collect data of various tests conducted on it.
d) Prepare a report on diagnosis of transformer oil sample by conducting various tests on it.
e) Collect information of specifications, uses, cost of various tools and equipment needed for maintenance of different electrical machines.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Electrical Machines	Bhattacharya,S. K.	McGraw Hill Education. New Delhi, ISBN : 9789332902855
2	Electrical Technology Vol-II (AC and DC machines)	Theraja, B.L.	S.Chand and Co.Ltd., New Delhi ISBN : 9788121924375
3	Electrical Machines Theory and Practice	Bandyopadhyay, M. N.	PHI Learning Pvt. Ltd., New Delhi, ISBN :9788120329973 Vi
4	IS codes for transformers	IS 2026 (part 1-2011, part 2-2010), IS 10028 (part III) -1981.	
5	IS codes for induction motors	IS 325-1996, IS 4029-2010, IS 900-1992.	
6	Guide for testing of single phase and universal motors	IS 7572 – 1974 (reaffirmed 2002)	

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a) https://www.youtube.com/watch?v=w4jHpHoYZhk
b) https://www.youtube.com/results?search_query=artificial+respiration+methods
c) https://www.youtube.com/results?search_query=dielectric+tests+of+transformer
d) https://www.youtube.com/results?search_query=maintenance+charts+for+transformer
e) https://www.youtube.com/watch?v=ntOc4h792UE
f) https://www.youtube.com/watch?v=uMxK6djp_rI
g) https://www.youtube.com/results?search_query=transformer+oil+filtration+procedure
h) www.nptel.ac.in
i) www.wikipedia.com
j) www.electricaltechnology.org
k) www.howstuffworks.com
l) www.electrical4u.com