Program Name : **Electrical Engineering Program Group**

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

Semester : **Fourth**

Course Title : **Electric Motors and Transformers**

Course Code : **22418**

1. RATIONALE

The electrical engineering applications in industries use small and large electric motors in some crucial application systems. This course will empower the students with the necessary skills to handle/maintain the motors in general. Further the electrical power systems of all sorts and at all levels are incomplete without the use of the relevant transformers employed to change the voltage/current levels according to the applications. This course will also make the students familiar with the working and applications of single phase and three phase transformers including those for special applications.

2. COMPETENCY

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

- **Use electric motors and transformers.**

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. Use different electric motors.
b. Use DC machines.
c. Use single phase transformer for different applications.
d. Use three phase transformers for different applications.
e. Use relevant special purpose transformers for different applications.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory							Practical				
				Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
L	T	P			Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	2	2	8	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.

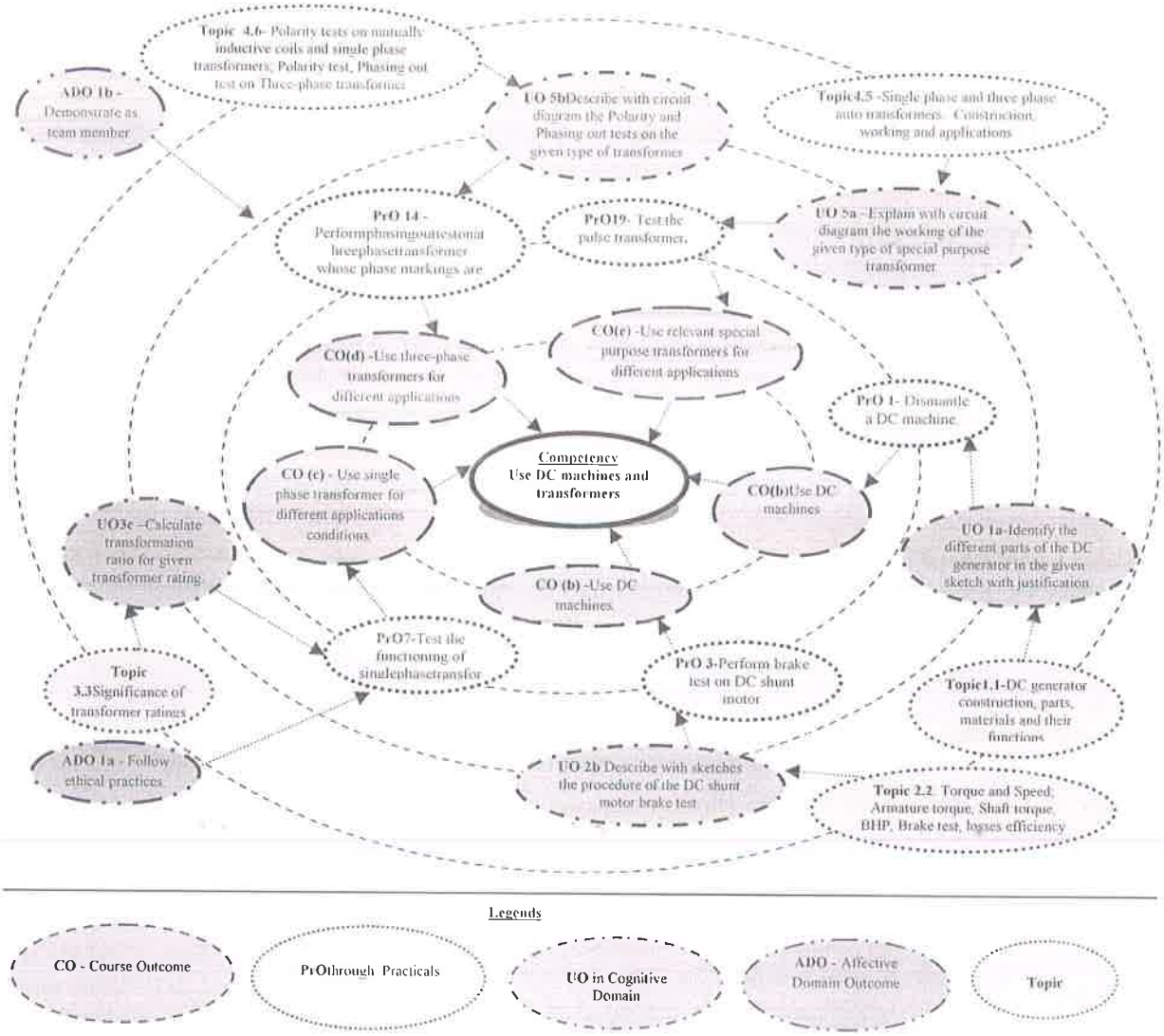

Figure 1 - Course Map

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	Dismantle a DC machine.	II	02*
2	Reverse the direction of rotation of the DC shunt motor.	II	02
3	Perform brake test on DC shunt motor.	II	02*
4	Control the speed of DC shunt motor by different methods.	II	02
5	Control the speed of DC series motor by different methods.	II	02
6	Perform the brake test on DC series motor.	II	02
7	Check the functioning of single phase transformer.	III	02
8	Determine regulation and efficiency of single phase transformer by direct loading.	III	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
9	Perform open circuit and short circuit test on single phase transformer to determine equivalent circuit constants.	III	02
10	Perform open circuit and short circuit test on single phase transformer to determine voltage regulation and efficiency.	III	02
11	Perform parallel operation of two single phase transformers to determine the load current sharing.	III	02
12	Perform parallel operation of two single phase transformers and determine the apparent and real power load sharing.	III	02*
13	Perform polarity test on a single phase transformer whose polarity markings are masked.	IV	02
14	Perform phasing out test on a three phase transformer whose phase markings are masked.	IV	02*
15	Connect the auto-transformer in step-up and step-down modes noting the input/output readings.	V	02*
16	Check the functioning of the CT.	V	02
17	Check the functioning of the PT.	V	02
18	Check the functioning of the isolation transformer.	V	02*
19	Test the pulse transformer.	V	02*
	Total		**38**

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 practical 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
	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. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
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
- 'Organizing Level' in 2nd year
- 'Characterizing 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	DC series and shunt machines at least one each (up to 230 V, 5 hp).	1 to 5
2	DC Ammeter range (0-5-10A), Portable analog PMMC type as per relevantBIS standard.	2, 3, 4, 5.
3	DC Voltmeter Range (0-150/300V), Portable analog PMMC type as per relevant BIS standard.	2, 3, 4, 5.
4	AC Ammeter range (0-2.5-5-10A), Portable analog MI type as per relevant BIS standard	6 to 12
5	AC Voltmeter Range (0-75/150/300V), Portable analog MI type as per relevant BIS standard.	6 to 12
6	Lamp load of 10-20 A	7, 9, 12.
7	Rheostat (0-500 Ohm, 1.2A), Nichrome wire wound rheostat on epoxy resin or class F insulating tube with two fixed and one sliding contact.	2, 3, 4, 5.
8	Rheostat (0-100 Ohm, 5A), Nichrome wire wound rheostat on epoxy resin or class F insulating tube with two fixed and one sliding contact.	2, 3, 4, 5.
9	Rheostat (0-50 Ohm, 10A), Nichrome wire wound rheostat on epoxy resin or class F insulating tube with two fixed and one sliding contact.	1, 2, 3, 4, 5.
10	Rheostat (0-350 Ohm,1.5A), Nichrome wire wound rheostat on epoxy resin or class F insulating tube with two fixed and one sliding contact.	1, 2, 3, 4, 5.
11	D. C. Supply, 230 V,25 A.	1, 2, 3, 4, 5.
12	Single phase transformer of suitable size (500 VA to 1 kVA).	7 to 13.
13	Three phase transformer of suitable size (1kVA to 3 kVA).	14
14	Single phase auto transformer 0-270 V, 15 A.	15
15	CT of suitable ratio.	16
16	PT of suitable ratio	17
17	Isolation transformer of suitable ratio	18
18	Pulse transformer of suitable ratio	19
19	Wattmeter 0-300/600 V, 5/10 A, for use in AC circuits.	7, 8, 9.
20	LPF Wattmeter, 0-300/600 V, 1A to 2A, for use in AC circuits.	8

8. UNDERPINNING THEORY COMPONENTS

The following topicsare to betaught 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 Introducti on to electric motors	1a. Explain the principle of working of given electric motor. 1b. Identify the different parts and their respective materials of the given motor with justification. 1c. Explain with sketches the functions of the given parts of the specified type of motor.	1.1 Electric motors: principles of operation of different motors. 1.2 Construction and representation: parts with their materials. Schematic diagrams. 1.3 Functions of parts of motors: Functions of the various parts of different electric motors.
Unit – II D.C. Machines	2a. Explain with sketches the working principle of the specified type of DC machine. 2b. Describe with sketches the procedure of the DC shunt motor brake test. 2c. Recommend relevant DC motor for given application with justification. 2d. Calculate the torque, speed, output power and efficiency of the given DC motor. 2e. Describe with sketch the working of the starter for the given type of DC motor. 2f. Explain with diagram using the given method(s) to control the speed of specified DC motor. 2g. Explain with diagram the working of the brushless DC motor.	2.1 DC machine: Types of DC machines. Fleming's right hand rule, Fleming's left hand rule, Principle of operation of dc generator and motor, Back e.m.f. and its significance , Voltage equation of DC motor 2.2 Torque and Speed; Armature torque, Shaft torque, BHP, Brake test, losses, efficiency 2.3 DC motor starters: Necessity, two point and three point starters. 2.4 Speed control of DC shunt and series motor: Flux and Armature control. 2.5 Brushless DC Motor: Construction and working.
Unit- III Single Phase Transform ers.	3a. Differentiate the salient features between the given types of transformers. 3b. Describe the functions of the given parts of a transformer. 3c. Calculate transformation ratio for given transformer rating. 3d. Explain with a phasor diagram for no load/on load for the given type of transformer. 3e. Calculate regulation and efficiency by OC/ SC tests and	3.1 Types of transformers: Shell type and core type; Construction: Parts and functions, materials used for different parts 3.2 Transformer: Principle of operation, EMF equation of transformer: Derivation, Voltage transformation ratio, 3.3 Significance of transformer ratings 3.4 Transformer No-load and on-load phasor diagram, Leakage reactance. 3.5 Equivalent circuit of transformer.

	direct loading for the given type of transformer.	Equivalent resistance and reactance. 3.6 Voltage regulation and Efficiency: Direct loading. OC/SC method. All day efficiency.
Unit– IV Three Phase Transformers	4a. Identify the different parts of the given type transformer. 4b. Describe with diagrams various connections of the given three phase transformer. 4c. Compare distribution transformer and power transformer on the given criteria. 4d. Calculate the given load sharing between two given transformers operating in parallel. 4e. Describe the criteria with justification for selection of the transformer for the given application. 4f. Describe with circuit diagram the Polarity and Phasing out tests on the given type of transformer. 4g. Explain the effects of harmonics on the operation of transformers.	4.1 Bank of three single phase transformers. Single unit of three phase transformer. 4.2 Distribution and Power transformers. 4.3 Construction. cooling, Three phase transformers connections as per IS:2026 (part IV)-1977. Three phase to two phase conversion (Scott Connection), 4.4 Selection of transformer as per IS: 10028 (Part I)-1985, Criteria for selection of distribution transformer, and power transformer, Amorphous Core type Distribution Transformer, Specifications of three-phase distribution transformers as per IS:1180 (part I)-1989 4.5 Need of parallel operation of three phase transformer, Conditions for parallel operation. 4.6 Polarity tests on mutually inductive coils and single phase transformers; Polarity test, Phasing out test on Three-phase transformer. 4.7 Harmonics and their effects on transformers.
Unit– V Special purpose Transformers	5a. Explain with circuit diagram the working of the given type of special purpose transformer. 5b. Calculate ratio for the specified instrument transformer of the given rating. 5c. Explain with justification the use of isolation transformer for the given application. 5d. Differentiate between the given two types of special purpose transformers. 5e. Explain the importance of 'K' factor of transformers.	5.1 Single phase and three phase auto transformers: Construction, working and applications. 5.2 Instrument Transformers: Construction, working and applications of Current transformer and Potential transformer. 5.3 Isolation transformer: Constructional Features and applications. 5.4 Single phase welding transformer: constructional features and applications. 5.5 Pulse transformer: constructional features and applications. 5.6 'K' factor of transformers: overheating due to non-linear loads and harmonics.

***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	Introduction to Electric Motors	08	02	02	02	06
II	DC Machines	12	04	04	06	14
III	Single Phase Transformers	20	04	06	11	21
IV	Three Phase Transformers	16	04	06	09	19
V	Special Purpose Transformers	08	02	02	06	10
Total		**64**	**16**	**20**	**34**	**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 a report on market survey of different electric motors
b. Prepare report on market survey of various three phase transformers(specification, manufacturer, application, cost)
c. Prepare model of single phase transformer.
d. Prepare power point presentation related to D.C. Machines.
e. Prepare power point presentation related to transformers.
f. Prepare a chart of industrial application of D.C. Machines.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment ofthe 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.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. **Types of D.C. Machines**: Prepare chart showing different material used for various parts of d.c. machines.
b. **D.C. Machines**: Collect specification from different manufacturers and prepare report.
c. **Single phase transformers:** Prepare a simple model of single phase transformer.
d. **Three phase transformers:** Collect photographs with details of various power/ distribution transformer and identify different parts (specification, application, cost, features, manufacturer)
e. **Special transformers:** Prepare report on different special transformer.(specification, application, cost, features, manufacturer)

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Basic Electrical Engineering	Mittle, V.N. and Mittle, Arvind	McGraw Hill Education. New Delhi ISBN :9780070593572
2	Electrical Machines	Kothari, D. P. and Nagrath, I. J.	McGraw Hill Education. New Delhi ISBN :9780070699670
3	Electrical Machines	Bhattacharya,S. K.	McGraw Hill Education. New Delhi ISBN : 9789332902855
4	Principles of Electrical Machines	Mehta, V. K. and Mehta, Rohit	S.Chand and Co.Ltd., New DelhiISBN : 9788121930888
5	Electrical Technology Vol-II (AC and DC machines)	Theraja, B.L.	S.Chand and Co.Ltd., New Delhi ISBN : 9788121924375
6	Electrical Machines Theory and Practice	Bandyopadhyay, M. N.	PHI Learning Pvt. Ltd., New Delhi ISBN :9788120329973 Vi
7	DC Machines and Transformers	Murugesh Kumar, K.	ISBN : 9788125916055

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a. https://www.youtube.com/watch?v=fWyzPdyCAzU
b. https://www.youtube.com/watch?v=IC-PWxtcirI
c. https://www.youtube.com/watch?v=H2hYUu8lPY0
d. https://www.youtube.com/watch?v=mKbyFpoNZ_w
e. https://www.youtube.com/watch?v=b2MXK9oi_Gs

f. https://www.youtube.com/watch?v=SIIi_20pAWiE
g. www.nptel.ac.in
h. www.wikipedia.com
i. www.electricaltechnology.org
j. www.howstuffworks.com
k. www.electrical4u.com