Program Name : **Electrical Engineering Program Group**

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

Semester : **Fifth**

Course Title : **Industrial AC Machines**

Course Code : **22523**

1. RATIONALE

Induction motors are widely used in various industries as drive motors for variety of machines. Due to its rugged construction, smoother and efficient operation, it has replaced dc motors in variety of applications. By reason of the important role played by synchronous machines (alternators and motors) in the electrical generation systems, the electrical technologistsalso need to be well versed in the construction and working of these machines. Further fractional horse power (FHP) machines are used in many control circuits of automation systems. Since technologists are expected to maintain industrial systems involving these machines it is highly essential to provide them necessary knowledge about construction and operation of these machines. This course therefore, aims to equip the students with the fundamental requirements of using these machines in different 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 relevant Induction, Synchronous and FHP Machines for different electrical engineering applications.**

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 the relevant three phase induction motor (IM) for different applications.
b) Use the relevant single phase induction motors in different applications.
c) Use the relevant three phase alternator for different load conditions.
d) Use suitable synchronous motors in different applications.
e) Use suitable Fractional HP motors for different applications.

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
4	-	2	6	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.

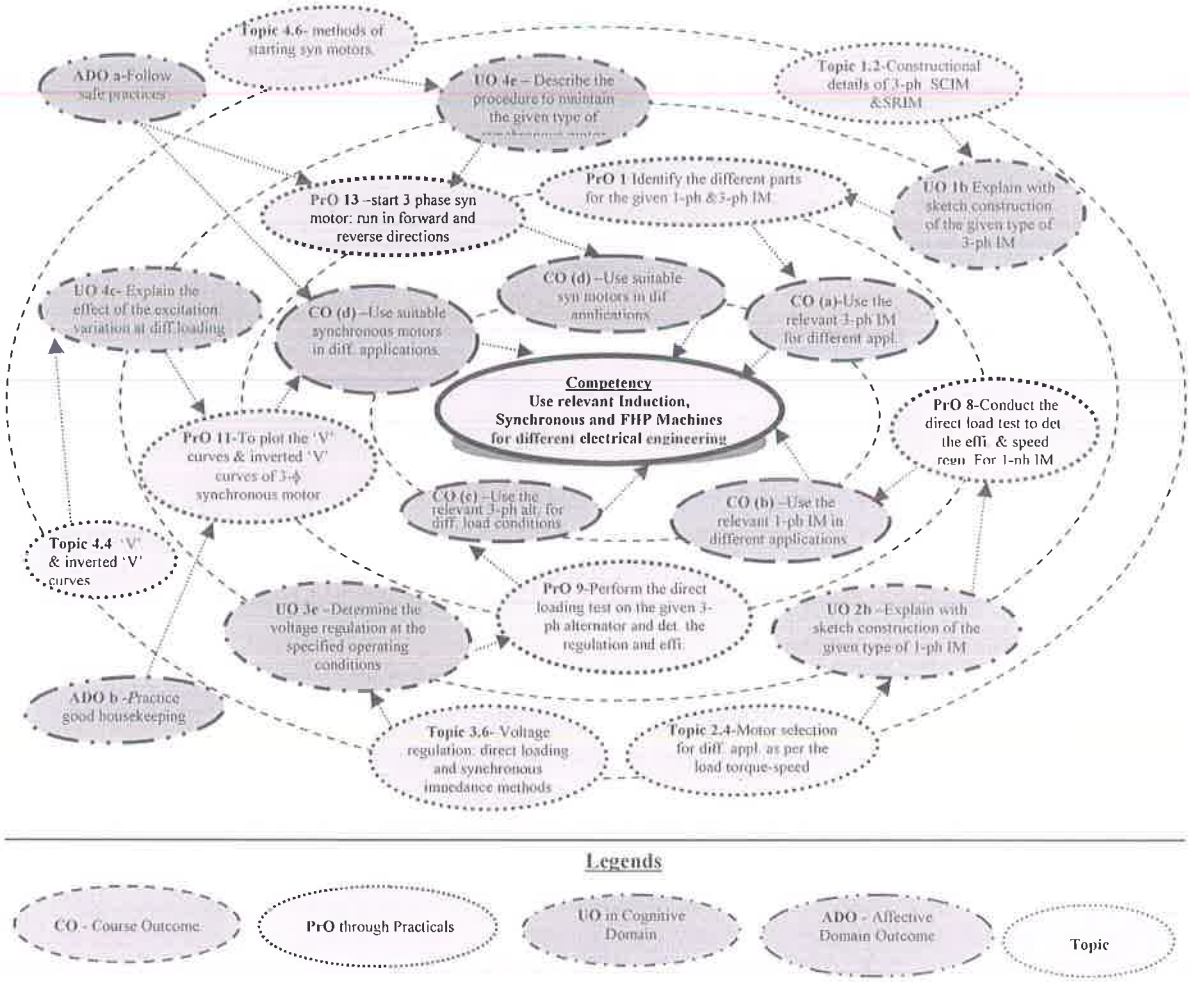

Figure 1 - Course Map

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	Identify the different parts (along with function and materials) for the given single phase and three phase induction motor.	I/II	02*
2	Connect and run the three phase squirrel cage induction motors (in both directions) using the DOL, star-delta, auto-transformer starters (any two)	I	02*
3	Perform the direct load test on the three phase squirrel cage induction motor and plot the i) efficiency versus output, ii) power factor versus output, iii) power factor versus motor current and iv) torque – slip/speed characteristics.	I	02*
4	Conduct the No-load and Blocked-rotor tests on given 3-ϕ squirrel	I	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	cage induction motor and determine the equivalent circuit parameters.		
5	Conduct the No-load and Blocked-rotor tests on given 3-ϕ squirrel cage induction motor and plot the Circle diagram.	I	02*
6	Control the speed of the given three phase squirrel cage/slip ring induction motor using the applicable methods: i) auto-transformer, ii) VF.	I	02*
7	Control the speed of the given three phase slip ring induction motor using rotor resistance starter.	I	02*
8	Control the speed of the given three phase induction motor using pole changing methods	I	02#
9	Identify different windings & components of single phase capacitor start Induction Run motor & Connect to start & reverse the direction of rotation	II	02#
10	Conduct the direct load test to determine the efficiency and speed regulation for different loads on the given single phase induction motor; plot the efficiency and speed regulation curves with respect to the output power.	II	02*
11	Perform the direct loading test on the given three phase alternator and determine the regulation.	III	02*
12	Determine the regulation of the given three phase alternator from OC and SC tests (Synchronous impedance method)	III	02*
13	Start 3 phase synchronous motor & run synchronous motor in forward & reverse direction	IV	02*
14	Conduct the test on load or no load to plot the 'V' curves and inverted 'V' curves (at no-load) of 3-ϕ synchronous motor.	IV	02*
	Total		**28**

Minimum 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 10 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 %
a.	Preparation of experimental set up	20
b.	Setting and operation	20
c.	Safety measures	10
d.	Observations and Recording	10
e.	Interpretation of result and Conclusion	20
f.	Answer to sample questions	10
g.	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. Practice energy conservation.
d. Demonstrate working 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
- 'Organizing Level' in 2nd year
- 'Characterizing Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTSREQUIRED

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

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Induction motors 3 hp/ 5hp, 415 V, 50 Hz, 1440 RPM squirrel cage type	1 to 6, 8
2	Induction motors 3 hp/ 5hp, 415 V, 50 Hz, 1440 RPM slip ring type.	1, 6, 7
3	Ammeters MI Type: AC/DC 0-5-10Amp	1 to 12, 14
4	Voltmeter MI Type: AC/DC, 0-150/300V, 0-250/500V	1 to 12, 14
5	Wattmeter: Three phase double element 5/10Amp, 250/500V or sr no 6	1 to 12, 14
6	Wattmeter: Single phase, single element 2.5/5Amp, 200/400V,	1 to 12, 14
7	Low power factor wattmeter : Single phase, 2.5/5Amp, 250/500V	4, 5
8	Auto transformer: 3-phase, 5kVA, 0 to 500V.	2, 4, 5, 6.
9	Load bank: Resistive, 3-phase, 5kW, 415V	11
10	Load bank: inductive, 3-phase, 2 to 5kVAR, 415V	11
11	Load bank: capacitive, 3-phase, 2 to 5kVAR, 415V	11
12	Star- delta, auto transformers starters	2 to 6.
13	Clip on meter (amp, volts) digital/analog	All
14	Digital multimeter4 ½ digit with standard make for measurements	All
15	Tachometers: contact and non-contact types: 100 to 10000 RPM	all
16	Brake load or other suitable means to load motors with suitable measurement facilities of powers (mechanical).	3, 8
17	3 phase alternator: 5kVA, 415 V, 50 Hz, 4 pole, 1500 RPM.	9, 10
18	3 phase synchronous motor: 3hp, 415 V, 50 Hz, 1500 RPM.	11

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 (UOs) (in cognitive domain)	Topics and Sub-topics
Unit- I Three Phase Induction Motor	1a. Explain with sketch working of the given three phase induction motor. 1b. Explain with sketch construction of the given type of three phase induction motor. 1c. Derive the expressions for rotor induced emf and torque of three phase induction motor for different operating conditions. 1d. Explain with sketch the operation of the motor in the specified quadrant. 1e. Determine the specified performance parameters of the motor. 1f. Explain with sketch the operation of the relevant starter for the given motor. 1g. Explain the specified method of speed control. 1h. Suggest the relevant IM for the specified different given applications.	1.1 Working principle: production of rotating magnetic field, Synchronous speed, rotor speed and slip. 1.2 Constructional details of 3 phase induction motors: Squirrel cage induction motor and Slip ring induction motor. 1.3 Rotor quantities: frequency, induced emf, power factor at starting and running condition. 1.4 Characteristics of torque versus slip (speed), Torques: starting, full load and maximum with relations among them. 1.5 Induction motor as a generalized transformer with phasor diagram. 1.6 Four quadrant operation, Power flow diagram 1.7 Starters: need and types; stator resistance, auto transformer, star delta, rotor resistance and soft starters. 1.8 Speed control methods: stator voltage, pole changing, rotor resistance and VVVF. 1.9 Motor selection for different applications as per the load torque-speed requirements. 1.10 Maintenance of three phase induction motors
Unit– II Single phase induction motors	2a. Explain with sketch working of the given single phase induction motor. 2b. Explain with sketch construction of the given type of single phase induction motor. 2c. Suggest the relevant single phase motor for the specified different applications. 2d. Describe the procedure to maintain given type of single phase induction motor.	2.1 Double field revolving theory, principle of making these motors self start. 2.2 Construction and working: Resistance start induction run, capacitor start induction run, capacitor start capacitor run, shaded pole, repulsion type, series motor, universal motor, hysteresis motor. 2.3 Torque-speed characteristics for all of the above motors. 2.4 Motor selection for different applications as per the load torque-speed requirements. 2.5 Maintenance of single phase induction motors
Unit-III Three phase alternators	3a. Explain with sketch working of the given type of alternator 3b. Explain with sketch construction of the given type	3.1. Principle of working, moving and stationary armatures. 3.2. Constructional details: parts and their functions, rotor constructions.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	of alternator. 3c. Compare the rotor constructions of the given types of alternators. 3d. Determine the voltage regulation at the specified operating conditions. 3e. Describe the procedure to maintain the given type f three phase alternators.	Windings: Single and Double layer. 3.3. E.M.F. equation of Alternator with numerical by considering short pitch factor and distribution factor. 3.4. Alternator loading: Factors affecting the terminal voltage of alternator; Armature resistance and leakage reactance drops. 3.5. Armature reaction at various power factors and synchronous impedance. 3.6. Voltage regulation: direct loading and synchronous impedance methods. 3.7. Maintenance of alternators
Unit –IV Synchronous motors	4a. Explain with sketch working of the given type of synchronous motor. 4b. Explain with sketch construction of the given type synchronous motor. 4c. Explain the effect of the excitation variation for the given loading conditions.. 4d. Suggest suitable synchronous motors for given applications. 4e. Describe the procedure to maintain the given type of synchronous motor	4.1 Principle of working /operation, significance of load angle. 4.2 Torques: starting torque, running torque, pull in torque, pull out torque. 4.3 Synchronous motor on load with constant excitation (numerical), effect of excitation at constant load (numerical). 4.4 V-Curves and Inverted V-Curves. 4.5 Hunting and Phase swinging. 4.6 Methods of Starting of Synchronous Motor. 4.7 Losses in synchronous motors and efficiency (no numericals). 4.8 Applications areas.
Unit-V Fractional horse power motors (FHP)	5a. Explain the working principle of the given FHP motor. 5b. Explain construction of the given type of FHP. 5c. Suggest relevant FHP motor for the specified application. 5d. Describe the procedure to maintain the given type of FHP motor	5.1.Construction and working: Synchronous Reluctance Motor, Switched Reluctance Motor, BLDC , Permanent Magnet Synchronous Motors, stepper motors, AC and DC servomotors. 5.2.Torque speed characteristics of above motors. 5.3. Applications of above motors.

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 FORQUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Three phase induction motors	18	02	08	10	20
II	Single phase induction motors	12	04	04	06	14

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
III	Three phase alternators	14	02	06	08	16
IV	Synchronous motors	12	02	04	06	12
V	Fractional horse power motors (FHP)	08	02	02	04	08
Total		**64**	**12**	**24**	**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 any two of the 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) Collect information/product brochures on three phase induction motors.
b) Collect information/product brochures on single phase induction motors.
c) Collect information/product brochures on stepper motors.
d) Collect information/product brochures on AC servomotors.
e) Collect information/product brochures on DC servomotors.
f) Collect information/product brochures on synchronous motors.
g) Collect information/product brochures on different types of alternators.
h) Collect information/product brochures on AC servomotors.
i) Collect information in brochures or other means for setting up VVVF drives.
j) Determine the full load torque form the name plate specifications of induction motors in the laboratory or other places.

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) Guide student(s) in undertaking micro-projects.
f) Flash/Animations to explain working of Electric Locomotive and Elevatos.
g) Pre-guided visits to, railway stations and Elevator manufacturing componay toobserve operation.

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 is 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 she/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 is given here. Similar micro-projects could be added by the concerned faculty:

a. **Induction motors:** Prepare report on market survey of various single and three phase induction motors(specification, manufacturer, cost, area of use)
b. **Synchronous motors:** Prepare report market survey of various synchronous motors(specification, manufacturer, cost, area of use)
c. **Alternators:** Prepare report market survey of various synchronous generators (specification, manufacturer, cost, area of use)
d. **FHP motors:** Prepare report on market survey of various special purpose FHP motors(specification, manufacturer, cost, area of use)

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	A text book of Electrical technology Vol II	Theraja B. L. Theraja A. K.	S. Chand and Co. New Delhi ISBN 10: 8121924375
2	Electrical Machines	Bhattacharya S. K.	Tata McGraw Hill, New Delhi ISBN 9780075415396
3	Electrical Machines	Kothari D. P. and Nagrath I. J.	McGraw Hill, New Delhi ISBN13: 978-9352606405
4	Basic Electrical Engineering	Mittle V. N.	McGraw Hill, New Delhi, 2014 ISBN 9780074516324
5	Special Purpose Electrical Machines	Sen S. K.	Khanna Publishers, New Delhi, ISBN- 9788174091529
6	Special Electrical Machines	Janardanan E. G	Prentice Hall India, New Delhi ISBN: 9788120348806
7	Electrical Technology	Hughes E.	ELBS
8	Electrical Technology	Cotton H.	ELBS

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a) www.nptel.iitm.ac.in
b) www.howstuffworks.com/
c) www.vlab.com
d) www.khanacademy.com
e) https://freevideolectures.com/course/2335/basic-electrical-technology/35
f) https://freevideolectures.com/course/2335/basic-electrical-technology/36

g) https://freevideolectures.com/course/2335/basic-electrical-technology/37
h) https://freevideolectures.com/course/2335/basic-electrical-technology/38
i) https://freevideolectures.com/course/2335/basic-electrical-technology/39
j) https://www.youtube.com/watch?v=fYV_siCu_RI
k) https://www.explainthatstuff.com/how-stepper-motors-work.html
l) https://www.edn.com/design/sensors/4406682/Brushless-DC-Motors---Part-I--Construction-and-Operating-Principles
m) https://www.youtube.com/watch?v=bCEiOnuODac


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