A.C. MACHINES PERFORMANCE **Course Code : 315333**

Programme Name/s	**: Electrical Engineering/ Electrical and Electronics Engineering/ Electrical Power System**
Programme Code	**: EE/ EK/ EP**
Semester	**: Fifth**
Course Title	**: A.C. MACHINES PERFORMANCE**
Course Code	**: 315333**

I. RATIONALE

AC machines are widely used in various industries and generating stations, while three phase induction motors are work horse of the industries, alternators are used for generating electrical power. This course is designed to enable the diploma students to acquire the knowledge and skills related to operation and maintenance of these AC machines to enhance the employability in the field.

II. INDUSTRY / EMPLOYER EXPECTED OUTCOME

Test the performance of different AC machines in industries.

III. COURSE LEVEL LEARNING OUTCOMES (COS)

Students will be able to achieve & demonstrate the following COs on completion of course based learning

- CO1 - Test the performance of three phase induction motor.
- CO2 - Control the speed of three phase induction motor using appropriate technique(s).
- CO3 - Use single phase induction motor for industrial applications.
- CO4 - Test the performance of three phase alternator.
- CO5 - Use special purpose electrical machines for industrial applications.

IV. TEACHING-LEARNING & ASSESSMENT SCHEME

Course Code	Course Title	Abbr	Course Category/s	Learning Scheme					Credits	Assessment Scheme											
				Actual Contact Hrs./Week			SLH	NLH		Paper Duration	Theory				Based on LL & TL				Based on SL		Total Marks
															Practical						
				CL	TL	LL					FA-TH	SA-TH	Total		FA-PR		SA-PR		SLA		
											Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	
315333	A.C. MACHINES PERFORMANCE	ACM	DSC	5	-	2	2	9	3	3	30	70	100	40	25	10	25#	10	25	10	175

Total IKS Hrs for Sem. : 0 Hrs

Abbreviations: CL- ClassRoom Learning , TL- Tutorial Learning, LL-Laboratory Learning, SLH-Self Learning Hours, NLH-Notional Learning Hours, FA - Formative Assessment, SA -Summative assessment, IKS - Indian Knowledge System, SLA - Self Learning Assessment

Legends: @ Internal Assessment, # External Assessment, *# On Line Examination , @$ Internal Online Examination

Note :

1. FA-TH represents average of two class tests of 30 marks each conducted during the semester.
2. If candidate is not securing minimum passing marks in FA-PR of any course then the candidate shall be declared as "Detained" in that semester.
3. If candidate is not securing minimum passing marks in SLA of any course then the candidate shall be declared as fail and will have to repeat and resubmit SLA work.
4. Notional Learning hours for the semester are (CL+LL+TL+SL)hrs.* 10 Weeks
5. 1 credit is equivalent to 30 Notional hrs.
6. * Self learning hours shall not be reflected in the Time Table.
7. * Self learning includes micro project / assignment / other activities.

V. THEORY LEARNING OUTCOMES AND ALIGNED COURSE CONTENT

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.

A.C. MACHINES PERFORMANCE **Course Code : 315333**

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
1	TLO 1.1 Classify three phase AC machines. TLO 1.2 Explain constructional details and working principle of the given induction motor. TLO 1.3 Explain the production of a rotating magnetic field with two and three phases. TLO 1.4 Define synchronous speed. TLO 1.5 Mention the general specifications and ratings of three phase induction motor. TLO 1.6 Analyze the behavior of the rotor under the given conditions. TLO 1.7 Calculate the given parameter related to the induction motor. TLO 1.8 Describe the given method(s) for slip measurement of the given induction motor. TLO 1.9 Interpret the torque-slip characteristics of the given induction motor and state its applications.	**Unit - I Three phase induction motors** 1.1 Three phase AC machines: classification. 1.2 Squirrel cage induction motor and slip ring induction motor: constructional details. 1.3 Concept of rotating magnetic field: production of rotating magnetic field (with two and three phases), synchronous speed. 1.4 Squirrel cage induction motor and slip ring induction motor: working principle, comparison. 1.5 Rotor behavior and relations: standstill and running conditions, speed, slip, frequency of induced emf/currents, power factor. 1.6 Slip measurement methods: tachometer, stroboscope, galvanometer. 1.7 Torques: starting, full load and maximum torque & their ratios. 1.8 Torque-slip (T-S) characteristics. 1.9 Squirrel cage induction motor: losses and power stages.	Lecture Using Chalk-Board, Presentations, Video Demonstrations, Flipped Classroom, Collaborative Learning, Case Study, Industry Visit.
2	TLO 2.1 Justify the need of starter for three phase induction motor. TLO 2.2 Describe constructional details of the given type of starter for the induction motor. TLO 2.3 Explain working of the given starter for three phase induction motors. TLO 2.4 List all the components used in the given soft starter. TLO 2.5 Explain the working of the given soft starter. TLO 2.6 Explain the given method(s) of speed control for the induction motor.	**Unit - II Starting and speed control of three phase induction motors** 2.1 Necessity of starters for three phase induction motors. 2.2 Primary resistance starter, DOL, auto transformer starter, star delta starter, rotor resistance starter: constructional details and working. 2.3 Soft starters: component details and working. 2.4 Speed control methods: stator voltage control, pole changing, rotor resistance, variable frequency drives (VFD).	Lecture Using Chalk-Board, Presentations, Video Demonstrations, Flipped Classroom, Collaborative Learning, Case Study, Industry Visit.
3	TLO 3.1 Explain the double field revolving theory and its significance in single-phase induction motors. TLO 3.2 Describe the given self-starting technique(s) for the single-phase induction motors. TLO 3.3 Describe the constructional details of the given single-phase induction motor. TLO 3.4 Explain the working principles of the given single-phase induction motor. TLO 3.5 Interpret the torque-slip characteristics of the given single-phase induction motor and state its applications.	**Unit - III Single phase induction motors** 3.1 Necessity of single-phase induction motor 3.2 Double field revolving theory. 3.3 Self starting techniques : phase splitting, shaded pole, reluctance. 3.4 Types : capacitor start-induction run, capacitor start-capacitor run (two value and single value capacitor), shaded pole: construction, working, torque-slip (T-S) characteristics and applications.	Lecture Using Chalk-Board, Presentations, Video Demonstrations, Flipped Classroom, Collaborative Learning, Case Study.

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
4	TLO 4.1 Describe the constructional details of three phase alternators. TLO 4.2 Explain the working principle of alternator. TLO 4.3 State the advantages of rotating field in turbo alternators. TLO 4.4 Calculate the speed and frequency for the given three phase alternator. TLO 4.5 Calculate the pitch factor, distribution factor and EMF for the given three phase alternator. TLO 4.6 Explain the given type of excitation system used in three phase alternator. TLO 4.7 Explain the significance of synchronous reactance. TLO 4.8 Explain the impact of power factors on performance of the three phase alternator. TLO 4.9 Calculate the voltage regulation of three phase alternators for the given loading conditions. TLO 4.10 Explain the working principle of three phase synchronous motor and its use for power factor improvement. TLO 4.11 Explain necessity of synchronisation and describe the conditions for it.	**Unit - IV Three phase synchronous machines** 4.1 Three phase alternators: constructional details, working principle. Types of alternators and their comparison: turbo alternator and hydro alternator. 4.2 Turbo alternators: advantages of rotating field. 4.3 Relations for speed and frequency. 4.4 Winding: advantages of short pitched winding, relations for pitch factor and distribution factor. 4.5 Excitation system: DC, AC, static. 4.6 E.M.F. equation of alternator. 4.7 Synchronous reactance. 4.8 Armature reaction at various power factors. 4.9 Voltage regulation: direct loading method and synchronous impedance method. 4.10 Synchronisation of alternators: definition, necessity and conditions 4.11 Three phase synchronous motor: principle of operation, significance of load angle. 4.12 Synchronous motor for power factor improvement.	Lecture Using Chalk-Board Presentations Video Demonstrations Flipped Classroom Collaborative Learning, Case Study
5	TLO 5.1 Describe construction of the given type of special purpose machine. TLO 5.2 Explain the working principle of the given special purpose machine. TLO 5.3 Select relevant special purpose machine for the specified application.	**Unit - V Special purpose machines** 5.1 Universal motor, synchronous reluctance motor, permanent magnet synchronous motors (PMSM), stepper motors. 5.2 Constructional details and working of linear induction motor. 5.3 Single and double sided linear induction motor. 5.4 Applications of linear induction motor.	Lecture Using Chalk-Board Presentations Video Demonstrations Flipped Classroom Collaborative Learning, Case Study

VI. LABORATORY LEARNING OUTCOME AND ALIGNED PRACTICAL / TUTORIAL EXPERIENCES.

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 1.1 Identify the different parts of a three phase squirrel cage and slip ring induction motor. LLO 1.2 Reverse the direction of rotation of a three phase induction motors. LLO 1.3 Interpret the nameplate of three phase induction motor.	1	* Identification of different parts of a three phase squirrel cage and slip ring induction motor, interpretation of the nameplate of three phase induction motor and reversal of the direction of rotation	2	CO1

A.C. MACHINES PERFORMANCE **Course Code : 315333**

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 2.1 Measure slip of a three phase induction motor using tachometer. LLO 2.2 Measure slip of a three phase induction motor using galvanometer. LLO 2.3 Measure slip of a three-phase induction motor using stroboscope.	2	*Measurement of slip of a three-phase induction motor by : a) using Tachometer b) using galvanometer c) using stroboscope	2	CO1
LLO 3.1 Perform brake test on a three-phase induction motor.	3	*Brake test on three-phase induction motor.	2	CO1
LLO 4.1 Measure iron and copper losses in a three-phase induction motor. LLO 4.2 Calculate the efficiency of a three-phase induction motor.	4	* Measurement of iron and copper losses through no-load and blocked rotor test on a three-phase induction motor and calculation of efficiency	2	CO1
LLO 5.1 Start a three phase induction motor using a given starter. LLO 5.2 Set the current rating of DOL/ star-delta starter.	5	* Starting of a three-phase induction motor using (a) auto transformer (b) DOL starter (c) star-delta starter	2	CO2
LLO 6.1 Control the speed of a three phase slip ring induction motor by varying rotor resistance.	6	Speed control of a three-phase slip ring induction motor by varying rotor resistance.	2	CO2
LLO 7.1 Control the speed of a three phase slip ring induction motor by varying rotor resistance. LLO 7.2 Start the three phase induction motor using VFD. LLO 7.3 Control the speed of three phase induction motor using VFD.	7	Starting and controlling the speed of a three-phase induction motor using variable frequency drive (VFD)	2	CO2
LLO 8.1 Identify different parts of a single phase induction motor. LLO 8.2 Reverse the direction of rotation of a single phase induccion motor.	8	* Identification of different parts of a single phase induction motor and reversing the direction of rotation of a ceiling fan/ single phase induction motor/ universal motor	2	CO3
LLO 9.1 Operate three phase alternator for variable frequency output.	9	Operation of three phase alternator for variable frequency output by controlling speed of its prime mover	2	CO4
LLO 10.1 Perform a direct loading test on a three phase alternator to determine voltage regulation under various loads. LLO 10.2 Calculate up ad down regulation of three phase alternator.	10	Direct loading test of a three-phase alternator for determining voltage regulation with resistive, inductive, and capacitive loads	2	CO4
LLO 11.1 Perform open circuit (OC) and short circuit (SC) test on three-phase alternator. LLO 11.2 Calculate the efficiency of a three-phase alternator. LLO 11.3 Calculate the up and down regulation of three phase alternator.	11	* Open circuit (OC) and short circuit (SC) test on three phase alternator for determining its efficiency and voltage regulation	2	CO4
LLO 12.1 Control the speed of a stepper motor.	12	*Speed control of stepper motor	2	CO5

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

VII. SUGGESTED MICRO PROJECT / ASSIGNMENT/ ACTIVITIES FOR SPECIFIC LEARNING / SKILLS DEVELOPMENT (SELF LEARNING)

Assignment

- Calculate starting torque, full load torque and maximum torque for a given 3 phase induction motor connecte to a rated power supply.
- Calculate rotor current frequency, synchronous speed and rotor speed for a given slip, number of poles and power supply of 3 phase induction motor.
- Calculate the external resistance to be inserted in rotor circuit to get the maximum torque at the starting conditions for a given slip ring induction motor connected to a rated power supply.
- Calculate the external resistance to be inserted in rotor circuit to get the maximum torque at a given running conditions for a given slip ring induction motor connected to a rated power supply.
- Solve numerical to calculate voltage regulation of alternator.
- Solve numerical to calculate emf of alternator.

Micro project

- Collect information in brochures or other means for setting up VVVF drives.
- Collect information/product brochures on different types of alternators.
- Gather information and product brochures on both AC and DC servomotors commonly employed in robotics, CNC machining, conveyor systems, and other motion control applications.
- Collect information and product brochures, for single-phase induction motors and BLDC motor used in ceiling fans.
- Obtain information and product brochures on stepper motors utilized in precision positioning systems, 3D printers, CNC machines, and other motion control applications.
- Visit an industry and collect information/product brochures on three phase induction motors used for lifts, cranes and hoists and prepare reports covering interpretation of technical specification, name of manufacturer, frame size and applications.
- Visit an industry and collect information/product brochures on three phase induction motors used for floor mills, agricultural solar pumps and prepare reports covering interpretation of technical specification, name of manufacturer, frame size and applications.
- Design a model of a three-phase/single-phase induction motor using software such as CAD, CATIA, or SOLIDWORKS to visualize and understand its constructional details.

Suggested Student Activity

- Note: Sign in to perform below activities in virtual lab : " https://portal.coepvlab.ac.in/vlab/ ". Suggested virtual lab practical are the additional activities to be performed by students for the better understanding of the concept related to AC machines and should not be considered as a substitute for actual laboratory practical experiences.
- Perform short circuit test on three phase alternator.
- Perform speed control of a slip ring induction motor.
- Perform V and inverted V curves of synchronous motor.
- Perform starting of three phase induction motor with a) stator resistance starter b) auto transformer starter c star-delta starter.
- Perform no load test on three phase induction motor.

Note :

- Above is just a suggestive list of microprojects and assignments; faculty must prepare their own bank of microprojects, assignments, and activities in a similar way.
- The faculty must allocate judicial mix of tasks, considering the weaknesses and / strengths of the student in acquiring the desired skills.
- If a microproject is assigned, it is expected to be completed as a group activity.
- SLA marks shall be awarded as per the continuous assessment record.
- For courses with no SLA component the list of suggestive microprojects / assignments/ activities are optional, faculty may encourage students to perform these tasks for enhanced learning experiences.
- If the course does not have associated SLA component, above suggestive listings is applicable to Tutorials and maybe considered for FA-PR evaluations.

VIII. LABORATORY EQUIPMENT / INSTRUMENTS / TOOLS / SOFTWARE REQUIRED

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
1	Three Phase Induction Motor 3 hp / 5 hp, 415 V, 50 Hz, 1440 RPM Squirrel Cage type with Brake and Pulley arrangement.	1,2,3,4,5,6
2	Three Phase Induction Motor 3 hp / 5 hp, 415 V, 50 Hz, 1440 RPM Slip Ring type.	1,2,4,5,6,7
3	Experimentation kit of speed control of stepper motor for 1.8 degree step angle	12
4	Stroboscope or relative Mobile app (e.g. Strobolight/RPM meter).	2
5	Galvanometer (30-0-30).	2
6	Auto Transformer: 3-Phase, 5kVA, 0 to 470V.	2,3,4,5,6,7,8,9,10,11
7	Ammeters MI Type: AC/DC 0-5-10A, 0-10-20A.	2,3,4,5,6,7,8,9,10,11,12
8	Voltmeters MI Type: AC/DC, 0-150/300V, 0-250/500V.	2,3,4,5,6,7,8,9,10,11,12
9	Clip on Meter Digital/Analog.	2,3,4,5,6,7,8,9,10,11,12
10	Digital Multimeter with standard makes for measurements.	2,3,4,5,6,7,8,9,10,11,12
11	Tachometers: Contact and Non-contact types: 100 to 10000 RPM.	2,3,4,5,6,7,8,9,10,11,12
12	Three Phase Induction Motor 3 hp / 5 hp, 415 V, 50 Hz, 1440 RPM Squirrel Cage type coupled with suitable DC Shunt Machine.	6
13	Wattmeters: Single Phase, Single Element, 2.5/5A, 200/400V.	6,7
14	Wattmeters: Three Phase Double Element, 5/10A, 250/500V.	6,7
15	Low Power Factor Wattmeter: Single Phase, 2.5/5A, 250/500V.	6,7
16	Single Phase Induction Motor, Permanent Capacitor (single value), 1 hp, 230 V, 50 Hz, 1440 RPM.	8
17	Star- Delta Starter (Auto/Manual), DOL Starter, VFD for 3 to 5 hp Motors.	8
18	Ceiling Fan 230V preferably dismantled.	8
19	Mixer Grinder (as a Universal Motor) 230V, 500W, 2800RPM.	8
20	Frequency Meter.	9
21	Load Bank: Resistive, 3-Phase, 5kW, 415V.	9,10
22	Load Bank: Inductive, 3-Phase, 20A, 415V.	9,10
23	Load Bank: Capacitive, 3-Phase, 20A, 415V.	9,10
24	Three Phase Alternator: 5kVA, 415V, 50 Hz, 4 Pole, 1500 RPM coupled with appropriate DC Shunt Motor.	9,10,11

IX. SUGGESTED WEIGHTAGE TO LEARNING EFFORTS & ASSESSMENT PURPOSE (Specification Table)

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
1	I	Three phase induction motors	CO1	19	2	6	12	20
2	II	Starting and speed control of three phase induction motors	CO2	5	2	4	4	10
3	III	Single phase induction motors	CO3	10	2	8	4	14
4	IV	Three phase synchronous machines	CO4	12	2	4	10	16
5	V	Special purpose machines	CO5	4	2	4	4	10
Grand Total				**50**	**10**	**26**	**34**	**70**

X. ASSESSMENT METHODOLOGIES/TOOLS

Formative assessment (Assessment for Learning)

- 30 Marks of Theory FA shall be obtained from an average mark of two unit tests (each of 30 marks) held in the semester. At least 2 COs should be covered in each unit test.
- Continuous assessment shall be based on process and product related performance indicators and laboratory experiences. Each practical shall be assessed for 25 marks considering appropriate percentage weightage to both process and product.
- Rubrics of continuous assessment of practical, including performance indicators, shall be designed by concerned course teacher.

Summative Assessment (Assessment of Learning)

- End semester, practical summative assessment of 25 marks shall be based on student's performance in end semester practical exam.
- End semester, theory summative assessment of 70 marks shall be based on offline mode of written examination.

XI. SUGGESTED COS - POS MATRIX FORM

Course Outcomes (COs)	Programme Outcomes (POs)							Programm Specific Outcomes* (PSOs)		
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2	PS 3
CO1	3	2	-	3	-	2	1			
CO2	3	3	-	3	-	2	1			
CO3	3	1	-	3	-	2	1			
CO4	3	1	-	3	1	2	1			
CO5	3	2	1	3	-	2	1			

Legends :- High:03, Medium:02,Low:01, No Mapping: -
*PSOs are to be formulated at institute level

XII. SUGGESTED LEARNING MATERIALS / BOOKS

Sr.No	Author	Title	Publisher with ISBN Number
1	Theraja B. L., Theraja A. K.	A Textbook of Electrical Technology Vol II	S. Chand and Co. New Delhi ISBN10: 8121924375
2	Ashfaq Husain	Electric Machine	Dhanpat Rai & co. ISBN13: 978-8177001662
3	Kothari D. P. and Nagrath I. J.	Electrical Machines	McGraw Hill, New Delhi ISBN13: 978-9352606405
4	Bhattacharya S. K.	Electrical Machines	Tata McGraw Hill, New Delhi ISBN13: 978-9332902855
5	Dr. P. S. Bimbhra	Electrical Machinery	Khanna Publication ISBN13:978-9389139105
6	Mittle V. N., Arvind Mittle	Design of Electrical Machines	McGraw Hill, New Delhi, ISBN: 9788180141263, 9788180141263
7	Samarjit Ghosh	Electrical Machines	Pearson Education India, 2012; 9788131776025

XIII . LEARNING WEBSITES & PORTALS

Sr.No	Link / Portal	Description
1	https://ems-iitr.vlabs.ac.in/exp/speed-control-slip-ring/	Speed Control of Slip Ring Induction Motor (VLAB)

A.C. MACHINES PERFORMANCE **Course Code : 315333**

Sr.No	Link / Portal	Description
2	https://archive.nptel.ac.in/courses/108/106/108106072/	Operation of Induction Machine and Synchronous Machine
3	https://archive.nptel.ac.in/courses/108/105/108105131/	Construction of Three Phase Induction Motor
4	https://archive.nptel.ac.in/courses/108/102/108102146/	Electromechanical Energy Conversion and Synchronisation of Alternators
5	https://ems-iitr.vlabs.ac.in/exp/lab-equipment-familiarization/index.html	Familiarization of the electrical machine laboratory apparatus (VLAB)

Note :

- Teachers are requested to check the creative common license status/financial implications of the suggested online educational resources before use by the students