CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET307	SYNCHRONOUS AND INDUCTION MACHINES	PCC	3	1	0	4

Preamble: Nil

Prerequisite: DC Machines and Transformers

Course Outcomes: After the completion of the course, the student will be able to:

CO 1	Analyse the performance of different types of alternators.
CO 2	Analyse the performance of a synchronous motor.
CO 3	Analyse the performance of different types of induction motors.
CO 4	Describe operating principle of induction machine as generator.
CO 5	Explain the types of single phase induction motors and their working principle.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	2	2	-	-	-	2	-	-	-	-	-	2
CO 2	3	3	2	-	-	2	-	-	-	-	-	2
CO 3	3	3	2	-	-	2	-	-	-	-	-	2
CO 4	3	3	2	-	-	2	-	-	-	-	-	2
CO 5	2	2	-	-	-	2	-	-	-	-	-	2

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember	10	10	20
Understand	15	15	30
Apply	25	25	50
Analyse			
Evaluate			
Create			

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contains 10 questions (each carrying 3 marks) with 2 questions from each module. Students should answer all questions. Part B contains 2 questions from each module, out of which students should answer any one. Each question can have maximum 2 sub-divisions and carries 14 marks.

Part A: 10 Questions x 3 marks=30 marks, **Part B:** 5 Questions x 14 marks =70 marks

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the principle of operation of alternators.
2. List the advantages of stationary armature type alternators over rotating armature types.
3. Derive emf equation of an alternator.
4. Define coil pitch factor and distribution factor of an alternator.
5. Problems based on emf equation of alternators.
6. Draw the phasor diagram of an alternator operating under lagging/leading/unity power factor and hence derive an expression for the no load induced emf/phase.

Course Outcome 2 (CO2):

1. Why synchronous motors are not self starting?
2. Develop the equivalent circuit and phasor diagram of synchronous motor.
3. Explain the V and Inverted V curves of synchronous motor
4. Explain the power flow diagram of synchronous motor.

Course Outcome 3(CO3):

1. Explain the principle of operation of a three phase induction motor.
2. List the constructional differences between slip ring and squirrel cage induction motors.
3. Problems based on analysing the performance of three phase induction motors using circle diagrams.
4. Problems based on developing the equivalent circuit of a three phase induction motor.
5. Explain the various speed control methods of three phase induction motors.
6. Explain the working of DOL/Star-Delta starter for three phase induction motors.

Course Outcome 4 (CO4):

1. Explain the principle of operation of induction generator.
2. Explain the difference between Grid connected and self excited induction generators
3. Differentiate between induction generator and synchronous generator.
4. Enumerate application of induction generator.

Course Outcome 5 (CO5):

1. Why single phase induction motor is not self starting.
2. Explain double field revolving theory.
3. Draw the torque slip characteristics of single phase induction motor.
4. Develop the equivalent circuit of single phase induction motor.

Model Question paper

QP CODE:

PAGES:3

Reg.No:______________
Name:________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
FIFTH SEMESTER B.TECH DEGREE EXAMINATION,
MONTH& YEAR

Course Code: EET307
Course Name: SYNCHRONOUS AND INDUCTION MACHINES

Max. Marks: 100 **Duration: 3 Hrs**

PART A

Answer all questions. Each Question Carries 3 marks

1. List the advantages of stationary armature type alternators over rotating armature types.
2. Define coil pitch factor and distribution factor of an alternator.
3. State and explain Blondel's Two Reaction Theory.
4. What is meant by synchronisation? Lit the conditions to be met while synchronising an alternator to the common bus bars.
5. With the help of neat figures, explain why a synchronous motor is not self-starting.
6. Differentiate between slip ring and squirrel cage induction motors.
7. Explain the phenomenon of crawling and cogging in induction motors.
8. Explain any two braking techniques of induction motors.
9. Differentiate between synchronous and induction generators.
10. What is double field revolving theory?

PART B

Answer any one full question from each module. Each question carries 14 marks.

Module 1

11. a) List the causes of harmonics in alternators and suggest ways to mitigate them. **(5)**

    b) A 3-Φ, 10 pole alternator has 2 slots/ pole/ phase on its stator with 10 conductors per slot. The air gap flux is sinusoidally distributed and equals 0.05 Wb. The stator has a double layer winding with a coil span of 1500. If the alternator is running at 600 rpm, calculate the emf generated /phase at no load. **(9)**

12. With the help of neat diagrams, explain the effects of armature reaction in alternators under lagging, leading and unity power factors. **(14)**

Module 2

13. A 220V, 6 pole, 50 Hz, star connected alternator gave the following test results: -

If (A)	0.2	0.4	0.6	0.8	1	1.2	1.4	1.8	2.2	2.6	3	3.4
Voc (line) (V)	29	58	87	116	146	172	194	232	261	284	300	310
Vzpf (line) (V)	-	-	-	-	-	0	29	88	140	177	208	230
Isc (A)	6.6	13.2	20	26.5	32.4	40	46.3	59	-	-	-	-

Find % voltage regulation at full load current of 40A at power factor 0.8 lag by (i) m.m.f method (ii) ZPF method. Ra=0.06 Ω /phase. **(14)**

14. a) Two 3Φ, 6.6 kV star connected alternators supply a load of 3000kW at 0.8 pflag. The synchronous impedance/phase of machine A is 0.5 + j 10 Ω and that of machine B is 0.4+j12 Ω. The excitation of machine A is adjusted so that it delivers 150 A at a lagging power factor and the governors are so set that the load is equally shared between the machines. Determine the current, power factor and induced emf of each machine. **(10)**

    b) With the help of a neat circuit diagram, explain how an alternator is synchronised to the bus bars by bright lamp method. **(4)**

Module 3

15. a) With the help of a neat circuit diagram, explain how V and inverted V curves are obtained. **(6)**

    b) A 2000V, 3-phase, 4 pole star connected synchronous motor runs at 1500 rpm. The excitation is constant and corresponds to an open circuit voltage of 2000V.The resistance is negligible compared to synchronous reactance of 3Ω per phase. Determine power input, power factor, torque developed for an armature current of 200A. **(8)**

16. a) In rice/flour mills driven by squirrel cage induction motors, the hopper is loaded with the grains only after starting the motor. Similarly, the delivery valve of centrifugal pumps driven by squirrel cage induction motor is opened only after starting the motor. What is the reason behind this? Justify your answer with a relevant performance curve of squirrel cage induction motor. **(4)**

    b) A 6-pole, 50 Hz,3-Φ induction motor running on full load develops a useful torque of 150 Nm at a rotor frequency of 1.5 Hz. Calculate the shaft power output. If the mechanical torque lost in friction is 10 Nm, determine a) rotor copper loss b) input to the motor c) the efficiency. The total stator loss is 700W. **(10)**

Module 4

17. For the following test data, calculate (i) line current (ii) power factor (iii) rotor copper loss (iv) slip (v) efficiency (vi) maximum output power (vi) maximum torque and (vii) starting torque:

Induction Motor Details: 3.73kW, 200V, 50Hz, 4pole, 3ϕ star connected
No Load Test: 200V, 350W, 5A
Blocked Rotor Test: 100V, 26A, 1700W
Rotor Copper Loss at standstill is 60% of the total copper loss. **(14)**

18. Explain the methods of speed control in three phase induction motors. **(14)**

Module 5

19. a)Explain the working principle and modes of operation of an Induction Generator. **(8)**

b) With the help of a neat figure, explain the torque-slip characteristics of an induction machine. **(6)**

20. Explain the working of split phase and capacitor start single phase induction motors with the help of neat circuit diagrams and phasor diagrams. Also mention the applications of each. **(14)**

Syllabus

Module 1

Principle of Operation of three phase alternators, Constructional features, Types of Armature Windings(detailed winding diagram not required), EMF equation, Numerical Problems.

Harmonics-causes, suppression, Rating of alternators, Parameters of armature winding, Armature reaction, Equivalent Circuit, Phasor Diagram, Load characteristics, Power Flow Equations.

Module 2

Voltage regulation of three phase Alternators-Direct loading, EMF Method, MMF Method, Potier Method,ASA Method -Numerical Problems.

Blondel's two reaction theory, Phasor Diagram under lagging power factor, Determination of X_d and X_q by slip test, Power developed by a Salient pole machine, Numerical Problems.

Parallel Operation of Alternators- Necessary Conditions, Synchronisation- Synchronising current, Power and Torque, Effect of reactance, Numerical Problems, Methods of Synchronisation.

Module 3

Principle of Synchronous Motor, Equivalent circuit, Phasor diagrams, Power flow diagram and equations, Losses and efficiency -Numerical Problems, Power-angle Characteristics, V Curve and Inverted V Curves.

Three phase Induction motor – Constructional features, Expressions for Power and Torque-Torque- Slip characteristics, Phasor diagram, Equivalent Circuit of Induction motor- Tests on Induction motors for determination of equivalent circuit-Numerical Problems.

Module 4

Performance of three phase Induction motors using Circle diagram, Numerical Problems. Cogging and Crawling in cage motors, Double cage Induction motor-Torque-Slip Characteristics.

Starting of Induction motors – Types of Starters – DOL starter, Autotransformer Starter, Star-Delta starter, Rotor Resistance Starter-Numerical Problems.

Braking of Induction motors – Plugging, Dynamic braking, Regenerative braking, Speed control – Stator Voltage control, V/f control, Rotor Resistance Control.

Module 5

Induction generator – Principle of operation, Grid Connected and Self Excited Operation of Induction Generators, Torque-Slip Characteristics of an Induction machine.

Single phase Induction motors-Double field revolving theory, Equivalent Circuit, Torque-Slip Characteristics, Types of Single Phase Induction motor, Applications.

Selection of AC motors for different applications.

Text Books

1. Bimbra P S, Electric Machines, Khanna Publishers, 2ndedition, 2017.
2. KothariD. P., NagrathI. J., Electric Machines, Tata McGraw Hill, 5thedition.2017.
3. Say M G, The Performance and Design of AC Machines, CBS Publishers, New Delhi, 3rdedition, 2002.
4. Alexander SLangsdorf, "Theory of Alternating Current Machinery", Tata McGraw Hill,2nd revised edition, 2001.

Reference Books

1. Deshpande M. V., Electrical Machines, Prentice Hall India, New Delhi, Eastern Economy Edition, 2011.
2. Gupta B R, VandanaSinghal, "Fundamentals of Electric Machines", New Age International,.2010.
3. Ashfaq Husain, HaroonAshfaq, Electric Machines, DhanpatRai and Co., 3rd edition,2002.
4. Gupta J B, "Theory and Performance of Electrical Machines", S K Kataria& Sons, 14thedition, 2013.

Course Contents and Lecture Schedule

Sl. No.	Topic	No. of Lectures
1	**Basics of Alternators (10 hours)**	
1.1	Principle of operation and classification of alternators, Synchronous speed.	2
1.2	Construction of synchronous machines. Salient and Cylindrical types, Turbogenerators. Stationary and Rotating armature types.	1
1.3	Armature windings-Types.: Single layer, Double layer, Full pitched winding, Short pitched winding, Concentrated and Distributed winding	1
1.4	EMF Equation, Pitch factor and Distribution factor, Numerical problems	3
1.5	Harmonics in Alternators: Space and slot harmonics, Suppression, Effect of pitch factor on harmonics.	1
1.6	Armature Reaction, Equivalent Circuit and Phasor Diagrams, Power Flow Equations	2
2	**Voltage Regulation and Synchronisation of Alternators (10 hours)**	
2.1	Voltage Regulation of Alternators: EMF, MMF, Potier and ASA Method.	4
2.2	Blondel's Two Reaction Theory, Phasor Diagram under lagging power	3

	factor based on two reaction theory,Slip Test	
2.3	Parallel Operation of Alternators, Necessity of Parallel Operation. Advantages.	1
2.4	Synchronisation of Alternators: Dark Lamp and Bright Lamp Method.	2
3	**Three Phase Synchronous and Induction Motors (10 hours)**	
3.1	Synchronous Motors-Principle, Equivalent Circuit, Phasor Diagrams, Power Flow Diagram, Power and Torque Equations, Numerical Problems	3
3.2	Effects of excitation on armature current and power factor- V and Inverted V Curves, advantages, disadvantages and applications of Synchronous motors.	1
3.3	Three phase Induction Motors-Principle, Constructional details, Slip ring and Cage types.	1
3.4	Slip,frequency and rotor current, Expression for torque and Power-Starting torque, Full load and Pull out torque, Torque- Slip characteristics, Phasor diagram.	3
3.5	Tests on Induction motors for determination of Equivalent circuit, Equivalent Circuit of Induction motor-Numerical Problems.	2
4	**Three Phase Induction Motors Contd. (8 hours)**	
4.1	Circle Diagram, Numerical Problems.	3
4.2	Cogging, Crawling—remedial measures, Double Cage Induction Motor-Principle.	1
4.3	Starters for three phase Induction Motors: DOL, Autotransformer, Star Delta and Rotor Resistance Starters.	2
4.4	Speed Control in Induction Motors	1
4.5	Braking in Induction Motors	1
5	**Induction Generators and Single Phase Induction Motors (7 hours)**	
5.1	Induction Generators: Grid Connected and Self Excited types.	1
5.2	Single phase induction motors-principle, Double field revolving theory, Torque-Slip characteristics, Applications	2
5.3	Types-Split phase, Capacitor Start, Capacitor Start and Run types, Shaded pole motor, Shaded Pole Motor-Principle of operation and applications.	3
5.4	Selection of AC motors for different Applications.	1