



INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad-500043

ELECTRICAL AND ELECTRONICS ENGINEERING

TUTORIAL QUESTION BANK

Course Title	SOLID STATE ELECTRIC MOTOR DRIVES				
Course Code	AEE013				
Programme	B.Tech				
Semester	VI	EEE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	Theory			Practical	
	Lectures	Tutorials	Credits	Laboratory	Credits
	3	1	4	3	2
Chief Coordinator	Dr. B. Muaralidhar Nayak, Professor				
Course Faculty	Dr. B. Muaralidhar Nayak, Professor Mr. S. Srikanth, Assistant Professor				

COURSE OBJECTIVES:

The course should enable the students to:

I	Demonstrate DC drives through phase controlled rectifiers and choppers.
II	Analyze operating principle of four quadrant DC drives.
III	Illustrate the speed control of induction motors through various parameters.
IV	Outline the separate and self control of synchronous motors.

COURSE OUTCOMES (COs):

CO 1	Analyze the speed control of DC motors with phase controlled rectifiers
CO 2	Describe the four quadrant operation of DC Drive with dual converter and operation of DC drives with choppers
CO 3	Apply the variable voltage and variable frequency operation of induction motors with suitable converters
CO 4	Understand the speed control of induction motor through static rotor resistance control and vector control
CO 5	Demonstrate the speed control of synchronous motor with suitable converters

COURSE LEARNING OUTCOMES (CLOs):

AEE013.01	Understand the speed control of DC motors with single phase controlled rectifiers
AEE013.02	Analyze the speed control of DC motors with three phase controlled rectifiers
AEE013.03	Describe the speed torque characteristics of DC motors with variation in firing angle of the controlled rectifiers
AEE013.04	Demonstrate the motoring and braking operations of DC motor drives
AEE013.05	Analyze the four quadrant operation of DC Drive with dual converter and closed loop operation
AEE013.06	Describe the operation of chopper fed DC motors
AEE013.07	Apply the variable voltage operation of induction motors with AC voltage controllers
AEE013.08	Analyze the variable frequency operation of induction motors with voltage source inverters and current source inverters
AEE013.09	Describe the variable frequency operation of induction motors with cycloconverters and closed loop operations
AEE013.10	Understand the speed control of induction motor through static rotor resistance control
AEE013.11	Demonstrate the vector control operation of induction motor with direct methods
AEE013.12	Describe the vector control operation of induction motor with indirect methods
AEE013.13	Analyze the speed control of synchronous motor with voltage source inverters and current source inverters
AEE013.14	Understand the speed control of synchronous motor with variable frequency control using cycloconverters
AEE013.15	Demonstrate the closed loop control of synchronous motors with block diagram
AEE013.16	Apply the concept of solid state electric drives to solve real time world applications
AEE013.17	Explore the knowledge and skills of employability to succeed in national and international level competitive examinations

TUTORIAL QUESTION BANK

UNIT – I				
CONTROL OF DC MOTORS THROUGH PHASE CONTROLLED RECTIFIERS				
Part - A(Short Answer Questions)				
S No	QUESTION	Blooms taxonomy level	Course Outcomes	Course Learning Outcomes
1	Define electrical drive	Remember	CO1	AEE013.01
2	List the advantages of electric drives	Remember	CO1	AEE013.01
3	List the functions performed by electric drives	Remember	CO1	AEE013.01
4	Mention the parts of electrical drives	Remember	CO1	AEE013.01
5	Give the applications of electrical drives	Understand	CO1	AEE013.01
6	List the requirements of an electric drive	Remember	CO1	AEE013.02
7	List the advantages of three phase controlled converter fed DC Drives	Remember	CO1	AEE013.02
8	Give the advantages of single phase controlled fed DC Drives	Understand	CO1	AEE013.01
9	Write output voltage equations for single phase controlled converters and three phase controlled converters	Remember	CO1	AEE013.02
10	List out the drawbacks of rectifier fed DC drive	Remember	CO1	AEE013.01
11	Draw the block diagram of a drive system	Remember	CO1	AEE013.02
12	Write the speed equations for single phase fully controlled rectifier fed DC motors	Understand	CO1	AEE013.01
13	Draw the speed torque characteristics of DC shunt motor fed with single phase semi converter	Understand	CO1	AEE013.01
14	Write the speed equations for three phase fully controlled rectifier fed DC motors	Remember	CO1	AEE013.02
15	Draw the speed torque characteristics of DC series motor fed with single phase full converter	Understand	CO1	AEE013.01
Part - B (Long Answer Questions)				
1	Derive an expression relating speed and torque of a single phase full converter fed separately excited DC motor drive operating in the continuous current mode	Understand	CO1	AEE013.01
2	Describe the operation of single phase fully controlled rectifier control of DC series motor and obtain the expression for motor speed for continuous mode of operation	Remember	CO1	AEE013.01
3	Describe the operation of single phase semi controlled rectifier control of DC series motor and obtain the expression for motor speed for continuous mode of operation	Remember	CO1	AEE013.01
4	Describe the operation of single phase Semi controlled rectifier control of DC separately excited motor and obtain the expression for motor speed for continuous mode of operation	Remember	CO1	AEE013.01
5	Explain the motoring and braking operation of three phase fully controlled rectifier control of dc separately excited motor with aid of diagrams and waveforms. Also obtain the expression for motor terminal voltage speed.	Understand	CO1	AEE013.02
6	Explain the operation of three phase full controlled rectifier fed DC series motor drives with waveforms and characteristics	Understand	CO1	AEE013.02
7	Explain the operation of three phase half controlled rectifier fed DC series motor drives with waveforms and characteristics	Understand	CO1	AEE013.02

8	Explain the operation of three phase half controlled rectifier fed DC separately excited DC motor drives with waveforms and characteristics	Understand	CO1	AEE013.02
9	Explain the use of freewheeling diode in the converter fed DC drives. Take an example of 1-phase fully controlled converter fed for explanation. How it is going to affect the machine performance.	Understand	CO1	AEE013.03
10	Summarize the advantages of three phase drives over single phase drives	Understand	CO1	AEE013.03
11	Draw and explain the speed torque characteristics of a DC shunt motor fed single phase fully controlled rectifier with variation in firing angle	Understand	CO1	AEE013.01
12	Explain the use of freewheeling diode in the converter fed DC drives. Take an example of 3-phase fully controlled converter fed for explanation. How it is going to affect the machine performance.	Understand	CO1	AEE013.01
13	Draw and explain the speed torque characteristics of a DC series motor fed single phase half controlled rectifier with variation in firing angle	Understand	CO1	AEE013.02
14	Draw and explain the speed torque characteristics of a DC series motor fed three phase half controlled rectifier with variation in firing angle	Understand	CO1	AEE013.02
15	Draw and explain the speed torque characteristics of a DC shunt motor fed three phase fully controlled rectifier with variation in firing angle	Understand	CO1	AEE013.02
Part - C (Problem Solving and Critical Thinking Questions)				
1	The speed of a 15hp, 220V, 1000 rpm dc series motor is controlled using a single-phase half controlled bridge rectifier. The combined armature and field resistance is 0.2 Ω . Assuming continuous and ripple free motor current and speed of 1000 rpm and $K=0.03 \text{ Nm/Amp}^2$ determine a) motor current, b) motor torque for a firing angle $\alpha=30^\circ$ AC source voltage is 250 V	Understand	CO1	AEE013.01
2	A 1 ϕ semi converter is operated from 220 V, 50 Hz supply. It is used for controlling the speed of a separately excited dc motor whose armature resistance is negligible. When the firing angle is 60° the motor is rotating at a speed of 800 rpm. The armature is coupled to constant torque load. The firing angle for a speed of 600 rpm is	Understand	CO1	AEE013.01
3	A single phase full converter connected to 220 V, 50 Hz at supply is supplying power to a dc series motor. The combined armature resistance and field resistance is 0.5 Ω . The firing angle of the converter is 45° . The back emf is 100 V. calculate the average current drawn by the motor	Understand	CO1	AEE013.01
4	A 220 V, 1500 rpm, 10 A separately excited dc motor has an armature resistance of 1 Ω . It is fed from a single phase full converter with an ac source voltage of 230 V, 50 Hz. The motor emf constant is 1.337 N-m/A. Assume continuous load current at the firing angle of 30° and torque of 5 N- m, calculate the motor speed	Understand	CO1	AEE013.01
5	The speed of a 10hp, 220V, 1200 rpm dc series motor is controlled using a single-phase half controlled bridge rectifier. The combined armature and field resistance is 0.2 Ω . Assuming continuous and ripple free motor current and speed of 1200 rpm and $K=0.03 \text{ Nm/Amp}^2$ determine a) motor current, b) motor torque for a firing angle $\alpha=30^\circ$ AC source voltage is 230 V	Understand	CO1	AEE013.01
6	The speed of a separately excited dc motor is controlled by means of a 3 phase semi converter from a 3 phase, 415V, 50 Hz supply. The motor constants are inductance 10mH; resistance 0.9 Ω and armature constant 1.5V-sec/rad. Calculate the speed of this motor at a torque of 50N-M when the converter is fired at 45 degrees.	Understand	CO1	AEE013.02

7	The speed of a 10hp, 230V, 1000rpm dc series motor is controlled using a three phase fully controlled converter. The combined armature and field resistance is 0.2Ω . Assuming continuous and ripple free motor current and speed of 1000rpm and $k=0.03\text{Nm/A}^2$, determine a) motor current b) motor torque for a firing angle $\alpha=30^\circ$. Ac voltage is 250V. Derive the formula used.	Understand	CO1	AEE013.02
8	A 600V, 1500rpm, 80A separately excited dc motor is fed through a three phase semi converter from 3-phase 400V supply. Motor armature resistance is 1Ω the armature current assumed constant. For a firing angle of 45° at 1200rpm, compute the rms value of source and thyristor currents, average value of thyristor current and the input supply power factor	Understand	CO1	AEE013.02
9	A 100kW, 500 V, 2000 rpm separately excited dc motor is energized from 400 V, 50Hz, 3-phase source through a 3-phase full converter. The voltage drop in conducting thyristors is 2V. The dc motor parameters are as under: $R_a=0.1\Omega$, $K_m=1.6\text{V-s/rad}$, $L_a=8\text{mH}$. Rated armature current=21A. No-load armature current =10% of rated current. Armature current is continuous and ripple free. i. Find the no-load speed at firing angle of 30° ii. Find the firing angle for a speed of 2000 rpm at rated armature current. Determine also the supply power factor.	Understand	CO1	AEE013.02
10	A 230V, 1500 rpm, 20A separately excited dc motor is fed from 3-phase full converter. Motor armature resistance is 0.6Ω . Full converter is connected to 400V, 50Hz source through a delta-star transformer. Motor terminal voltage is rated when converter firing angle is zero. Calculate the transformer phase turns-ratio from primary to secondary	Understand	CO1	AEE013.02
11	A 220 V, 1000 rpm, 60 A separately excited dc motor has an armature resistance of 0.1Ω . It is fed from a single phase full converter with an ac source voltage of 230 V, 50Hz. Assuming continuous conduction. For 600 rpm and rated torque, the firing angle is	Understand	CO1	AEE013.01
12	A 230V, 10Kw, 1000rpm separately excited DC motor has its armature resistance of 0.3Ω and field resistance of 300Ω the speed of this motor is controlled by a 3 phase full converter fed from 400V, 50Hz supply. The motor constants are 1.1V-S/A rad , field voltage is 540V. Assuming continuous current calculate firing angle for load torque of 60Nm and rated speed	Understand	CO1	AEE013.02
13	A 220 V, 1500 rpm, 12 A separately excited dc motor has an armature resistance of 1.5Ω . It is fed from a single phase full converter with an ac source voltage of 230 V, 50 Hz. The motor emf constant is 1.337N-m/A . Assume continuous load current at the firing angle of 30° and torque of 5 N- m, calculate the motor speed	Understand	CO1	AEE013.01
14	A 230V, 10Kw, 1000rpm separately excited DC motor has its armature resistance of 0.3Ω and field resistance of 300Ω the speed of this motor is controlled by two 3 phase full converters one in armature and other in field circuit both are fed from 400V, 50Hz supply. The motor constant is 1.1V-S/A rad . Assuming continuous current i. With field converter setting to maximum field current calculate firing angle for load torque of 60Nm and rated speed ii. With load torque as 60Nm and zero degree firing angle for armature converter, speed is to be raised to 3000rpm. Determine the firing angle of the field converter	Understand	CO1	AEE013.02

15	A single phase full converter connected to 230 V, 50 Hz at supply is supplying power to a dc series motor. The combined armature resistance and field resistance is 0.5 Ω . The firing angle of the converter is 30°. The back emf is 120 V. calculate the average current drawn by the motor	Understand	CO1	AEE013.01
UNIT – II				
SPEED CONTROL OF DC MOTORS				
Part – A (Short Answer Questions)				
1	Describe regenerative braking of DC motor	Remember	CO2	AEE013.04
2	Define dynamic braking	Remember	CO2	AEE013.04
3	Define plugging	Remember	CO2	AEE013.04
4	Define four quadrant operations	Remember	CO2	AEE013.04
5	Mention different types of braking methods	Remember	CO2	AEE013.04
6	List the advantages of closed loop control of dc drives	Remember	CO2	AEE013.04
7	List the advantages of Dual converters	Remember	CO2	AEE013.05
8	List the applications of regenerative braking	Remember	CO2	AEE013.04
9	Give the conditions for the operation of motor in regenerative braking	Understand	CO2	AEE013.04
10	Describe counter current braking	Remember	CO2	AEE013.04
11	Give the operation of dual converter in third and fourth quadrants	Understand	CO2	AEE013.05
12	Draw the equivalent circuit diagram of a DC separately excited motor with dynamic braking	Understand	CO2	AEE013.05
13	Draw the equivalent circuit diagram of a DC shunt motor with plugging	Remember	CO2	AEE013.04
14	Give the operation of dual converter in first and second quadrants	Understand	CO2	AEE013.05
15	Draw the equivalent circuit diagram of a DC shunt motor with dynamic braking	Remember	CO2	AEE013.04
Part - B (Long Answer Questions)				
1	Explain the principle of operation of a dual converter in a circulating current mode. How the same is used for speed control of DC drive	Understand	CO2	AEE013.05
2	Explain the four quadrant operations with converters	Understand	CO2	AEE013.05
3	Describe the relative merits and demerits of the following types of braking for DC motors, mechanical braking, dynamic braking and regenerative braking with neat diagram.	Remember	CO2	AEE013.04
4	Draw the circuit diagram and explain the operation of closed loop speed control with inner-current loop and field weakening.	Understand	CO2	AEE013.05
5	Explain how four-quadrant operation is achieved by dual converter each of 3 ϕ full wave configuration for DC separately excited motor.	Understand	CO2	AEE013.05
6	Explain the principle of closed-loop control of a DC drive using suitable block diagram.	Understand	CO2	AEE013.04
7	Deduce the mathematical expression for minimum and maximum currents for a class A chopper operated DC motor with back emf.	Understand	CO2	AEE013.06
8	Distinguish between class A and class B choppers with suitable examples of speed control of motors	Understand	CO2	AEE013.06
9	Explain the operation of the two quadrant chopper fed DC drive system	Understand	CO2	AEE013.06
10	Draw and explain the diagram of regenerative chopper fed separately excited DC motor drive	Understand	CO2	AEE013.06

11	Describe the working of a single quadrant chopper fed DC series motor drive	Remember	CO2	AEE013.06
12	Explain the operation of four quadrant DC chopper drive	Understand	CO2	AEE013.06
13	Describe the working of DC shunt and series motors with dynamic braking	Understand	CO2	AEE013.04
14	Describe the working of DC shunt and series motors with regenerative braking	Understand	CO2	AEE013.04
15	Describe the working of DC shunt and series motors with plugging	Understand	CO2	AEE013.04
Part - C (Problem Solving and Critical Thinking Questions)				
1	A 220V, 970rpm, 100A DC separately excited motor as an armature resistance of 0.05ohm. It is braked by plugging from an initial speed of 1000rpm. Calculate the resistance to be placed in armature circuit to limit braking current to twice the full load value. Braking torque and torque when the speed has fallen to zero.	Understand	CO2	AEE013.04
2	A 200V, 100A DC series motor runs at 1000rpm is operated under dynamic braking at twice the rated torque and 800rpm. The resistance of armature and field winding is 0.1 ohm. Calculate the value of braking current and resistance.	Understand	CO2	AEE013.04
3	A 200V, 1500rpm, 50A separately excited motor with armature resistance of 0.5 ohm is fed from a circulating current dual converter with AC source voltage 165V. Determine converter firing angle for the following operating points i) Motoring operation at rated motor torque and 1000rpm. ii) Braking Operation at rated motor torque and 1000rpm	Understand	CO2	AEE013.05
4	A 220V DC series motor runs at 1200 rpm and takes an armature current of 100 A when driving a load with a constant torque. Resistances of the armature and field windings are 0.05 Ω each. DC series motor is operated under dynamic braking at twice the rated torque and 1000 rpm. Calculate the value of braking current and resistor. Assume linear magnetic circuit.	Understand	CO2	AEE013.04
5	A 220V, 200A, 800 rpm dc separately excited motor has an armature resistance of 0.05 Ω . The motor armature is fed from a variable voltage source with an internal resistance of 0.03 Ω . Calculate internal voltage of the variable voltage source when the motor is operating in regenerative braking at 80% of the rated motor torque and 600rpm.	Understand	CO2	AEE013.04
6	A 220V, 750 rpm, 200A separately excited motor has an armature resistance of 0.05 Ω . Armature is fed from a three phase non-circulating current dual converter consisting of fully controlled rectifiers A and B. Rectifier A provides motoring operation in the forward direction and rectifier B in reverse direction. Line voltage of ac source is 400V. Calculate firing angles of rectifiers for the following assuming continuous conduction. Motoring operation at rated torque and 600rpm Regenerative braking operation at rated torque and 600rpm.	Understand	CO2	AEE013.05
7	A DC series motor is fed from 600V DC source through a chopper. The DC motor has the following parameters. $R_a = 0.04$ ohm, $R_s = 0.06$ ohm, $k=4 \times 10^{-3}$ NM/A ² . Average armature current of 300A is ripple free. For a chopper duty cycle of 60% determine (a) input power from the source, (b) Motor speed and (c) Motor torque.	Understand	CO2	AEE013.06

8	The chopper used for on-off control of a DC separately excited motor has supply voltage of 230V DC and on-time of 10ms and off-time of 15ms. Assuming continuous conduction calculate the average load current when the motor speed is 1500rpm and has a voltage constant of 0.5V-sec/Rad and the armature resistance is 3 ohm.	Understand	CO2	AEE013.06
9	A DC chopper is used to control the speed of a separately excited DC motor. The DC supply voltage is 220V, armature is 0.2 ohm and motor constant is 0.08V/rpm. This motor drives a constant torque requiring an average armature current of 25A. Determine the (a) the range of speed control, (b) the range of duty cycle.	Understand	CO2	AEE013.06
10	A DC chopper is used for regenerative braking of a separately excited DC motor. The supply voltage is 400V. The motor has $R_a=0.2$ ohm, $k=1.2V\text{-Sec/Rad}$. The average armature current during regenerative braking is kept constant at 300A with negligible ripple. For a duty cycle of 60% determine i) Power returned to the DC supply Min and Max permissible breaking speeds	Understand	CO2	AEE013.06
11	A d.c. series motor, fed from 400 V dc source through a chopper, has the following parameters. $R_a = 0.05 \Omega$, $R_s = 0.07 \Omega$, $k = 5 * 10^{-3} \text{ Nm/amp}^2$ The average armature current of 200A ripple free. For a chopper duty cycle of 50%. Determine Input power from the source and ii) Motor speed	Understand	CO2	AEE013.06
12	A chopper used for ON and OFF control of a dc separately excited motor has supply voltage of 230V $T_{on} = 10\text{ms}$, $T_{off} = 15\text{ms}$. Neglecting armature inductance and assuming continuous conduction of motor current, Calculate the average load current when the motor speed is 1500 rpm, has a voltage constant $K_v = 0.5 \text{ V/rad/sec}$. The armature resistance is 2Ω .	Understand	CO2	AEE013.06
13	A 230V, 970rpm, 90A DC separately excited motor as an armature resistance of 0.05ohm. It is braked by plugging from an initial speed of 900rpm. Calculate the resistance to be placed in armature circuit to limit braking current to twice the full load value. Braking torque and torque when the speed has fallen to zero.	Understand	CO2	AEE013.04
14	A d.c. series motor, fed from 250 V dc source through a chopper, has the following parameters. $R_a = 0.05 \Omega$, $R_s = 0.07 \Omega$, $k = 5 * 10^{-3} \text{ Nm/amp}^2$ The average armature current of 100A ripple free. For a chopper duty cycle of 40%. Determine Input power from the source and ii) Motor speed	Understand	CO2	AEE013.06
15	A chopper used for ON and OFF control of a dc separately excited motor has supply voltage of 230V $T_{on} = 15\text{ms}$, $T_{off} = 10\text{ms}$. Neglecting armature inductance and assuming continuous conduction of motor current, Calculate the average load current when the motor speed is 1500 rpm, has a voltage constant $K_v = 0.5 \text{ V/rad/sec}$. The armature resistance is 2Ω .	Understand	CO2	AEE013.06

UNIT – III

SPEED CONTROL OF INDUCTION MOTORS THROUGH VARIABLE VOLTAGE AND VARIABLE FREQUENCY

Part – A (Short Answer Questions)

1	List the applications of slip ring induction motor	Remember	CO3	AEE013.07
2	Define rotor current frequency	Remember	CO3	AEE013.07
3	Draw the equivalent circuit of an induction motor	Remember	CO3	AEE013.07
4	Draw the speed torque characteristics of induction motor with variable stator voltage	Remember	CO3	AEE013.07
5	Describe the constant torque mode operation	Remember	CO3	AEE013.07

6	Write the torque equation of three phase induction motor and explain the related terms	Remember	CO3	AEE013.07
7	Draw the circuit diagram of closed loop control of induction motor using stator voltage controller	Remember	CO3	AEE013.07
8	Draw the circuit diagram of ac voltage controller for obtaining four quadrant operations of induction motor	Remember	CO3	AEE013.07
9	List the advantages of stator voltage control.	Remember	CO3	AEE013.07
11	List the applications of variable frequency drives	Remember	CO3	AEE013.08
12	List the advantages of variable frequency control	Remember	CO3	AEE013.08
13	Give the disadvantages of variable frequency control	Understand	CO3	AEE013.08
14	Explain the limitations of v/f control	Understand	CO3	AEE013.08
15	Draw the speed torque curves of variable frequency control under motoring and braking operations.	Remember	CO3	AEE013.08
16	Describe constant torque mode induction motor control	Remember	CO3	AEE013.08
17	Describe constant power mode induction motor control	Remember	CO3	AEE013.08
18	Draw the circuit diagram of voltage source inverter fed three phase induction motor	Remember	CO3	AEE013.08
Part – B (Long Answer Questions)				
1	Explain the speed control of induction motor using AC voltage controller.	Understand	CO3	AEE013.07
2	Describe why constant torque loads are not suitable for AC voltage controller fed induction motor drive.	Remember	CO3	AEE013.07
3	Using 3-phase solid state AC voltage controllers explain clearly how it is possible to achieve 4-quadrant operation of 3-phase induction motors	Understand	CO3	AEE013.07
4	Draw a closed loop block diagram for the AC voltage controller fed induction motor and explain the operation in one quadrant.	Understand	CO3	AEE013.07
5	Explain the four quadrant closed loop control of induction motor drive using AC voltage controller	Understand	CO3	AEE013.07
6	Draw and explain the torque speed characteristics of induction motor through stator voltage control	Understand	CO3	AEE013.07
7	Explain the analysis and performance of induction motor with equivalent circuit diagram.	Understand	CO3	AEE013.07
8	Explain the four quadrant operation of induction motor using AC voltage controller.	Understand	CO3	AEE013.07
9	Explain the mechanical characteristics of a three phase induction motor with stator frequency control.	Understand	CO3	AEE013.08
10	Sketch the mechanical characteristics of a three phase induction motor with V/f method	Understand	CO3	AEE013.08
11	Explain in detail the speed control scheme for a three phase induction motor using PWM inverter	Understand	CO3	AEE013.08
12	Explain the operation of induction motor with constant voltage and different frequencies	Understand	CO3	AEE013.08
13	Describe the importance of v/f control of induction motor	Remember	CO3	AEE013.08
14	Discuss the operation of induction motor control using voltage source inverter	Understand	CO3	AEE013.08
15	Discuss the operation of induction motor control using current source inverter	Understand	CO3	AEE013.08
16	Explain how voltage and frequency are varied in voltage source inverter fed induction motor drives	Understand	CO3	AEE013.09

Part - C (Problem Solving and Critical Thinking Questions)

1	A three phase SCIM drives a blower type load. No load rotational losses are negligible. Show that rotor current is maximum when the motor runs at a slip of 1/3. Find also an expression for maximum rotor current	Understand	CO3	AEE013.07
2	If three phase SCIM runs at a speed of (i) 1455rpm (ii) 1350rpm, determine the maximum current in terms of rated current at these speeds. The induction motor drives a fan and no load rotational losses are ignored.	Understand	CO3	AEE013.07
3	A 3-phase, 400V, 50Hz, 4-pole, 1440 rpm delta connected squirrel cage induction motor has a full load torque of 48.13 N-m. Motor speed is controlled by stator voltage control. When driving a fan load it runs at rated speed at rated voltage. Calculate the motor torque at 1200rpm.	Understand	CO3	AEE013.07
4	A 400V, 50Hz, 3-phase squirrel cage induction motor develops full load torque at 1470 rpm. If supply voltage reduces to 340 V, with load torque remaining constant, calculate the motor speed. Assume speed torque characteristics of the motor to be linear in the stable region. Neglect stator resistance.	Understand	CO3	AEE013.07
5	A 3-ph 20KW, 4-pole, 50Hz, 400V delta connected induction motor has the following parameters per phase $R_1=0.6$ ohm, $R_2=0.4$ ohm, $X_1=X_2=1.6$ ohm. If magnetizing reactance is neglected and operated at 200V, 25Hz with DOL starting. Calculate the current and power factor at the instant of starting and under the maximum torque conditions.	Understand	CO3	AEE013.07
6	A 400V, 4 pole, 50Hz, 3-ph star connected induction motor has $R_1=0$, $X_1=X_2=1$ ohm, $R_2=0.4$ ohm, $X_m=50$ ohm. This induction motor is fed from a constant voltage source of 230V/ph and (ii) a constant current source of 28A. for both parts (i) & (ii) calculate Slip for starting and maximum torques. The supply voltage required to sustain the constant current at the maximum torque.	Understand	CO3	AEE013.07
7	A 3-phase, 440V, 50Hz, 4-pole, 1440 rpm delta connected squirrel cage induction motor has a full load torque of 50 N-m. Motor speed is controlled by stator voltage control. When driving a fan load it runs at rated speed at rated voltage. Calculate the motor torque at 1200rpm.	Understand	CO3	AEE013.07
8	A 440V, 50Hz, 3-phase squirrel cage induction motor develops full load torque at 1400 rpm. If supply voltage reduces to 350 V, with load torque remaining constant, calculate the motor speed. Assume speed torque characteristics of the motor to be linear in the stable region. Neglect stator resistance.	Understand	CO3	AEE013.07
9	A three phase squirrel cage induction motor is developing torque of 1500 synchronous watts at 50 Hz and 1440 rpm (synchronous speed is 1500 rpm). If the motor frequency is increased to 75Hz using constant power mode, determine the new value of torque developed by the motor at constant slip.	Understand	CO3	AEE013.08
10	At 50 Hz the synchronous speed and full load speed are 1500 rpm and 370 rpm respectively. Calculate the approximate value speed for a frequency of 30 Hz and 80% of full load torque for inverter fed induction motor drive.	Understand	CO3	AEE013.08
11	A three phase, 50KW, 1475rpm, 420V, 50Hz, 4 pole, star connected induction motor has the following data: $R_s = 0.4\Omega$, $R_r' = 0.21\Omega$, $X_s = 0.95\Omega$, $X_r' = 32\Omega$. If the frequency is increased to 58Hz by frequency control determine i. The slip at maximum torque ii. The speed at maximum torque iii. The breakdown torque	Understand	CO3	AEE013.08

12	A three phase, 50KW, 1470rpm, 400V, 50Hz, 4 pole, star connected induction motor has the following data: $R_s = 0.42\Omega$, $R_r' = 0.23\Omega$, $X_s = 0.95\Omega$, $X_r' = 0.85\Omega$ and $X_m = 28\Omega$. The motor is operated with stator frequency control. If the slip for maximum torque at the given supply frequency is 0.12. determine i. Supply frequency ii. Break down torque iii. Speed at maximum torque	Understand	CO3	AEE013.08
13	An inverter supplies a 4 pole, 220V 50Hz squirrel cage induction motor. Determine the approximate required output of the inverter for speeds 900rpm, 1200rpm and 1500 rpm	Understand	CO3	AEE013.09
14	A three phase, 56KW, 3560rpm, 460V, 60Hz, 2 pole, star connected induction motor has the following data: $R_s = 0.2\Omega$, $R_r' = 0.18\Omega$, $X_s = 0.13\Omega$, $X_r' = 0.2\Omega$ and $X_m = 11.4\Omega$. The motor is controlled by a constant v/f ratio corresponding to the rated voltage and frequency i. Calculate the maximum torque and the corresponding speed for 60Hz and 30Hz ii. Calculate the maximum torque if R_s is negligible	Understand	CO3	AEE013.08
15	A three phase, 60KW, 1460rpm, 440V, 50Hz, 4 pole, star connected induction motor has the following data: $R_s = 0.4\Omega$, $R_r' = 0.21\Omega$, $X_s = 0.95\Omega$, $X_r' = 32\Omega$. If the frequency is increased to 60Hz by frequency control determine i. The slip at maximum torque ii. The speed at maximum torque iii. The breakdown torque	Understand	CO3	AEE013.08

UNIT-IV

SPEED CONTROL OF INDUCTION MOTORS THROUGH ROTOR RESISTANCE AND VECTOR CONTROL

Part – A (Short Answer Questions)

1	Classify the slip power recovery schemes	Understand	CO4	AEE013.10
3	List the advantages of Kramer system	Remember	CO4	AEE013.10
4	Mention the advantages of static Scherbius drive	Remember	CO4	AEE013.10
5	Draw the speed torque characteristics of rotor resistance control	Remember	CO4	AEE013.10
6	Classify the rotor resistances control in induction motor	Understand	CO4	AEE013.10
7	Draw the circuit diagram of rotor resistance control of induction motor	Remember	CO4	AEE013.10
8	List the applications of rotor resistance control of induction motor	Remember	CO4	AEE013.10
9	Classify the vector control methods in induction motor	Understand	CO4	AEE013.11
10	Define vector control	Remember	CO4	AEE013.12
11	Draw the speed torque characteristics of induction motor drive with variable rotor resistance	Remember	CO4	AEE013.10
12	Define slip power	Understand	CO4	AEE013.10
13	Draw the circuit diagram of static rotor resistance control of induction motor	Understand	CO4	AEE013.10
14	List the advantages of vector control of induction motor drives	Remember	CO4	AEE013.12
15	Write the expression for torque in static kramer drive	Remember	CO4	AEE013.10

Part – B (Long Answer Questions)

1	Draw the speed-torque characteristics of a rotor resistance controlled induction motor and explain the effect of rotor resistance variation	Understand	CO4	AEE013.10
2	Draw and explain the operation of a static Kramer drive	Understand	CO4	AEE013.10
3	Draw and explain static scherbius drive	Understand	CO4	AEE013.10

4	In which way a static Kramer control is different from static scherbius drive	Remember	CO4	AEE013.10
5	Explain the static rotor resistance control of induction motor	Understand	CO4	AEE013.10
6	Describe the principles of vector control of induction motor	Remember	CO4	AEE013.11
7	Explain the indirect methods of vector control of induction motor	Understand	CO4	AEE013.12
8	Explain the direct methods of vector control of induction motor	Understand	CO4	AEE013.11
9	Describe the conventional method of rotor resistance control with speed torque characteristics	Remember	CO4	AEE013.10
10	List the advantages and applications of slip power recovery schemes	Remember	CO4	AEE013.10
11	Draw and explain the closed loop operation of a static Kramer drive	Understand	CO4	AEE013.10
12	Explain the closed loop operation of static rotor resistance control of induction motor	Understand	CO4	AEE013.10
13	Explain the conventional methods used for rotor resistance control of induction motor	Understand	CO4	AEE013.10
14	Describe the importance of field oriented control of induction motor drive	Understand	CO4	AEE013.11
15	Explain the park and clark transformation matrix	Understand	CO4	AEE013.11
Part - C (Problem Solving and Critical Thinking Questions)				
1	A 440V, 50Hz, 6 pole star connected wound rotor motor has the following parameters. $R_s=0.5$ ohm, $R'_r=0.4$ ohm, $X_s=X'_r=1.2$ ohm, $X_m=50$ ohm, stator to rotor turns ratio is 3.5. Motor is controlled by static rotor resistance control. External resistance is chosen such that the breakdown torque is produced at standstill for a duty ratio of zero. Calculate the value of external resistance. How duty ratio should be varied with speed so that the motor accelerates at maximum torque.	Understand	CO4	AEE013.10
2	A 440V, 50Hz, 6 pole, 970rpm star connected 3-ph wound rotor motor has the following parameters referred to stator. $R_s=0.1$ ohm, $R'_r=0.08$ ohm, $X_s=0.3$ ohm, $X'_r=0.4$ ohm, stator to rotor turns ratio is 2. Motor speed is controlled by static scherbius drive. Drive is designed for a speed range of 25% below the synchronous speed. Max. value of firing angle 165 deg, calculate (i) transformer turns ratio, (ii) torque for a speed of 780rpm and $\alpha=140$ deg.	Understand	CO4	AEE013.10
3	A 3 phase, 400V, 6 pole, 50Hz, delta connected, slip ring induction motor has rotor resistance of 0.2Ω and leakage reactance of 1Ω per phase referred to stator. When driving a fan load it runs at full load at 4% slip what resistance must be inserted in the rotor circuit to obtain a speed of 850 rpm neglect stator impedance and magnetizing branch. Stator to rotor turns ratio is 2.2	Understand	CO4	AEE013.10
4	The rotor of a 4 pole, 50Hz wound rotor induction motor has a resistance of 0.3Ω per phase and runs at 1440rpm at full load. Calculate the external resistance per phase which must be added to lower the speed to 1320rpm, the torque being the same before.	Understand	CO4	AEE013.11
5	A static krammer drive is used for the speed control of a 4 pole SRIM fed from 415V, 50Hz supply. The inverter is directly connected to supply. If the motor is required to operate at 1200 rpm, find the firing advance angle of the inverter. Voltage across open circuited slip rings at standstill is 700V. Allow a voltage drop of 0.7V and 1.5V across each of the diodes and SCRs respectively.	Understand	CO4	AEE013.12

6	A 3 phase, 400V, 50Hz, 6 pole, 960rpm star connected wound rotor motor has the following parameters referred to stator. $R_s=0.4\Omega$, $R'_r=0.6\Omega$, $X_s=X'_r=1.4\Omega$, stator to rotor turns ratio is 2. The motor drives a fan load at 960 rpm. What resistance must be connected in each phase of rotor circuit to reduce the speed to 800rpm	Understand	CO4	AEE013.10
7	A 3 phase, 440V, 50Hz, 6 pole star connected slip ring induction motor has the following parameters referred to stator. $R_s=0.5\Omega$, $R'_r=0.4\Omega$, $X_s=X'_r=1.2\Omega$, $X_m=50\Omega$ stator to rotor turns ratio is 3.5. motor is controlled by static rotor resistance control external resistance is chosen such that the breakdown torque is produced at standstill for a duty cycle of zero. Calculate the value of external resistance	Understand	CO4	AEE013.10
8	If 40Ω is the resistance and 0.75 is the duty cycle for the induction motor speed control using chopper, what is the effective value of resistance R_e	Understand	CO4	AEE013.10
9	A three phase wound rotor induction motor is controlled by resistance controlled chopper with three phase diode bridge rectifier. Resistance of 2Ω is connected in the rotor circuit and resistance 4Ω is additionally connected during chopper off time, off of 4msec. If the chopper frequency is 200Hz and motor slip is 2%. Find the motor torque. Resistance values are referred to stator side.	Understand	CO4	AEE013.10
10	The wound rotor motor is rated at 30kw, 1170rpm, 460V, 60Hz. The open circuit voltage is 400V, and the load resistor is 0.5Ω . if the chopper frequency is 200Hz, calculate the time T_{on} so that the motor develops a torque of 200Nm at 900rpm	Understand	CO4	AEE013.10
11	A 400V, 50Hz, 4 pole star connected wound rotor motor has the following parameters. $R_s=0.4\text{ohm}$, $R'_r=0.2\text{ ohm}$, $X_s=X'_r=1.5\text{ ohm}$, $X_m=60\text{ ohm}$, stator to rotor turns ratio is 3.5. Motor is controlled by static rotor resistance control. External resistance is chosen such that the breakdown torque is produced at standstill for a duty ratio of zero. Calculate the value of external resistance. How duty ratio should be varied with speed so that the motor accelerates at maximum torque.	Understand	CO4	AEE013.10
12	The rotor of a 4 pole, 50Hz wound rotor induction motor has a resistance of 0.4Ω per phase and runs at 1460rpm at full load. Calculate the external resistance per phase which must be added to lower the speed to 1260rpm, the torque being the same before.	Understand	CO4	AEE013.11
13	A static krammer drive is used for the speed control of a 4 pole SRIM fed from 440V, 50Hz supply. The inverter is directly connected to supply. If the motor is required to operate at 1300 rpm, find the firing advance angle of the inverter. Voltage across open circuited slip rings at standstill is 600V. Allow a voltage drop of 0.7V and 1.5V across each of the diodes and SCRs respectively.	Understand	CO4	AEE013.12
14	If 60Ω is the resistance and 0.6 is the duty cycle for the induction motor speed control using chopper, what is the effective value of resistance R_e	Understand	CO4	AEE013.10
15	The wound rotor motor is rated at 30kw, 1160rpm, 460V, 60Hz. The open circuit voltage is 440V, and the load resistor is 0.5Ω . if the chopper frequency is 200Hz, calculate the time T_{on} so that the motor develops a torque of 150Nm at 1000rpm	Understand	CO4	AEE013.10

UNIT-V

SPEED CONTROL OF SYNCHRONOUS MOTORS

Part - A (Short Answer Questions)

1	Write torque equation of synchronous motor	Remember	CO5	AEE013.13
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2	List the different methods for variable frequency control in synchronous motor	Remember	CO5	AEE013.14
3	Give the advantages of voltage source inverter	Understand	CO5	AEE013.13
4	Mention the advantages of current source inverter	Remember	CO5	AEE013.13
5	List the possible methods to provide variable voltage variable frequency to synchronous motor fed from VSI	Remember	CO5	AEE013.15
6	Define square wave inverter	Remember	CO5	AEE013.13
7	Describe PWM inverter	Remember	CO5	AEE013.13
8	List the factors effecting speed of synchronous motor	Remember	CO5	AEE013.13
9	Define torque angle	Remember	CO5	AEE013.13
10	List the advantages of constant margin angle control	Remember	CO5	AEE013.14
11	Describe current source inverter	Remember	CO5	AEE013.13
12	Describe voltage source inverter	Remember	CO5	AEE013.13
13	Write the importance of constant v/f ratio control	Understand	CO5	AEE013.13
14	Define DC link converter	Understand	CO5	AEE013.14
15	Describe the function of controller used in self control of synchronous motor drive	Remember	CO5	AEE013.15
Part - B (Long Answer Questions)				
1	Draw and explain the block diagram of a closed loop synchronous motor drive fed from VSI	Understand	CO5	AEE013.13
2	Describe the open-loop method of speed control of a synchronous motor using VSI	Remember	CO5	AEE013.13
3	Explain the speed control of a synchronous motor using PWM inverter.	Understand	CO5	AEE013.13
4	Describe self-controlled and a loop commutated inverter controlled synchronous motor drives in detail and compare them	Remember	CO5	AEE013.15
5	Describe separate controlled mode of operation of a synchronous motor drive in detail	Remember	CO5	AEE013.13
6	Explain the operation of a open loop V/f control of multiple synchronous motor with schematic diagram	Understand	CO5	AEE013.14
7	Describe the converter used for low frequency high power synchronous motor drives with relevant waveforms	Remember	CO5	AEE013.13
8	Describe cycloconverter fed synchronous motor with neat diagrams	Remember	CO5	AEE013.14
9	Compare VSI and CSI fed synchronous motor drives	Understand	CO5	AEE013.13
10	Derive the torque equation of synchronous motor and give the importance of parameters in speed control of synchronous motor	Understand	CO5	AEE013.15
11	Describe self-controlled mode of operation of a synchronous motor drive in detail	Remember	CO5	AEE013.13
12	Draw and explain the block diagram of a closed loop synchronous motor drive fed from CSI	Understand	CO5	AEE013.13
13	Describe the open-loop speed control of a synchronous motor using CSI	Remember	CO5	AEE013.13
14	Describe the applications and advantages of synchronous motor drives	Understand	CO5	AEE013.14
15	Explain the importance of constant v/f ratio control in synchronous motor drives	Understand	CO5	AEE013.13

Part - C (Problem Solving and Critical Thinking Questions)

1	A 500KW, 3-ph, 3.3KV, 50Hz, 0.8(lag) pf, 4 pole star connected synchronous motor has a following parameters. $X_s=15$ ohm, $R_s=0$, rated field current is 10A calculate (i) Armature current and pf at half the rated torque and rated field current (ii) Field current to get upf at the rated torque.	Understand	CO5	AEE013.13
2	A 6MW, 3-ph, 11KV, Y connected, 6 pole, 50Hz, 0.9(lead) pf synchronous motor has $X_s=9$ ohm, $R_s=0$, rated field current is 50A. Machine is controlled by variable frequency control at constant V/F ratio upto the base speed and at constant V above base speed determine the Torque and field current for the rated armature current, 750rpm and 0.8 leading pf.	Understand	CO5	AEE013.13
3	A 6MW, 3-ph, 11KV, Y connected, 6 pole, 50Hz, 0.9(lead) pf synchronous motor has $X_s=9$ ohm, $R_s=0$, rated field current is 50A. Machine is controlled by variable frequency control at constant V/F ratio upto the base speed and at constant V above base speed determines the armature current and power factor for half the rated motor torque, 1500rpm and rated field current.	Understand	CO5	AEE013.14
4	A 3 phase, 400V, 50Hz, 6 pole, star connected round-rotor synchronous motor has $Z_s=0+j2\Omega$. Load torque, proportional to speed squared, is 340N- m at rated synchronous speed. The speed of the motor is lowered by keeping V/f constant and maintaining unity Pf by field control of the motor. For the motor operation at 600rpm, calculate a) supply voltage b) armature current.	Understand	CO5	AEE013.14
5	A 6MW, 3-phase, 11KV, star connected, 6-Pole, 50Hz, 0.9 (leading) power factor synchronous motor has $X_s = 8 \Omega$ and $R_s = 0$. Rated field current is 45A. Machine is controlled by variable frequency control at constant (v/f) ratio up to the base speed and at constant V above base speed. Determine, i) Torque and field current for the rated armature current, 700 rpm and 0.58 leading power factor. ii) Armature current and power factor for half the rated motor torque, 1400 rpm and rated field current,	Understand	CO5	AEE013.15
6	A 6MW, 3-phase, 11KV, star connected, 6-Pole, 50Hz, 0.9 (leading) power factor synchronous motor has $X_s = 8 \Omega$ and $R_s = 0$. Rated field current is 45A. Machine is controlled by variable frequency control at constant (v/f) ratio up to the base speed and at constant V above base speed. Determine, i) Armature current and power factor for regenerative braking power output of 4.2MVA at 700 rpm and rated field current, ii) Torque and field current for regenerative braking operation at rated armature current, 1400 rpm and unity power factor	Understand	CO5	AEE013.15
7	A synchronous motor is controlled by a load commutated inverter, which in turn is fed from a line commutated converter. Source voltage is 6.6kV, 50Hz. Load commutated inverter operates at a constant firing angle α_1 of 130° and when rectifying $\alpha_f = 0^\circ$ dc link inductor resistance $R_d = 0.2 \Omega$. Drive operates in self control mode with a constant (V/f) ratio. Motor has the details; 8MV, 3 phase 6600V, 6pole, 50Hz unity power factor, star connected, $X_s = 2.6 \Omega$, $R_s = 0$. Determine source side converter firing angles for the Motor operation at the rated and 500rpm. What will be the power developed by motor	Understand	CO5	AEE013.14

8	A synchronous motor is controlled by a load commutated inverter, which in turn is fed from a line commutated converter. Source voltage is 6.6kV, 50Hz. Load commutated inverter operates at a constant firing angle α_1 of 130° and when rectifying $\alpha_2 = 0^\circ$ dc link inductor resistance $R_d = 0.2 \Omega$. Drive operates in self control mode with a constant (V/f) ratio. Motor has the details; 8MV, 3 phase 6600V, 6pole, 50Hz unity power factor, star connected, $X_s = 2.6 \Omega$, $R_s = 0$. Determine source side converter firing angles for the Regenerative braking operation at 600 rpm and rated motor current. Also calculate power supplied to the source	Understand	CO5	AEE013.13
9	A 3 phase, 400V, 50Hz, 6 pole, star connected round-rotor synchronous motor has $Z_s = 0 + j2\Omega$. Load torque, proportional to speed squared, is 340N- m at rated synchronous speed. The speed of the motor is lowered by keeping V/f constant and maintaining unity Pf by field control of the motor. For the motor operation at 600rpm. a) Excitation angle b) load angle c) the pull-out torque. Neglect rotational losses	Understand	CO5	AEE013.13
10	A synchronous motor is controlled by a load commutated inverter, which is fed from a line commutated converter,. Source voltage is 606KV, 50Hz. Load commutated inverter operates at a constant firing angle α of 140° and when rectifying $\alpha = 0^\circ$ dc link inductor resistance $R_d = 0.1\Omega$. Drive operates in self control mode with a constant (V/f) ratio. Motor has the details; 8MW, 3-phase, 6600V, 6pole, 50Hz, unity power factor, star connected, $X_s = 2.8\Omega$ $R_s = 0$. Determine source side converter firing angles for the following.	Understand	CO5	AEE013.13
11	A 400KW, 3-ph, 3.2KV, 50Hz, 0.6(lag) pf, 4 pole star connected synchronous motor has a following parameters. $X_s = 15 \text{ ohm}$, $R_s = 0$, rated field current is 12A calculate i. Armature current and pf at half the rated torque and rated field current ii. Field current to get upf at the rated torque.	Understand	CO5	AEE013.13
12	A 3 phase, 415V, 50Hz, 6 pole, star connected round-rotor synchronous motor has $Z_s = 0 + j4\Omega$. Load torque, proportional to speed squared, is 350Nm at rated synchronous speed. The speed of the motor is lowered by keeping V/f constant and maintaining unity Pf by field control of the motor. For the motor operation at 600rpm, calculate a) supply voltage b) armature current.	Understand	CO5	AEE013.14
13	A 6MW, 3-ph, 11KV, Y connected, 6 pole, 50Hz, 0.8(lead) pf synchronous motor has $X_s = 9\text{ohm}$, $R_s = 0$, rated field current is 45A. Machine is controlled by variable frequency control at constant V/F ratio upto the base speed and at constant V above base speed determines the armature current and power factor for rated motor torque, 1500rpm and rated field current.	Understand	CO5	AEE013.14
14	A 3 phase, 440V, 50Hz, 6 pole, star connected round-rotor synchronous motor has $Z_s = 0 + j6\Omega$. Load torque, proportional to speed squared, is 300N- m at rated synchronous speed. The speed of the motor is lowered by keeping V/f constant and maintaining unity Pf by field control of the motor. For the motor operation at 600rpm. a) Excitation angle b) load angle c) the pull-out torque. Neglect rotational losses	Understand	CO5	AEE013.13

15	A 450KW, 3-ph, 3.3KV, 50Hz, 0.6(lag) pf, 4 pole star connected synchronous motor has a following parameters. $X_s=10$ ohm, $R_s=0$, rated field current is 8A calculate i. Armature current and pf at rated torque and rated field current ii. Field current to get upf at the rated torque.	Understand	CO5	AEE013.13
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