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EE8353 - ELECTRICAL DRIVES AND CONTROLS

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OBJECTIVES

- To understand the different characteristics of electrical DC and AC motors
- To study the braking mechanism of electrical motors
- To study the conventional and solid-state drives
- To study the different methods of starting D.C motors and induction motors
- To understand the basic concepts of different types of electrical machines and their performance

UNIT I INTRODUCTION **8**

Basic Elements – Types of Electric Drives – factors influencing the choice of electrical drives – heating and cooling curves – Loading conditions and classes of duty – Selection of power rating for drive motors with regard to thermal overloading and Load variation factors.

UNIT II DRIVE MOTOR CHARACTERISTICS **9**

Mechanical characteristics – Speed-Torque characteristics of various types of load and drive motors – Braking of Electrical motors – DC motors: Shunt, series and compound - single phase and three phase induction motors.

UNIT III STARTING METHODS **8**

Types of D.C Motor starters – Typical control circuits for shunt and series motors – Three phase squirrel cage and slip ring induction motors.

UNIT IV CONVENTIONAL AND SOLID STATE SPEED CONTROL OF D.C. DRIVES **10**

Speed control of DC series and shunt motors – Armature and field control, Ward-Leonard control system - Using controlled rectifiers and DC choppers –applications.

UNIT V CONVENTIONAL AND SOLID STATE SPEED CONTROL OF A.C. DRIVES **10**

Speed control of three phase induction motor – Voltage control, voltage / frequency control, slip power recovery scheme – Using inverters and AC voltage regulators – applications.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Completion of this subject, the students can able to explain different types of electrical machines and their performance

TEXT BOOKS:

1. Vedam Subrahmaniam, “Electric Drives (concepts and applications)”, Tata McGraw-Hill, 2001
2. Nagrath .I.J. & Kothari .D.P, “Electrical Machines”, Tata McGraw-Hill, 1998

REFERENCES:

1. Pillai.S.K “A first course on Electric drives”, Wiley Eastern Limited, 1998
2. Singh. M.D., K.B.Khanchandani, “Power Electronics”, Tata McGraw-Hill, 1998
3. Partab. H., “Art and Science and Utilisation of Electrical Energy”, Dhanpat Rai and

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DETAILED LESSON PLAN AIM

To expose the students to understand the main concept of electrical drives their characteristics, braking, starting, control and applications.

OBJECTIVES

- To understand the different characteristics of electrical DC and AC motors
- To study the braking mechanism of electrical motors
- To study the conventional and solid-state drives
- To study the different methods of starting D.C motors and induction motors
- To understand the basic concepts of different types of electrical machines and their performance

S.No	Topics Covered	Hours	Cum. Hours	Books Referred
	UNIT I INTRODUCTION			
1	Introduction and Basic Elements of electrical drives	1	1	T_1
2	Types of Electric Drives	1	2	T_1
3	Factors influencing the choice of electrical drives	1	3	T_1
4	Heating curves of Electrical Machines	1	4	T_1
5	Cooling curves of Electrical Machines	1	5	T_1
6	Loading conditions and classes of duty	1	6	T_1
7	Selection of power rating for drive motors with regard to thermal overloading and Load variation factors	1	7	T_1
8	Selection of power rating for drive motors with regard to Load variation factors	1	8	T_1
9	Numerical on heating and cooling of Electrical drives	1	9	T_1
	UNIT II DRIVE MOTOR CHARACTERISTICS			
10	Introduction to Mechanical characteristics of electrical motor drives	1	10	T_2
11	Speed-Torque characteristics of DC shunt drive motors	1	11	T_2
12	Speed-Torque characteristics DC series and compound drive motors	1	12	T_2
13	Speed-Torque characteristics of various types of Induction drive motors	1	13	T_2
14	Introduction to braking of electrical motors	1	14	T_2
15	Braking of Electrical motors – DC motors: Shunt motor	1	15	T_2
16	Braking of Electrical motors – DC motors: series and compound motor	1	16	T_2
17	Braking of Electrical motors – AC motors: single phase induction motors.	1	17	T_2

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18	Braking of Electrical motors – AC motors: three phase induction motors.	1	18	T_2
UNIT III STARTING METHODS				
19	Introduction to DC Motor starters	1	19	T_2
20	D.C Motor starters – Typical control circuits for shunt motors	1	20	T_2
21	D.C Motor starters – Typical control circuits for series and compound motors	1	21	T_2
22	Introduction to AC Motor starters	1	22	T_2
23	AC Motor starters – Three phase squirrel cage induction motors.	1	23	T_2
24	AC Motor starters – Three phase squirrel cage induction motors.	1	24	T_2
25	AC Motor starters – Three phase squirrel cage induction motors.	1	25	T_2
26	AC Motor starters – Three phase slip ring induction motors.	1	26	T_2
27	AC Motor starters – Three phase slip ring induction motors.	1	27	T_2
UNIT IV CONVENTIONAL AND SOLID STATE SPEED CONTROL OF DC DRIVES				
28	Introduction to conventional Speed control of DC motors	1	28	T_1,T_2
29	Speed control of DC shunt motors – Armature and field control	1	29	T_1,T_2
30	Speed control of DC series motors – Armature and field control	1	30	T_1,T_2
31	Ward-Leonard control system	1	31	T_1,T_2
32	Introduction to solid state Speed control of DC motors	1	32	T_1,T_2
33	Speed control Using controlled rectifiers half control	1	33	T_1,T_2
34	Speed control Using controlled rectifiers fully control	1	34	T_1,T_2
35	Speed control by DC choppers	1	35	T_1,T_2
36	Speed control by DC choppers –Class A,B	1	36	T_1,T_2
37	Speed control by DC choppers – 4 quadrant	1	37	T_1,T_2
UNIT V CONVENTIONAL AND SOLID STATE SPEED CONTROL OF AC DRIVES				
38	Introduction to Speed control of AC motor Drives	1	38	T_1,T_2
39	Speed control of three phase induction motor	1	39	T_1,T_2
40	Speed control of three phase induction motor – Voltage control	1	40	T_1,T_2
41	Speed control of three phase induction motor voltage / frequency control	1	41	T_1,T_2
42	Conventional speed control of slip power recovery scheme-Sherbius system	1	42	T_1,T_2
43	Conventional speed control of slip power recovery scheme-Krammer system	1	43	T_1,T_2
44	Speed control of three phase induction motor – Using inverters	1	44	T_1,T_2

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45	Speed control of three phase induction motor – Using AC voltage regulators	1	45	T_1,T_2
46	Solid state speed control of slip power recovery scheme-Sherbius system	1	46	T_1,T_2
47	Solid state speed control of slip power recovery scheme-Krammer system	1	47	T_1,T_2

Industrial Connectivity

- Manufacturing Industry
- Steel Industries &Welding Industries

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UNIT 1 – INTRODUCTION

PART A

1. What is meant by electrical drives?

Systems employed for motion control are called "Drives" and many employ any of the prime movers such as, diesel or petrol engines, gas or steam turbines, hydraulic motors and electric motors for supplying mechanical energy for motion control. Drives employing electrical motors are known as "Electrical drives".

2. What are the different types of drives? (Dec 2014)

1. Group drive 2. Individual drive 3. Multi motor drive

3. What are the different types of electrical drives? (June 2013)

1. DC drives 2. AC drives

4. What are the advantages of electric drives?

i. flexible control

ii. Drives can be provided with automatic fault detection systems

iii. They are available in wide range of torque, speed and power.

iv. It can operate in all the four quadrants of speed-torque plane.

5. Mention the different factors for the selection of electric drives.

(May 2013) (May 2014)

1. Steady state operation requirements 2. Transient operation requirements
3. Requirements related to the source 4. Capital and running cost, maintenance needs, life 5. Environment and location 6. Reliability

6. What are the parts of electrical drives?(May 2014)

1. Electrical motors and load 2.Power modulator 3.Sources 4. Control unit
5. Sensing unit

7. What are the applications of electrical drives?

1. Paper mills 2.Electric traction 3.Cement mills 4.Steel mills

8. What are the advantages of group drive?

a) Initial cost is less b) Less space is required in group drive c) Maintenance cost is less d) Group drive system is useful because all operation are stopped simultaneously

9. What are the different types of classes of duty?

Continuous duty
Short time duty operation of motor
Intermittent periodic duty
Intermittent periodic duty with starting

} Main classes of duties

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Intermittent periodic duty with starting & braking

Continuous duty with intermittent periodic loading

Continuous duty with starting & braking

Continuous duty with periodic load changes

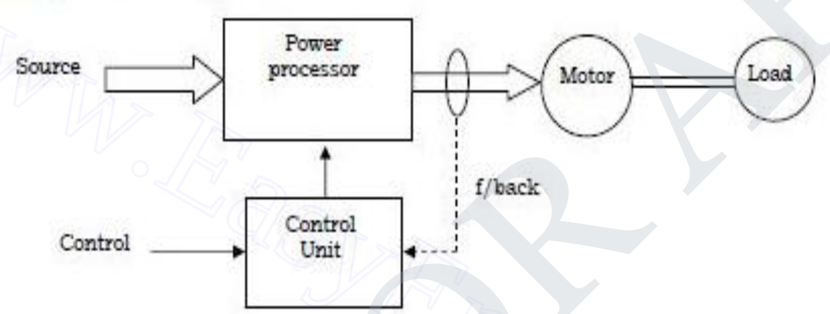
10. What is meant by cooling time constant?

Cooling time constant is defined as the time required to cool the machine down to 0.368 times the initial temperature rise above the ambient temperature.

11. What are the factors that influence the choice of electrical drives? (Dec 2011)

1. Shaft power & speed 2.Power range 3.Speed range 4.Starting torque
5.Efficiency 6.Starting torque 7.Influence on the supply network

12. Draw the basic block diagram of electric drive. (Dec 2013)



13. What is meant by "load equalization"?

In the method of "load Equalization" intentionally the motor inertia is increased by adding a flywheel on the motor shaft, if the motor is not to be reversed. For effectiveness of the flywheel, the motor should have a prominent drooping characteristic so that on load there is a considerable speed drop.

14. What is heating time constant?

Heating time constant is defined as the time taken by the machine to attain 0.632 of its final steady temperature rise. The heating time constant of the machine is the index of the time taken by the machine to attain its final steady temperature rise.

PART-B

1. What is meant by electrical drive? Explain the types of electrical drive?

Electrical Drive:

Systems employed for motion control are called "Drives" and many employ any of the prime movers such as, diesel or petrol engines, gas or steam turbines, hydraulic motors and electric motors for supplying mechanical energy for motion control. Drives employing electrical motors are known as "Electrical drives".

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Types of electrical Drives:

The drive system with Electric as prime mover is known as Electric drive. Depending on type of the motor used Electric drive system is classified
(i)AC drives and (ii)DC drives.

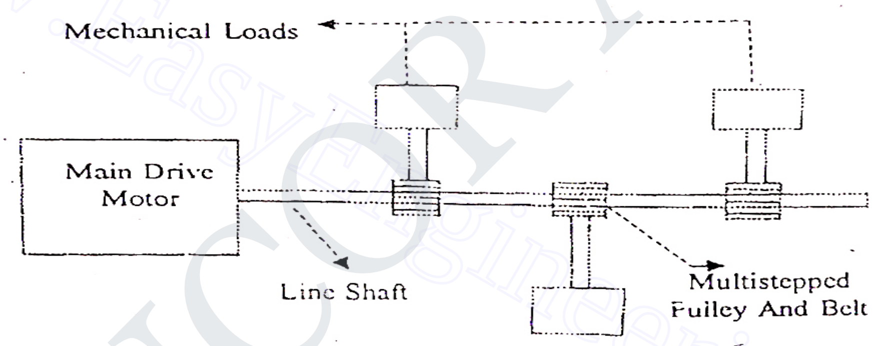
Generally the electric drive system consists of Electric drive motor, Energy Transmitting device, Mechanical load and Speed control devices and circuitry.

Depending upon the mode of connection between Electric drive motor and Mechanical load, the number of drive motor used and the layout of drive, the electrical drive motor is classified as,

1. Group drive or Line shaft drive, 2. Individual drive, 3. Multi-motor drive.

Group Drive or Line Shaft Drive

The Group drive consists of a single motor which drives or actuates several mechanical load by means of one or more line shafts supported on bearings. It is also called as 'Line Shaft Drive'.



Block Diagram showing Layout of Group Drive

The line shaft of the group drive is connected with mechanical load through multi-stepped pulleys and belts. The size of the line shaft pulley and load shaft pulley determines the speed of the drives machines or loads.

Advantage of Group Drive

1. The group drive is the most economic even after taking into account the cost of line shaft, pulleys, belts and other installations. This is because the rating of the main motor is less than sum of the rating of the individual motors required to drive each load separately.
2. All the loads may not be working at the same time. So the HP of the group drive motor is less than the sum of HP of individual motor working separately. So the cost is reduced.

Disadvantages of Group Drive

Nowadays group drive is rarely used because of following factors.

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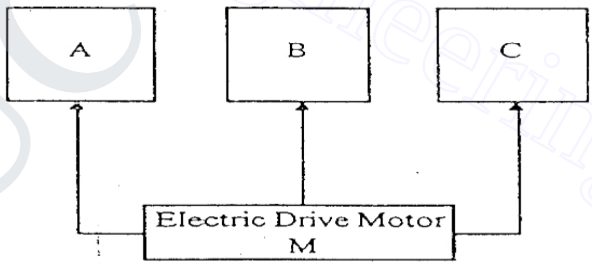
1. If the fault occur in driving motor, then all the driven loads becomes idle.
2. Since line shaft is long and large and numbers of pulleys are connected, considerable power loss takes place in energy transmitting device. [Line shaft]
3. The level of noise produced at the work site is high
4. The driven loads have to be installed to suit the layout of line shaft.
5. Due to the line shaft arrangement and belts the drive do not have clean appearance.
6. Due to the belt and multi stepped pulley arrangement, this drive is not safe.
7. An Individual load speed control is very difficult because of the usage of stepped pulleys and belt arrangement.

Applications of Group Drive

Group drive is used in processes where the stoppage of one operation needs the stoppage of sequence of operation, as in the case of 'Textile mills'

Individual Drive

The individual drive systems consist of only one electric drive motor. This system activates various parts of single Mechanical equipment. Here each part of Mechanical equipment is considered as a separate load. The single electric drive motor is connected to all the individual mechanical load through suitable energy transmission devises



In the above block diagram the mechanical equipment has single electric drive motor M and three individual load parts namely A, B and C. The individual load parts A,B and C are connected to the electric motor M. The individual load parts are kept at different position inside the mechanical equipment. Each load part is connected to the electric motor through different energy transmission devices.

Example for individual drive is Lathe. Here the individual motor drive is used for activating various parts i.e., rotating the spindle with the tools, moving the feed (job) and drives cooling and lubricating pumps. Here all the operation mentioned is carried out by single electric motor. The energy transmission devices used here are gears and pulley etc.

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Advantages of individual Drive:

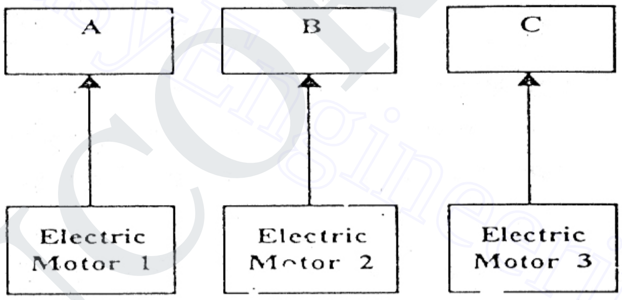
1. Individual drive has affective layout flexibility i.e. all the drive parts are placed inside single equipment.
2. Individual drive provides safe working condition, because no moving parts are visible.
3. The appearance of the Individual drive is clean and neat.

Disadvantages of Individual Drive:

1. The Individual drives are less efficient because the single electric motor is connected with number of load parts through number of gears. So the energy loss is high.
2. The failure of electric motor stops the entire operations of the mechanical equipment.

Multi-Motor Drive:

The Multi-motor drive has separate electric motor to drive the different load parts of single mechanical equipment. In some cases all the motors are used to drive only one load part of the equipment to fulfil different operation.



The block diagram shows Multi-motor drive system with three separate electric motors (1, 2, and 3). Each motor drives separate load parts (A, B, C). In some cases there is only one load, each motor drive this load at different instant of time.

Example of multi-motor drive is travelling cranes .The Travelling crane has only one load i.e., the movies arm with hook. There are three basic operations in Travelling crane, namely Hoisting (lowering and raising), Long-travel motion (stretching forward and backward of the arm) and Cross-travel motion(moving to the Right and Lift) These three operations are carried out by three separate electric motor i.e. one for Hoisting, one for cross-travel motion and one for long –travel motion.

Applications of Multi – Motor Drive:

Multi –motor is mostly used in

1. Paper mills, 2. Rolling mills, 3. Rotary printing machines 4. Metal working machines.

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Advantages of Multi-Motor Drive:

1. Multi-motor driver offers flexibility of layout of loads.
2. Stoppage of one motor do not affects the operation of other motors and loads.
3. The speed control is very easy.

Disadvantage of Multi-Motor Drive:

1. Its only disadvantage is that it is costly in the initial stages
2. The usage of number of motors leads to confusion during control operation.

2. Compare the AC and DC drives.

S.No	DC Drives	AC Drives
1	The Power circuit and control circuits are simple & inexpensive	The power circuit and control circuits are complex
2	It requires frequent maintenance	Less maintenance required
3	The commutation makes the motor bulky, costly and heavy.	These problems are not there. Motors are inexpensive, particularly the squirrel cage motor.
4	Speed and design rating are limited due to commutation.	Speed and design rating have no upper limits.
5	It is used in certain locations only.	It can be used in all locations.
6	Fast response and wide speed range are smoothly achieved by conventional method and solid state control.	In solid state control the speed range is wide and in conventional method it is stepped and limited.
7	The line conditions are very poor. ie, Poor power factor, harmonic distortion of the current.	For regenerative drives the line power factor is poor. For non-regenerative drives the line power factor is better.
8	Power/Weight ratio is small.	Power/Weight ratio is large

3. What are all the Factors Influencing choice of Electrical Drives? Explain.

There are certain factor that governs or influences, the selection choice electrical drives. They are:

1. Availability of Electrical Supply

The electric drive is a drive system with electrical motor as a prime mover. The selection of electrical drive is based on the availability of electrical supply. There are three-types electrical supplies, namely AC supply, DC supply, and Rectified DC supply. If AC supply is available. Then AC drive is selected motor. An AC drive consists of AC

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motor as a drive motor .If DC supply is available, then DC drive is selected .DC drive consist of DC motor as a drive motor. Hence nature of electrical supply available governs selection of electric drive.

2. Nature of Operation characteristics of Electric drive motors

The electric drive motor has different types of operating characteristics such as

1) Starting characteristics
2) Running characteristics
3) Speed control characteristics
4) Braking characteristics

For example the running characteristic of electric drive motor shows how the motor behaves where it is loaded .In some cases if the load is increased , the speed of the motor is drastically reduced .so such motors are not selected for constant speed applications.

3. Economic Consideration

The electrical motor is selected based on two economic considerations, namely

a) Initial cost:

The initial cost is nothing out capital cost. This is the cost occurred during purchase and erection.

b) Running cost :

This is the cost running the electric drive E.G. maintenance cost, fuel cost etc.

4. Type of the Drive system

Type of the Drive system available also governs the choice of electric motor. There are three types of drive system namely Group drive, Individual diver and Multi motor drive. Assume that at any particular location, different small loads are available. Since the loads are separate unit, it can be driven by single large motor (group drive). So here a DC motor or an AC motor is selected with huge HP rating.

5. Types of Load

The type of load available, also governs the selection of electric drive. Generally the loads are classified based on the Torque characteristics .Torque is the twisting force required to drive (rotate) the load, based on the Torque characteristics loads are classified as follows.

1. Load requiring constant Torque with speed
2. Load requiring increasing Torque with speed
3. Load requiring high starting Torque (high inertia load)

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Assume that load cannot with high inertia available .This high inertia loads cannot be accelerated or decelerated quickly .They require high starting Torque. Therefore motor with high starting torque such as DC series or 3 (There Phase) Slip ring induction motor is selected .Thus type of load influence the choice of electric motor.

6. Mechanical considerations

(i)Type of enclosure (ii)Type of bearings (iii)Type of Transmission devices

7. Environmental Considerations

(i)Noise pollution (ii)Environmental Pollution

8. Load – With standing Capability of motors

The size and rating required for the drive motor influence the selection of the electric drive motor. The size of the motor describes load- withstanding capability .when the motor is loaded, the line current drawn by the motor increases. As a result losses increases and more heat is developed .If the heat is hot dissipated then insulation in the motor fails leading to complete breakdown of the motor. Here duty cycle of the load and the Torque requirement are important factors in deciding size and rating of the motor.

4. Explain about the classes of duty in detail.

Classes of Duty:

The Size and rating of a motor is selected from the viewpoint of heat development, when the motor is loaded. The temperature inside the motor rises due to the losses taking place in it. The losses are mainly due to high current taken by the motor, when it is loaded. Temperature rise varies directly with the square of current (Losses I2 and T I2). If the heat is not dissipated properly, then temperature rises to the extreme limit. As a result, motor get damaged.

The heating of the motor depends upon load conditions or duty to which it is subjected. Here the Duty means the application of load with respect to time. If the load is applied continuously without any gap, then it is known as Continuous Duty. In this case, motor heats up and never cools down. From the above discussion it is clear that load applied to motor with respect to time is known as Duty. The duty can be classified under three broad categories, namely

a. Continuous duty, b. Short time duty, c. Intermittent duty

(a) Continuous duty

The load, which is applied continuously without any break is known as Continuous duty. I.e the drive motor always run with some load. It is classified into three types as follows

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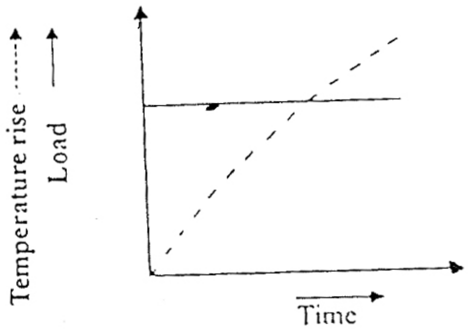
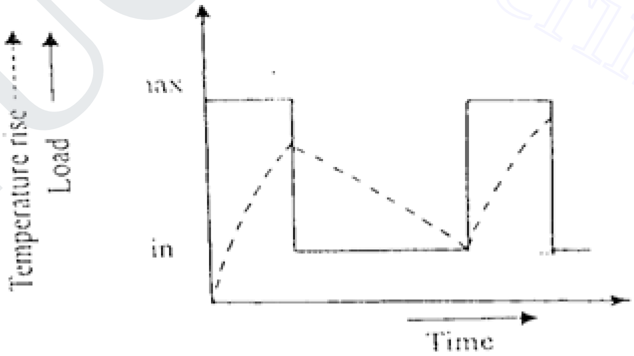
(i) Continuous Duty with Constant Load (ii) Continuous Duty with Short Time Load (iii) Continuous Duty with Intermittent Load

(i) Continuous Duty With Constant Load



The load that is continuous without any break and of constant magnitude is known as Continuous Duty with Constant Load. Here the motor is always loaded with constant load. Due to continuous duty temperature rises exponentially in the drive motor as the time progresses. The duty (Load) is shown as straight line and the temperature rise is shown as broken line in the fig above. Since temperature rises continuously, selection of rating of the motor is very important. The rating of the motor selected for Continuous duty load is known as Continuous rating. The continuous rating here means, the temperature rise is inside the maximum limit, when the motor is continuously loaded. Since temperature rises exponentially, small load is normally selected for continuous rating. The example of this kind of load is fan type loads.

(ii) Continuous Duty with Short Time Load



The load that is continuous and fluctuates between two levels (maximum and minimum) with the maximum level existing only for short duration is known as Continuous Duty with Short time Load. Here the time interval between the occurrences of two maximum levels is large. Even thought the load fluctuates, the motor is constantly loaded with the minimum level load. The temperature rises when the load is at maximum level and falls when at minimum level. The temperature never falls to zero

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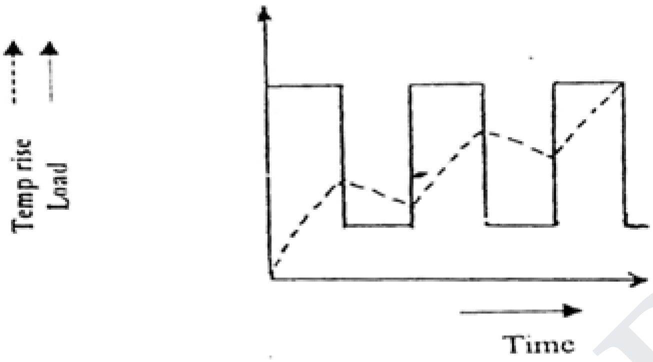
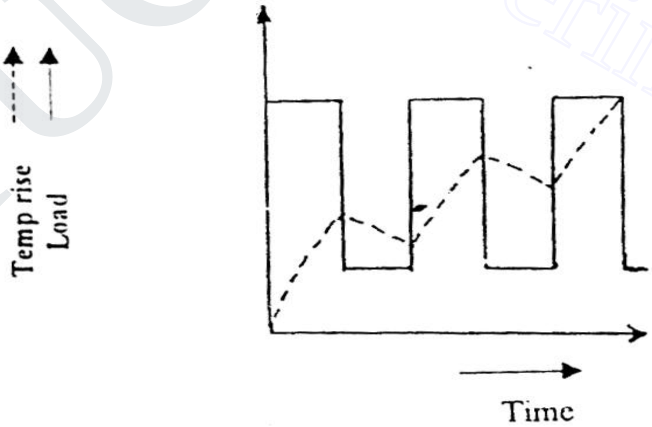
level (ambient temperature) because the motor is always loaded with minimum level of load. The best example of this kind of load is Metal cutting lathes and conveyors.

(iii)Continuous Duty with Intermittent Load



The load that is continuous and fluctuates between two levels (maximum and minimum) with the maximum level occurring intermittently is known as Continuous Duty With Intermittent Load. Her time interval between the occurrence two maximum levels is small. Even though the load fluctuates intermittently, the motor is continuously loaded with the minimum level load..the temperature rises when the load is at maximum level and falls when at minimum level. The temperature never falls to zero level (ambient temperature) because the motor is always loaded with minimum level of load. The temperature rises steadily because of intermittent nature of the load. The bet examples of kind o load are Metal cutting lathes and Conveyors.

(b) Short time duty



The load that exists only for the short duration of time is known as short Time Load. Between two short time loads the motor is not loaded and it is switched off. The time interval between two short time load is known as Off-Load Period. When the motor is subjected to short time load, the temperature rises and during the off load period the motor cool completely and the temperature falls to the ambient temperature (room or

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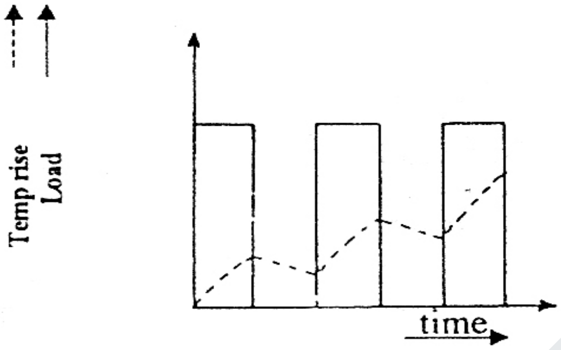
initial temperature). The best examples of this kind of load are Weirs, Household appliances, Automatic lock gates and bridges.

(c) Intermittent duty



The load that occurs intermittently with very small off-load period is known as Intermittent Duty. The time interval between two load is known as Off-Load Period. Between two load occurrences the motor can be switched off. When the motor is subjected to intermittent load, the temperature rises during the on-load period and the temperature falls during off-load period. But the motor is not completely cooled to ambient temperature. This is because the off-load period is very small and not sufficient to cool to ambient temperature. The best examples of this kind of load are Weirs, Household appliances, Automatic lock gates and bridges.

5. Explain and derive the Heating curve of electrical motor drive.

The heating and cooling calculations are made based on the following assumptions.

(i) The machine is considered to be homogeneous body having a uniform temperature gradient that means it has the same temperature throughout its body

(ii) Heat dissipation taking place is proportional to the differences of temperature of the body and the surrounding medium. No heat is radiated.

(iii) The rate of dissipation of heat is constant at all temperatures.

Heating cure:

During operation of motor various losses such as copper loss, iron loss and windage loss takes place. Due to this losses heat produced inside the machine and increases the temperature of the motor. This motor temperature is greater than ambient temperature, the part of hear produced flows to the surrounding medium

Assuming the heat developed is proportional to the losses, we have the standard and balanced equation.

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$$\textbf{Total heat generated in the body}$$

$$= \textbf{Heat dissipated to surrounding medium}$$

$$+ \textbf{Heat stored in body /heat abserbed.}$$

$$Wdt = A\lambda\theta dt + GS\,d\theta \qquad \textbf{(1)}$$

Where W = power loss in the motor due to heat in watts

A= area of cooling surface in m^2

λ= rate of heat dissipation in W/ m^2/C^o

G= weight of active part of motor in Kg

S= specific heat of the materials used in the body in J/Kg/ C^o

θ= temperature raise of the body

dθ= temperature raise in a small interval dt

by rearrange the equation (1)

$$Wdt - A\lambda\theta dt = GS\,d\theta$$

$$(W - A\lambda\theta)dt = GS\,d\theta$$

$$A\lambda\left(\frac{W}{A\lambda} - \theta\right)dt = GS\,d\theta$$

$$\left(\frac{W}{A\lambda} - \theta\right)dt = \frac{GS}{A\lambda}\,d\theta$$

$$\frac{dt}{\left(\frac{GS}{A\lambda}\right)} = \frac{d\theta}{\left(\frac{W}{A\lambda} - \theta\right)} \qquad \textbf{(2)}$$

The temperature raise reaches its maximum value, then the body is said to have reached the maximum temperature raise θ_m

Therefore the equation (1) becomes

Heat generated = Heat dissipated

$$Wdt = A\lambda\theta m dt$$

$$W = A\lambda\theta m$$

$$\theta m = \frac{W}{A\lambda} \qquad \textbf{(3)}$$

Substitute equation (3) in (2) we get

$$\frac{dt}{\left(\frac{GS}{A\lambda}\right)} = \frac{d\theta}{(\theta m - \theta)} \qquad \textbf{(4)}$$

Integrating above equation both sides, we get

$$\frac{A\lambda}{GS}\,t = -\ln(\theta m - \theta) + K \qquad \textbf{(5)}$$

At t=0, $\theta = \theta_0$

$$0 = -\ln(\theta m - \theta) + K$$

$$K = \ln(\theta m - \theta o) \qquad \textbf{(6)}$$

Substitute eqn (6) in eqn (5) we get,

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$$\frac{A\lambda}{GS} t = -\ln(\theta m - \theta) + \ln(\theta m - \theta o)$$

$$e^{\left(\frac{A\lambda}{GS}\right)t} = \frac{(\theta m - \theta o)}{(\theta m - \theta)}$$

$$(\theta m - \theta)e^{\left(\frac{A\lambda}{GS}\right)t} = (\theta m - \theta o)$$

$$\theta = \theta m - (\theta m - \theta o)e^{-\left(\frac{A\lambda}{GS}\right)t} \quad \textbf{(7)}$$

Where $\left(\frac{GS}{A\lambda}\right) = \tau =$ Thermal heating time constant

It is defined as time taken to reach 63.2% steady state temperature θm

Now the equation (7) becomes

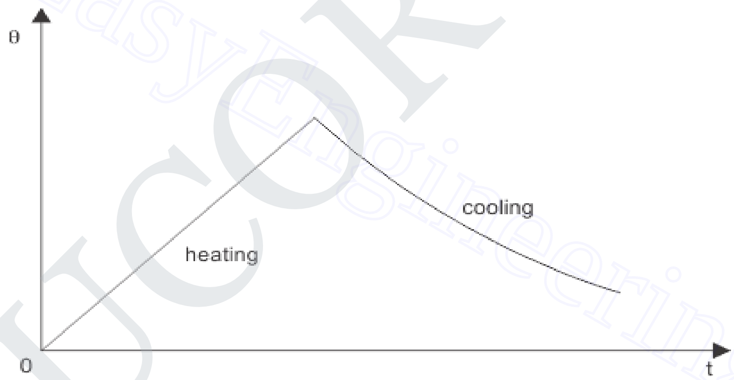
$$\theta = \theta m - (\theta m - \theta o)e^{-\left(\frac{t}{\tau}\right)} \quad \textbf{(8)}$$

Motor starting from cool conditions and hence $\theta o = 0$ C^{o}

Substituting this condition in eqn (8) we get

$$\theta = \theta m\,[1 - e^{-\left(\frac{t}{\tau}\right)}] \quad \textbf{(9)}$$

Based on the eqn (8) & (9) the heating curve of the machine is drawn.



Heating and Cooling curves

PART C

6. Explain and derive the Cooling curve of electrical motor drive.

Cooling curve:

If the machine is switched off from main supply or when the load on the machine is reduced the machine get cools. It cools to the ambient temperature, when it is switched off

There is no heat generated and all the heat stored in the machine is dissipated to surroundings. The balance equation can be written as bellow

$$\textbf{Heat generated in the body} + \textbf{Heat stored in body} = \textbf{Heat dissipated to surrounding medium}$$

$$\text{Wdt} + GS\, d\theta = A\lambda'\, \theta dt \quad \textbf{(1)}$$

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$$GS\, d\theta = A\lambda'\theta dt - Wdt$$

$$\frac{GS}{A\lambda'}\, d\theta = \left(\theta - \frac{W}{A\lambda'}\right) dt \qquad \textbf{(2)}$$

$d\theta$ - degrease in temperature, so a negative sign has to be included in the left hand side of eqn(2)

$$-\frac{GS}{A\lambda'}\, d\theta = \left(\theta - \frac{W}{A\lambda'}\right) dt$$

$$-\frac{d\theta}{\left(\theta - \frac{W}{A\lambda'}\right)} = \frac{dt}{\frac{GS}{A\lambda'}} \qquad \textbf{(3)}$$

When the final temperature drop θ_f is reached then the heat generated if equal to heat dissipated.

$$Wdt = A\lambda'\,\theta_f\, dt$$

$$\theta_f = \frac{W}{A\lambda'} \qquad \textbf{(4)}$$

Substituting eqn(4) in eqn (3) we get

$$-\frac{d\theta}{(\theta - \theta f)} = \frac{dt}{\frac{GS}{A\lambda'}}$$

Integrating the above equation both sides, we get

$$-\ln(\theta - \theta f) = \frac{A\lambda'}{GS} t + K$$

$$\ln(\theta - \theta f) = -\frac{A\lambda'}{GS} t + K \qquad \textbf{(5)}$$

at t=0, $\theta = \theta_m$

The eqn (5) becomes

$$\ln(\theta_m - \theta f) = K \qquad \textbf{(6)}$$

Substitute eqn (6) in eqn (5) we get

$$\ln(\theta - \theta f) = -\frac{A\lambda'}{GS} t + \ln(\theta_m - \theta f)$$

$$\theta = \theta_f + (\theta_m - \theta f)\, e^{-\left(\frac{A\lambda'}{GS}\right)}$$

where $\frac{GS}{A\lambda'} = \tau'$ = cooling time constant

$$\theta = \theta_f + (\theta_m - \theta f)\, e^{-\left(\frac{t}{\tau'}\right)}$$

$$\theta = \theta_f \left(1 - e^{-\left(\frac{t}{\tau'}\right)}\right) + \theta_m e^{-\left(\frac{t}{\tau'}\right)} \qquad \textbf{(7)}$$

The above equation is suitable only when the load is switched off, Otherwise the equation (7) becomes

$$\theta = \theta_m e^{-\left(\frac{t}{\tau'}\right)} \qquad \textbf{(8)}$$

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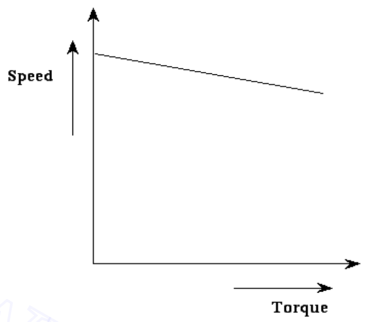
The above equation represents the cooling time constant of the motor.

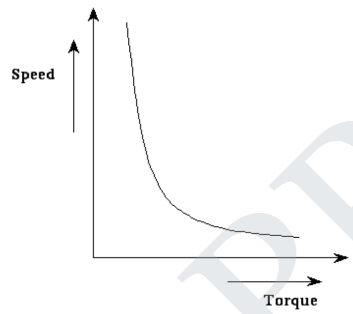
UNIT 2 - DRIVE MOTOR CHARACTERISTICS

PART A

1. Draw the speed-torque characteristics of dc shunt motor and series motor.

(May2013) (May 2014)





2. A series motor should never be started without some mechanical load why?

When the load current Ia falls to a small value, speed becomes dangerously high. Hence a series motor should never be started without some mechanical load.

3. What is rheostat braking?

In rheostat breaking the armature is disconnected from the supply and external resistance is connected as a variable resistance. The braking is controlled by varying the series resistance.

4. What is the application of dc motor?

DC shunt motor:-

1. For driving constant speed operations 2. Machine tools 3. Lathes
4. Blowers and fans 5. Centrifugal pumps 6.Reciprocating pumps

DC series motor:-

1.Electric locomotives 2. Rapid transit systems 3.Trolley cars 4.Cranes and hoists 5. Conveyors

DC compound motor:-

1. Elevators.2. Air compressors3.Rolling mills 4. Heavy planers

5. A dc shunt motor is called as constant speed motor-why?

The drop in speed from no-load fuel-load is small; hence the dc shunt motor is also called as constant speed motor.

6. What are the different types of electric braking? (Nov2013)(May 2013)

1. Regenerative braking 2. Dynamic braking 3. Plugging

7. What are the advantages of electric braking?

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1. High efficient method 2. Low maintenance 3. Braking is very smooth

8. What is meant by regenerative braking? (Dec 2011)

In the regenerative braking operation, the motor operators as a generator, while it is still connected to the supply. Here, the motor speed is greater than the synchronous speed. Mechanical energy is converted into electrical energy, part of which is returned to the supply and rest of the energy is last as heat in the winding and bearings.

9. What is meant by plugging? (Dec 2014)

The plugging operation can be obtained by changing the polarity of the motor. For a machine, the phase sequence of the starter windings and dc machines the polarities of the field or armature terminals.

10. What is the necessity of braking? (Dec 2014)

The quickness and accuracy of braking techniques determine the productivity and quality of the manufactured goods. Control the motor for our optimum requirement.

PART B

1.(a)Explain speed – torque characteristics of dc shunt motor with suitable diagrams. (Dec-2014)

Torque speed characteristics of a shunt motor:

A constant applied voltage V is assumed across the armature. As the armature current Ia, varies the armature drop varies proportionally and one can plot the variation of the induced emf E. The mmf of the field is assumed to be constant. The flux inside the machine however slightly falls due to the effect of saturation and due to armature reaction. The variation of these parameters is shown in Fig. Knowing the value of E and flux one can determine the value of the speed. Also knowing the armature current and the flux, the value of the torque is found out. This procedure is repeated for different values of the assumed armature currents and the values are plotted as in Fig.

From these graphs, a graph indicating speed as a function of torque or the torque-speed characteristics is plotted. As seen from the figure the fall in the flux due to load increases the speed due to the fact that the induced emf depends on the product of speed and flux. Thus the speed of the machine remains more or less constant with load. With highly saturated machines the on-load speed may even slightly increase at over load conditions. This effect gets more pronounced if the machine is designed to have its normal field ampere turns much less than the armature ampere turns. This type of external characteristics introduces instability during operation and hence must be

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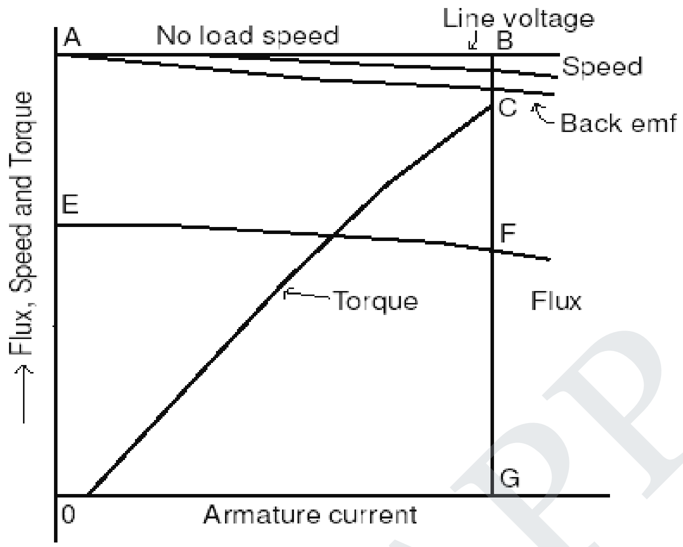
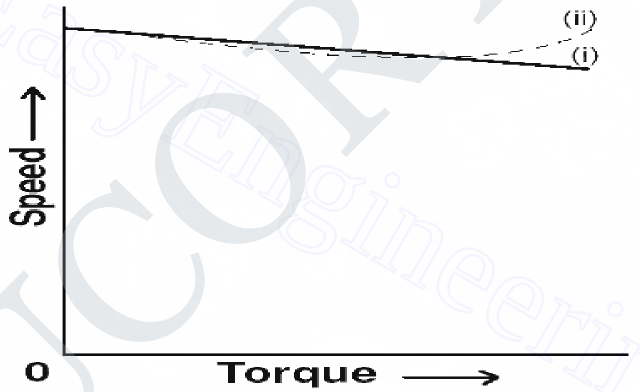
avoided. This may be simply achieved by providing a series stability winding which aids the shunt field mmf.



(a)Load characteristics



(b)Torque speed curve

DC Shunt motor characteristics

1(b). Explain about speed – torque characteristics of dc series motor. (Dec 2006)

Load characteristics of a series motor

Following the procedure described earlier under shunt motor, the torque speed Characteristics of a series motor can also be determined. The armature current also happens to be the excitation current of the series field and hence the flux variation resembles the magnetization curve of the machine. At large value of the armature currents the useful flux would be less than the no-load magnetization curve for the machine. Similarly for small values of the load currents the torque varies as a square of the armature currents as the flux is proportional to armature current in this region. As the magnetic circuit becomes more and more saturated the torque becomes

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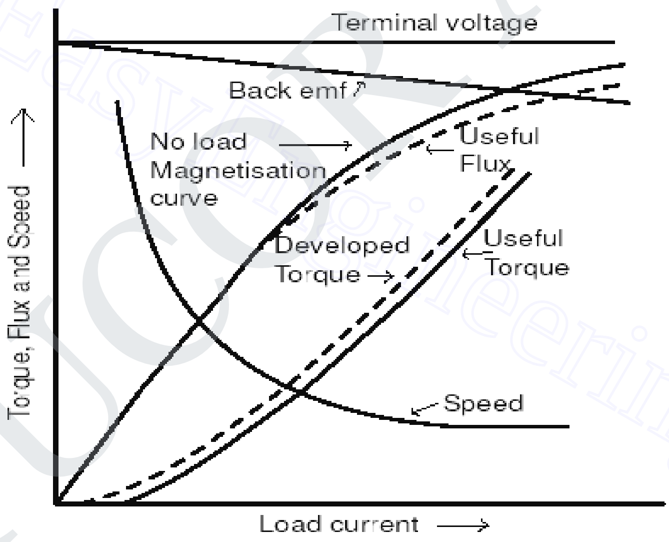
proportional to Ia as flux variation becomes small. Fig. (a) shows the variation of E1, flux, torque and speed following the above procedure from which the torque-speed characteristics of the series motor for a given applied voltage V can be plotted as shown in Fig.(b) The initial portion of this torque-speed curve is seen to be a rectangular hyperbola and the final portion is nearly a straight line. The speed under light load conditions is many times more than the rated speed of the motor. Such high speeds are unsafe, as the centrifugal forces acting on the armature and commutator can destroy them giving rise to a catastrophic break down. Hence series motors are not recommended for use where there is a possibility of the load becoming zero. In order to safeguard the motor and personnel, in the modern machines, a 'weak' shunt field is provided on series motors to ensure a definite, though small, value of flux even when the armature current is nearly zero. This way the no-load speed is limited to a safe maximum speed. It is needless to say, this field should be connected so as to aid the series field.



(a)Load characteristics

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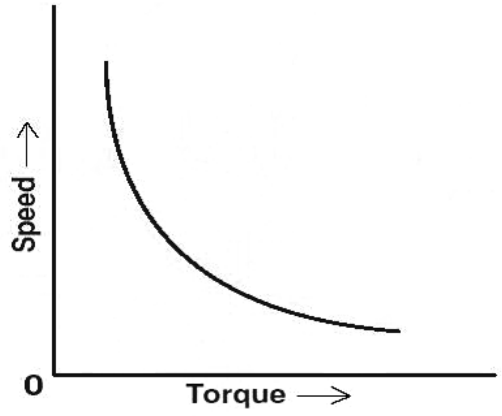

(b)-Torque speed curve

2. Explain in detail operation of regenerative braking and plugging of dc motors. (May-2006)

In regenerative braking as the name suggests the energy recovered from the rotating masses is fed back into the d.c. power source. Thus this type of braking improves the energy efficiency of the machine. The armature current can be made to reverse for a constant voltage operation by increase in speed/excitation only. Increase in speed does not result in braking and the increase in excitation is feasible only over a small range, which may be of the order of 10 to 15%. Hence the best method for obtaining the regenerative braking is to operate, the machine on a variable voltage supply. As the voltage is continuously pulled below the value of the induced emf the speed steadily comes down. The field current is held constant by means of separate excitation. The variable d.c. supply voltage can be obtained by Ward-Leonard arrangement, shown schematically in Fig. .

Braking torque can be obtained right up to zero speed. In modern times static Ward-Leonard scheme is used for getting the variable d.c. voltage. This has many advantages over its rotating machine counterpart. Static set is compact, has higher efficiency, and requires lesser space and silent in operation; however it suffers from drawbacks like large ripple at low voltage levels, unidirectional power flow and low over load capacity. Bidirectional power flow capacity is a must if regenerative braking is required. For Series motors Series motors regenerative braking cannot be applied.

Plugging :

The third method for braking is by plugging. Fig. shows the method of connection for the plugging of a shunt motor. Initially the machine is connected to the supply with the switch S in position number 1. If now the switch is moved to position 2, then a reverse voltage is applied across the armature. The induced armature voltage E and supply voltage V aid each other and large reverse current flows through the armature.

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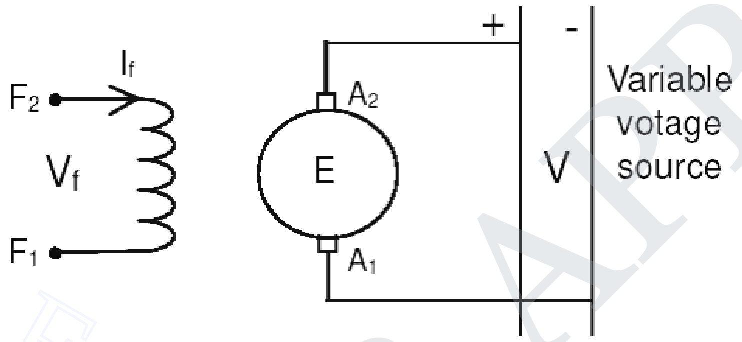
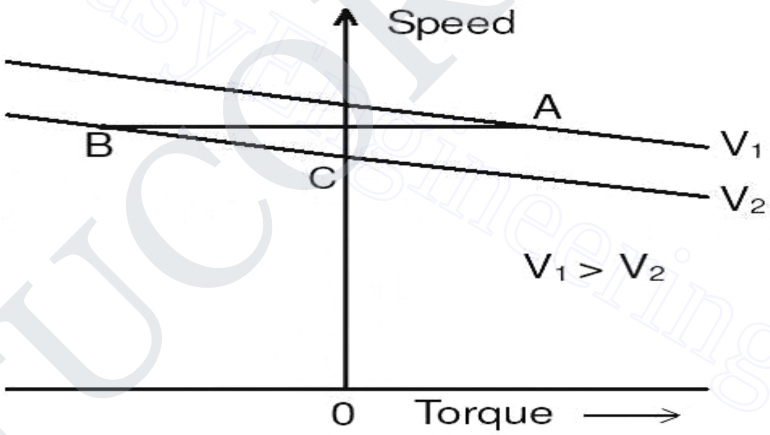
This produces a large negative torque or braking torque. Hence plugging is also termed as reverse voltage braking. The machine instantly comes to rest. If the motor is not switched off at this instant the direction of rotation reverses and the motor starts rotating the reverse direction. This type of braking therefore has two modes viz. 1) plug to reverse and 2) plug to stop. If we need the plugging only for bringing the speed to zero, then we have to open the switch S at zero speed. If nothing is done it is plug to reverse mode. Plugging is a convenient mode for quick reversal of direction of rotation in reversible rives. Just as in starting, during

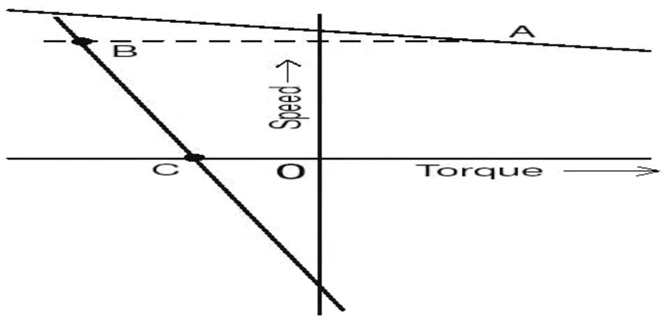


(a)Physical connection



(b)Characteristics

Figure Regenerative braking of a shunt machine



(b)Characteristics

Figure : Plugging or reverse voltage braking of a shunt motor

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Plugging also it is necessary to limit the current and thus the torque, to reduce the stress on the mechanical system and the commutator. This is done by adding additional resistance in series with the armature during plugging.

Series motors :

In the case of series motors plugging cannot be employed as the field current too gets reversed when reverse voltage is applied across the machine. This keeps the direction of the torque produced unchanged. This fact is used with advantage, in operating a d.c. series motor on d.c. or a.c. supply. Series motors thus qualify to be called as `Universal motors'.

Compound motors :

Plugging of compound motors proceeds on similar lines as the shunt motors. However some precautions have to be observed due to the presence of series field winding. A cumulatively compounded motor becomes differentially compounded on plugging. The mmf due to the series field can 'over power' the shunt field forcing the flux to low values or even reverse the net field. This decreases the braking torque, and increases the duration of the large braking current. To avoid this it may be advisable to deactivate the series field at the time of braking by short-circuiting the same. In such cases the braking proceeds just as in a shunt motor. If plugging is done to operate the motor in the negative direction of rotation as well, then the series field has to be reversed and connected for getting the proper mmf. Unlike dynamic braking and regenerative braking where the motor is made to work as a generator during braking period, plugging makes the motor work on reverse motoring mode.

3. Explain load characteristics of DC series motor.

Load characteristics of a series motor

Following the procedure described earlier under shunt motor, the torque speed Characteristics of a series motor can also be determined. The armature current also happens to be the excitation current of the series field and hence the flux variation resembles the magnetization curve of the machine. At large value of the armature currents the useful flux would be less than the no-load magnetization curve for the machine. Similarly for small values of the load currents the torque varies as a square of the armature currents as the flux is proportional to armature current in this region. As the magnetic circuit becomes more and more saturated the torque becomes proportional to Ia as flux variation becomes small.

Fig. (a) shows the variation of E1, flux, torque and speed following the above

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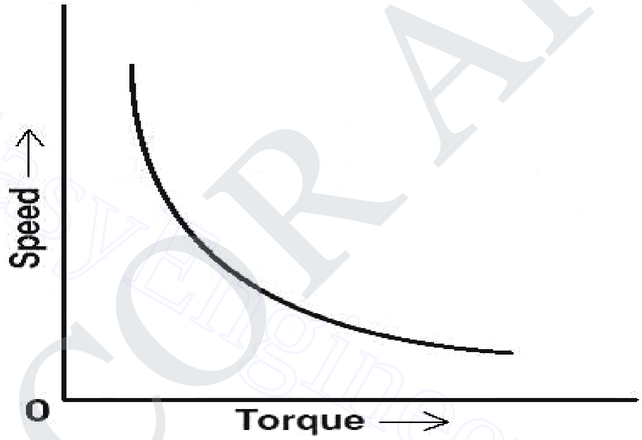
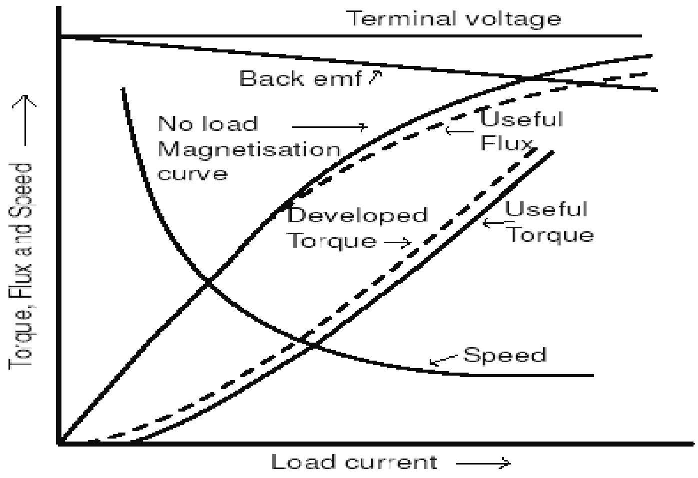
procedure from which the torque-speed characteristics of the series motor for a given applied voltage V can be plotted as shown in Fig.(b) The initial portion of this torque-speed curve is seen to be a rectangular hyperbola and the final portion is nearly a straight line. The speed under light load conditions is many times more than the rated speed of the motor. Such high speeds are unsafe, as the centrifugal forces acting on the armature and commutator can destroy them giving rise to a catastrophic break down. Hence series motors are not recommended for use where there is a possibility of the load becoming zero. In order to safeguard the motor and personnel, in the modern machines, a 'weak' shunt field is provided on series motors to ensure a definite, though small, value of flux even when the armature current is nearly zero. This way the no-load speed is limited to a safe maximum speed. It is needless to say, this field should be connected so as to aid the series field.



(b)-Torque speed curve

4. Explain load characteristics of DC compound motor.

Load characteristics of a compound motor



(a)Load characteristics

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` Two situations arise in the case of compound motors. The mmf of the shunt field and series field may oppose each other or they may aid each other. The first configuration is called differential compounding and is rarely used. They lead to unstable operation of the machine unless the armature mmf is small and there is no magnetic saturation. This mode may sometimes result due to the motoring operation of a level-compounded generator, say by the failure of the prime mover. Also, differential compounding may result in large negative mmf under overload/starting condition and the machine may start in the reverse direction. In motors intended for constant speed operation the level of compounding is very low as not to cause any problem. Cumulatively compounded motors are very widely used for industrial drives. High degree of compounding will make the machine approach a series machine like characteristics but with a safe no-load speed. The major benefit of the compounding is that the field is strengthened on load. Thus the torque per ampere of the armature current is made high. This feature makes a cumulatively compounded machine well suited for intermittent peak loads. Due to the large speed variation between light load and peak load conditions, a y wheel can be used with such motors with advantage. Due to the reasons provided under shunt and series motors for the provision of an additional series/shunt winding, it can be seen that all modern machines are compound machines. The difference between them is only in the level of compounding.

5. Explain various methods of braking.

Rheostatic braking

Consider a d.c shunt motor operating from a d.c supply with the switch S connected to position 1 as shown in figure. S is a *single pole double throw switch* and can be connected either to position 1 or to position 2. One end of an external resistance *Rb* is connected to position 2 of the switch S as shown.

Let with S in position 1, motor runs at n rpm, drawing an armature current *Ia* and the back emf is $E_b = k\phi\, n.$ Note the polarity of *Eb* which, as usual for motor mode in opposition with the supply voltage. Also note *Te* and n have same clockwise direction.

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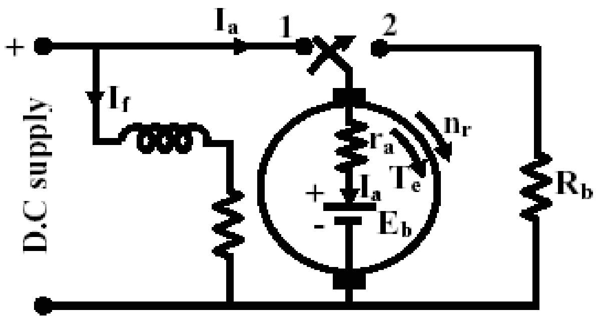
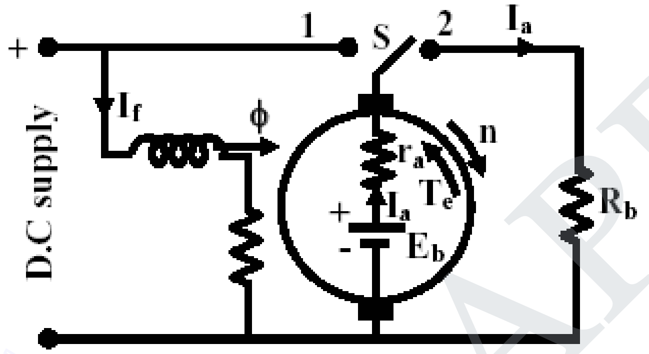


Machine operates as motor



Machine operates as generator during braking

Now if S is suddenly thrown to position 2 at *t* = 0, the armature gets disconnected from the supply and terminated by *Rb* with field coil remains energized from the supply. Since speed of the rotor can not change instantaneously, the back emf value *Eb* is still maintained with same polarity prevailing at *t* = 0-. Thus at *t* = 0+, armature current will be *Ia* = *Eb*/(*ra* + *Rb*) and with reversed direction compared to direction prevailing during motor mode at *t* = 0- Obviously for *t* > 0, the machine is operating as generator dissipating power to *Rb* and now the electromagnetic torque *Te* must act in the opposite direction to that of *n* since *Ia* has changed direction buthas not (recall $T_e \propto \phi\, I_a$). As time passes after switching, *n* decreases reducing K.E and as a consequence both *Eb* and *Ia* decrease. In other words value of braking torque will be highest at *t* = 0+, and it decreases progressively and becoming zero when the machine finally come to a stop.

Plugging or dynamic braking

This method of braking can be understood by referring to figures 39.25 and 39.26. Here S is a double pole double throw switch. For usual motoring mode, S is connected to positions 1 and 1'.Across terminals 2 and 2', a series combination of an external resistance *Rb* and supply voltage with polarity as indicated is connected. However, during motor mode this part of the circuit remains inactive.

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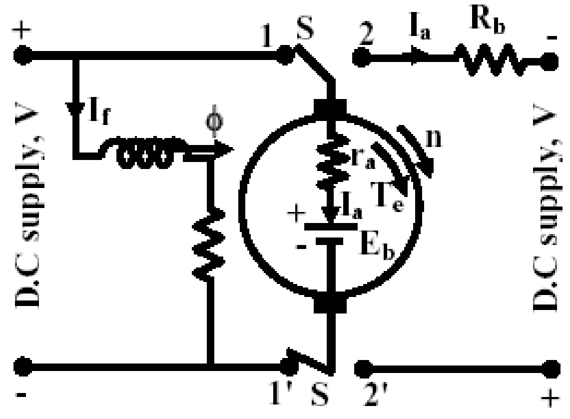
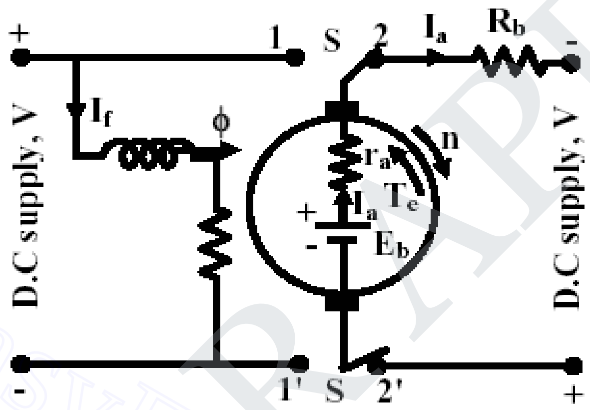


Machine operates as motor



Machine operates as generator during braking (plugging).

To initiate braking, the switch is thrown to position 2 and 2' at $t = 0$, thereby disconnecting the armature from the left hand supply. Here at $t = 0+$, the armature current will be $Ia = (Eb + V)/(ra + Rb)$ as Eb and the right hand supply voltage have additive polarities by virtue of the connection. Here also Ia reverses direction-producing Te in opposite direction to n. Ia decreases as Eb decreases with time as speed decreases. However, Ia can not become zero at any time due to presence of supply V. So unlike rheostatic braking, substantial magnitude of braking torque prevails. Hence stopping of the motor is expected to be much faster then rheostatic breaking. But what happens, if S continuous to be in position 1' and 2' even after zero speed has been attained? The answer is rather simple, the machine will start picking up speed in the reverse direction operating as a motor. So care should be taken to disconnect the right hand supply, the moment armature speed becomes zero.

Regenerative braking

A machine operating as motor may go into regenerative braking mode if its speed becomes sufficiently high so as to make back emf greater than the supply voltage i.e., $Eb > V$. Obviously under this condition the direction of Ia will reverse imposing torque which is opposite to the direction of rotation. The situation is explained

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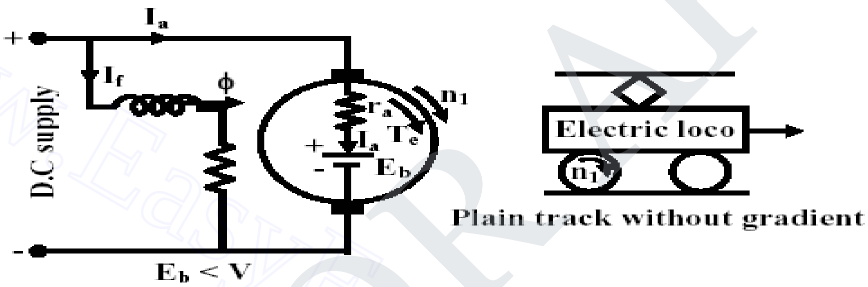
in figures 39.27 and 39.28. The normal motor operation is shown in figure 39.27 where armature motoring current *Ia* is drawn from the supply and as usual *Eb*<*V*. Since $E_b = k\phi\, n_1$. The question is how speed on its own become large enough to make *Eb* < *V* causing regenerative braking. Such a situation may occur in practice when the mechanical load itself becomes active. Imagine the d.c motor is coupled to the wheel of locomotive which is moving along a plain track without any gradient as shown in figure. Machine is running as a motor at a speed of *n*1 rpm. However, when the track has a downward gradient (shown in figure 39.28), component of gravitational force along the track also appears which will try to accelerate the motor and may increase its speed to *n*2 such that *E*b $= k\phi\, n_2 > V$. In such a scenario, direction of *Ia* reverses, feeding power back to supply.



PART C

6 (a). Explain in detail the operation of dynamic braking on dc motors.

Dynamic braking of Shunt machine:

In dynamic braking the motor is disconnected from the supply and connected to a dynamic braking resistance RDB. This is done by changing the switch from position 1 to 2. The supply to the field should not be removed. Due to the rotation of the armature during motoring mode and due to the inertia, the armature continues to rotate. An emf is induced due to the presence of the field and the rotation. This voltage drives a current through the braking resistance. The direction of this current is opposite to the one which was owing before change in the connection. Therefore, torque developed also gets reversed. The machine acts like a brake. for a particular value of RDB.

The positive torque corresponds to the motoring operation. Fig. shows the dynamic braking of a shunt excited motor and the corresponding torque-speed curve. Here the machine behaves as a self-excited generator. Below a certain speed the self-excitation collapses and the braking action becomes Zero. Basically the electric braking involved is fairly simple. The electric motor can be made to work as a generator by

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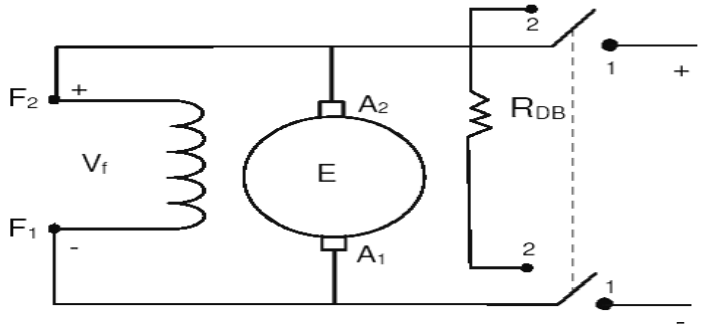
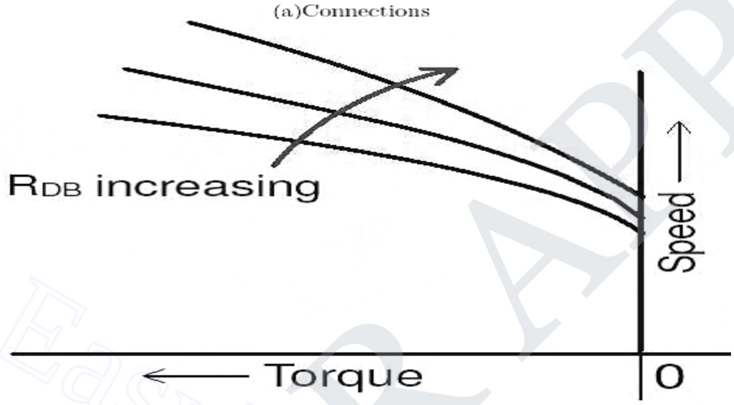
suitable terminal conditions and absorb mechanical energy. This converted mechanical power is dissipated used on the electrical network suitably.



(a)Connections



(b)Characteristics

Figure : Dynamic Braking of a shunt motor Series machine :

In the case of a series machine the excitation current becomes zero as soon as the armature is disconnected from the mains and hence the induced emf also vanishes. In order to achieve dynamic braking the series field must be isolated and connected to a low voltage high current source to provide the field. Rather, the motor is made to work like a separately excited machine. When several machines are available at any spot, as in railway locomotives, dynamic braking is feasible. Series connection of all the series fields with parallel connection of all the armatures connected across a single dynamic braking resistor is used in that case.

Compound machine:

In the case of compound machine, the situation is like in a shunt machine. A separately excited shunt field and the armature connected across the braking resistance are used. A cumulatively connected motor becomes differentially compounded generator and the braking torque generated comes down. It is therefore necessary to reverse the series field if large braking torques are desired.

6(b)Explain in detail speed – torque characteristics of induction motor.(May-2007)

In order to estimate the speed torque characteristic let us suppose that a sinusoidal voltage is impressed on the machine. Recalling that the equivalent circuit is

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the per-phase representation of the machine, the current drawn by the circuit is given by

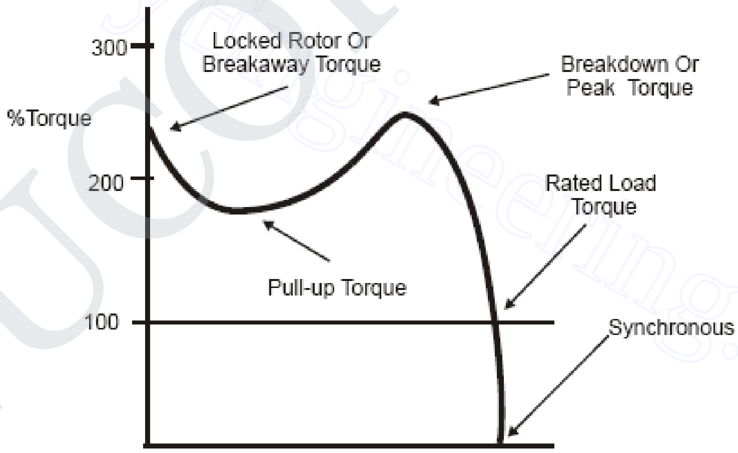
$$I_s = \frac{V_s}{\left(R_s + \frac{R'_r}{s}\right) + j\left(X_{ls} + X'_{lr}\right)} \quad (1)$$

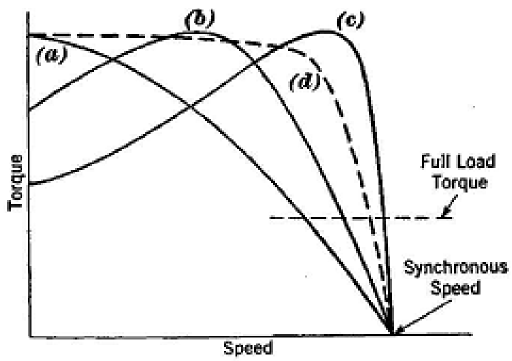
Where Vs is the phase voltage phasor and Is is the current phasor. The magnetizing current is neglected. Since this current is owing through , the air-gap power is given by

$$\boldsymbol{P}_{\boldsymbol{g}} = |I_s{}^2| \frac{R'_r}{s}$$

The torque may be plotted as a function of `s' and is called the torque-slip (or torque- speed, since slip indicates speed) characteristic | a very important characteristic of the induction machine. Equation(1) is valid for a two-pole (one pole pair) machine. In general, this expression should be multiplied by p, the number of pole-pairs. A typical torque-speed characteristic is shown in figure bellow. This plot corresponds to a 3 kW, 4 pole, 60 Hz machine. The rated operating speed is 1780 rpm.

Further, this curve is obtained by varying slip with the applied voltage being held constant. Coupled with the fact that this is an equivalent circuit valid under steady state, it implies that if this characteristic is to be measured experimentally, we need to look at the torque for a given speed after all transients have died down.





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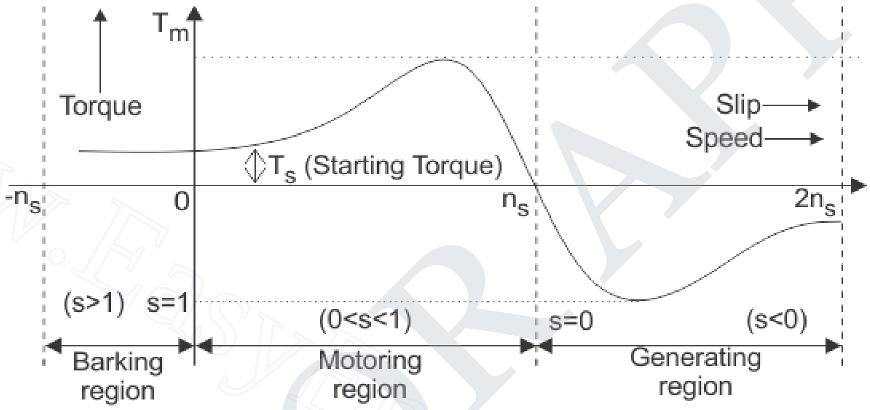
Another point to note is that the equivalent circuit and the values of torque predicted is valid when the applied voltage waveform is sinusoidal. With non-sinusoidal voltage waveforms, the procedure is not as straightforward.

With respect to the direction of rotation of the air-gap flux, the rotor maybe driven to higher speeds by a prime mover or may also be rotated in the reverse direction. The torque-speed relation for the machine under the entire speed range is called the complete speed-torque characteristic. A typical curve is shown in fig for a four-pole machine, the synchronous speed being 1500 rpm. The plot also shows the operating modes of the induction machine in various regions. The slip axis is also shown for convenience.



UNIT 3 - STARTING METHODS

PART – A

1. What is the need for a starter in electrical motors? (Nov/Dec-2015, Apr/May-2015, Nov/Dec-2014, May/June-2016)

A DC motor is directly switched on, at the time of starting, the motor back emf is zero. Due to this, the Armature current is very high. Due to the very high armature current, the motor become damaged. The starting current can be limited by using starter.

2. Mention the advantages of four point starter over three point starter.(Nov/Dec-2015)

The main advantage of the 4-point starter is the dc motor used for field control (above rated speed control).

3. What are the different methods of DC motor starters?(Nov/Dec-2014, May/June-2014)

Two point starter, three point starter, and four point starter

4. What are the methods of starting three phase squirrel cage induction motor?(Nov/Dec-2014)

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DOL starter, Primary resistance starter, Star/delta starter, and Auto transformer starter

5. List various method of starting of DC series motor.(Apr/May-2015)

Two point starter

6. What is the objectives of rotor resistance starter?(Apr/May-2015)

To limit the starting current, to control the starting torque and to vary the motor speed

7. State the difference between three phase squirrel cage and slip-ring induction motors.(May/June-2016)

S.No	Slip ring induction motor	Squirrel cage induction motor
1	Have end rings in rotor circuit	No end rings in rotor circuit
2	External resistance can be added	External resistance cannot be added
3	High starting torque	Low starting torque

8. What is the basic principle of primary resistance starter used in 3-phase induction motor?(May/June-2014)

A variable resistance is connected in series with supply terminal of the motor. The purpose of these resistances is to reduce the supply voltage. This reduces the supply voltage given to the motor terminal. The reduced voltage is to limit the starting current (50%).

9. What are the two types of rotors of three phase induction motor?(Nov/Dec-2013)

(i)Squirrel cage rotor,

(ii)Slip ring rotor

10. State the basic principle of DOL for 2-phase induction motor. (May/June-2013)

The 3ϕ induction motor below 5 HP can be directly switched on to the supply mains by means of DOL Starter. The motor below 5 HP has high armature resistance and hence has low starting current. Hence the motors up to 5 HP can be directly switched on using DOL Starter.

11. What is the condition for starting of DC series motor? Why?(Nov/Dec-2011)

The series motor should be started with the loaded condition because of high starting torque.

$$T \alpha I_a^2$$

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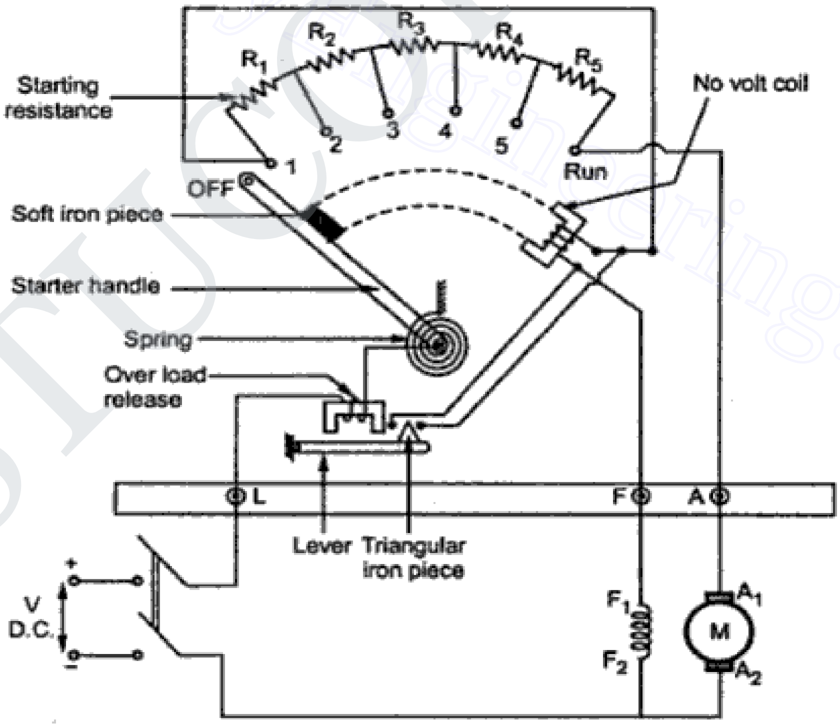
PART -B

1. Explain three point starters in detail. (Nov/Dec-2015, Apr/May-2015, May/June-2016)

The three – point starter consist of the variable resistance, available with number of partitions. It has three connection points namely L, F and A. Hence it is known as three-point starter. L - Line terminal - Connected with supply mains. F - Field terminal - Connected with field circuit of DC motor A - Armature terminal - Connected with armature circuit of DC motor The supply main is connected to the connection point L. The connection point L is connected to Over Current magnet (OC). The OC is connected with conducting movable arm which makes contact with variable starting resistor. The other end of the starting resistor is connected to the connection point A. The connection point F is connected with the No volt magnet (NV)

Operation:

The motor is connected with the starter as shown in the connection. Here the DC shunt motor is connected with the Three-point starter. The supply main is connected with point L.



3 point Starter

The shunt field (f1 and f2) of the motor is connected with point. The armature (A1 and A2) is connected with the control spring. The start the motor, the handle is

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slowly moved against the control spring force, to make contact with first division (on position) of the variable starting resistance. At this point field winding gets supply through the metal rod and the No-Volt coil is energized. The metal rod forms parallel path with the starting resistance. The this point entire starting resistance is available in the armature circuit. As the handle moved further, it goes on making contact with divisions 2, 3, 4 etc. When starter handle is at division 3, the division to 1 and 2 are removed from the circuit. If the starter handle reaches Run position, the entire starting resistance is removed from the armature circuit. Now the motor runs at rated speed. The starter is placed in the Run position with the help of No – Volt magnet.

Function of No-Volt magnet (NV)

(i) The No-Volt magnet keeps starter handle at run position against the control spring. The No-Volt magnet attracts the soft iron bar placed in the handle. The No-Volt magnet is energized by the current flowing through the field circuit. If there is no No-Volt magnet, the starter handle is pulled back to the Off position by the control spring and the motor is switched Off.

(ii)During the failure of DC supply the No-Volt magnet is de-energized so the magnetic power is lost. The handle comes backs to the Off position by the action of control spring, if the No-Volt magnet is not there. Due to the presence of No-Volt magnet and control spring the starter handle comes backs back to the Off position whenever the supply fails. If there is no control spring then handle remains in the run position when the supply fails. When the supply returns the motor is directly connected to the supply main, developing high starting current.

(iii)During low voltage condition the No-Volt magnet releases the handle to the Off position and hence protect the motor form low voltage

Function of Over Current magnet (OC)

When the load on motor increases above the rated limit then the armature takes high current. When the motor is left unprotected from this high current, then it is damaged. The over current magnet is used for this protection. When there is high current due to over load or due to short circuit the over current magnet is energized and attracts soft iron rod H. As a result, the soft iron rod H closes the switch S. When the switch S is closed, it short circuits the No-Volt magnet. As a result No-Volt magnet is de- energized and release the starter handle to the off position. So the motor is switched off and protected from the over current or high current. Disadvantage of Three point starter

is reduced to get speed above the rated speed. Now the No-Volt magnet is de-

During the speed control of DC shunt motor, using flux control method, the field current

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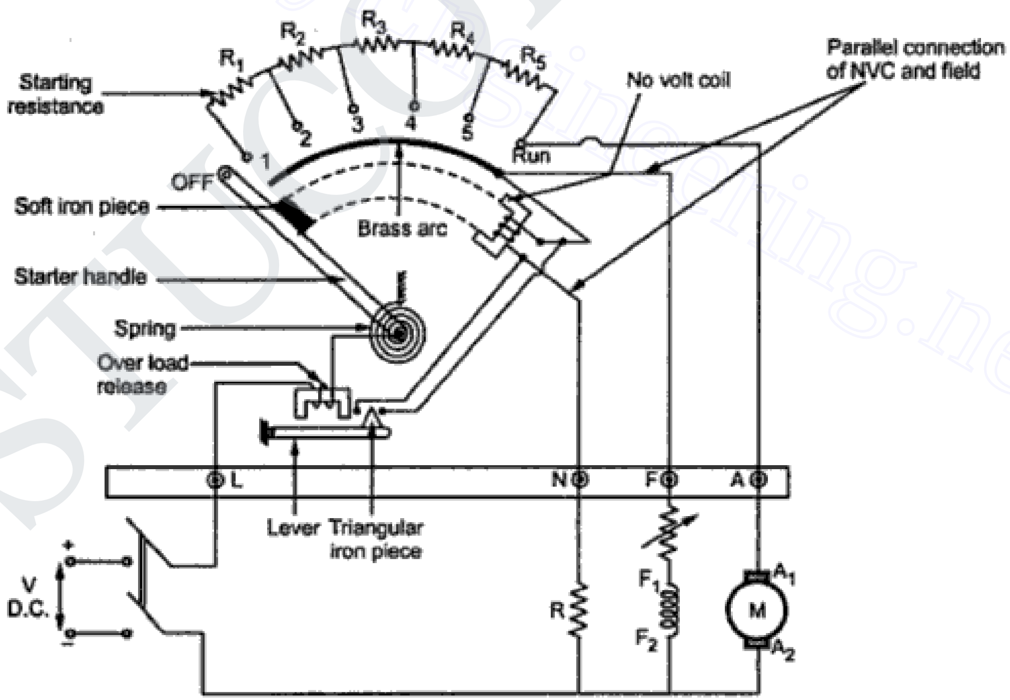
energized due to reduced field current. This is because No-Volt magnet is connected in the field circuit. Since the No-Volt magnet is de-energized, the handle reaches Off position and the motor is switches Off. This problem can be rectified if No-Volt coil and field circuit are separated. This is done four – point starter, which is described in the following section.

2. Explain four point starters in detail. (Apr/May-2015, May/June-2014)

The four point starter like in the case of a 3 point starter also acts as a protective device that helps in safeguarding the armature of the shunt or compound excited DC motor against the high starting current produced in the absence of back emf at starting. The 4 point starter has a lot of constructional and functional similarity to a three point starter, but this special device has an additional point and a coil in its construction. This naturally brings about some difference in its functionality, though the basic operational characteristic remains the same. The basic difference in circuit of 4 point starter as compared to 3 point starter is that the holding coil is removed from the shunt field current and is connected directly across the line with current limiting resistance in series.



4 point Starter

A 4 point starter as the name suggests has 4 main operational points, namely

1. 'L' Line terminal. (Connected to positive of supply.)

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2. 'A' Armature terminal. (Connected to the armature winding.)
3. 'F' Field terminal. (Connected to the field winding.)
4. Like in the case of the 3 point starter, and in addition to it there is, A 4th point N. (Connected to the No Voltage Coil NVC)

The remarkable difference in case of a 4 point starter is that the No Voltage Coil is connected independently across the supply through the fourth terminal called 'N' in addition to the 'L', 'F' and 'A'. As a direct consequence of that, any change in the field supply current does not bring about any difference in the performance of the NVC. Thus it must be ensured that no voltage coil always produce a force which is strong enough to hold the handle in its 'RUN' position, against force of the spring, under all the operational conditions. Such a current is adjusted through No Voltage Coil with the help of fixed resistance R connected in series with the NVC using fourth point 'N' as shown in the figure above.

Function of No-Volt magnet (NV)

(i) The No-Volt magnet keeps starter handle at run position against the control spring. The No-Volt magnet attracts the soft iron bar placed in the handle. The No-Volt magnet is energized by the current flowing through the field circuit. If there is no No-Volt magnet, the starter handle is pulled back to the Off position by the control spring and the motor is switched Off.

(ii)During the failure of DC supply the No-Volt magnet is de-energized so the magnetic power is lost. The handle comes backs to the Off position by the action of control spring, if the No-Volt magnet is not there. Due to the presence of No-Volt magnet and control spring the starter handle comes backs back to the Off position whenever the supply fails. If there is no control spring then handle remains in the run position when the supply fails. When the supply returns the motor is directly connected to the supply main, developing high starting current.

(iii)During low voltage condition the No-Volt magnet releases the handle to the Off position and hence protect the motor form low voltage

3. Explain in detail DOL and Auto transformer starter. (Apr/May-2015)

Direct-On-Line Starter (DOL Starter)

The 3ϕ induction motor below 5 HP can be directly switched on to the supply mains by means of DOL Starter. The motor below 5 HP has high armature resistance and hence has low starting current. Hence the motors up to 5 HP can be directly

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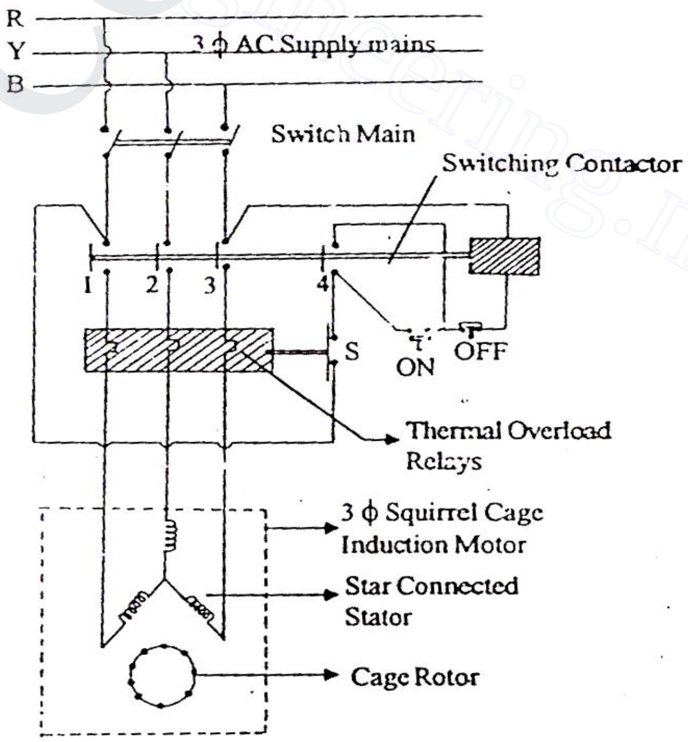
switched on using DOL Starter. The DOL starter provides protection against No-Voltage and Overload current.

Operation

The 3ϕ induction motor (upto 5HP) is started by means of DOL starter. Typical control circuit for starting 3ϕ induction motor by DOL starter. The induction motor is connected to supply mains through switching main and four normally open contacts. Initially the switching main is closed. The DOL starter consists of a Switching contacts are activated by plunger and No-volt coil arrangement. No-Volt coil is connected through two push buttons (ON and OFF) across any of the two phases of 3ϕ supply. The ON and OFF button are used to start and stop the motor. These are the manually operated control buttons available in DOL starter. There is a set of thermal relays which is connected in series with stator of induction motor provide overload protection.

To start the motor, the “ON” push button (normally open) is pressed which energize the ‘No-Volt Coil’ by connecting across two phase. The No-Volt, Coil pulls the plunger is such a direction that all the normally open (N.O) contacts are closed and now the motor is connected across the supply through three contacts. The fourth contact (4) serves as a ‘hold on contact’, which keeps the no volt coil circuit complete even after the ON Push butto



When the supply goes off or when ‘OFF’ switch (normally closed) is pressed, the No-Volt coil circuit is opened and hence is de-energized, as a result plunger is released.

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And all the contacts returns to open position thereby, disconnecting the motor from the supply mains. When the motor is overloaded, the thermal over load coil opens the switch S, hence the No-Volt coil circuit is open and plunger is sent back the contacts to normally open position. Thus disconnecting motor from the supply.

Auto transformer Starter

Principle

A 3ϕ Star-connected Autotransformer is used to reduce the voltage applied to the stator of the 3ϕ induction motor. Such starter is known as Autotransformer starter. The primary winding of Autotransformer is supplied with 3ϕ voltage from the supply mains. The secondary of Autotransformer produce reduced variable voltage.

Construction

An Auto-transformer is connected between 3ϕ supply mains and 3ϕ squirrel cage induction motor. The primary (P) of the autotransformer is connected with the 3ϕ supply mains through a change over switch. The secondary (S) of the autotransformer is connected with the 3ϕ induction motor through change over switch.

The change over switch has two positions namely, Start and Run. When the change over switch is in Start position, the 3ϕ induction motor is connected to 3ϕ supply mains through autotransformer. When the change over switch is in Run position, the 3ϕ induction motor is directly connected to the 3ϕ supply mains. i.e., Auto transformer is removed.

Operation

To start the 3ϕinduction motor the change over switch is kept is Start position. Now the 3ϕ induction motor is connected to 3ϕ supply mains through Autotransformer. The voltage is reduced in the Auto-transformer and it depends upon on position of slide contact available in the transformer and this position decides transformation ratio (K). If the transformation ratio is 0.5, then half of the voltage applied to the primary appears across the secondary. This reduced voltage is now applied to the stator of 3 ϕ induction motor, through change over switch. Sincere reduced voltage is applied across the stator, the starting current is reduced to the safe limit.

Once the motor picks up 80% of rated speed, the change over switch can be switched to the Run position. Now the transformer is eliminated from the stator circuit. So 3ϕ induction motor is directly connected to supply mains. Due to this, rated voltage is

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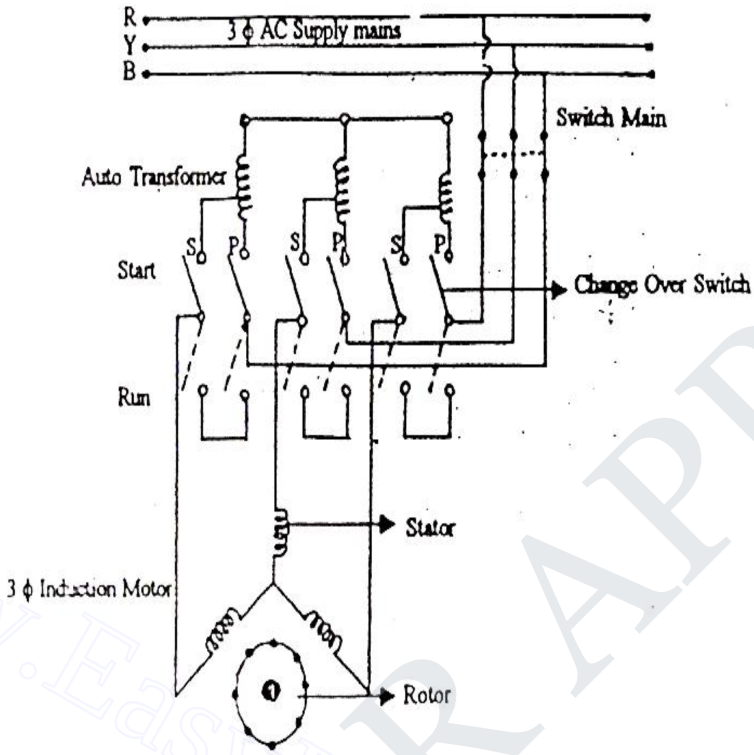
applied to the stator winding. The motor starts rotating with rated speed. The changing of switch position can also be done automatically by the usage of relays.



Expression for Staring Torque

Let the motor be started by an Auto-transformer having transformation ratio (K). If Isc is the starting current when normal voltage is applied and applied voltage during starting is KV, then motor input current Ist = KIsc (Secondary current)

Supply current = Current of auto transformer

$KI_{st} = K(KI_{sc}) = K^2 I_{sc}$

$T_{st} \propto K^2 I_{sc}^{\,2}$

$$T_f \propto \frac{I_f^2}{S_f}$$

$$\frac{T_{st}}{T_f} = K^2 \left(\frac{I_{sc}}{I_f}\right)^2 \times s_f$$

If may be noted is similar o the expression obtained for stator rheostat starter except that x has been replaced by transformer ratio K.

4. Explain in detail about star to delta starter. (Apr/May-2015)

The 3ϕ stator winding of 3ϕ induction motor can be connected either in Star of Delta. If it is connected in Star the voltage per phase is reduced by the factor √3. If connected in Delta the voltage per phase is not reduced. During staring the stator

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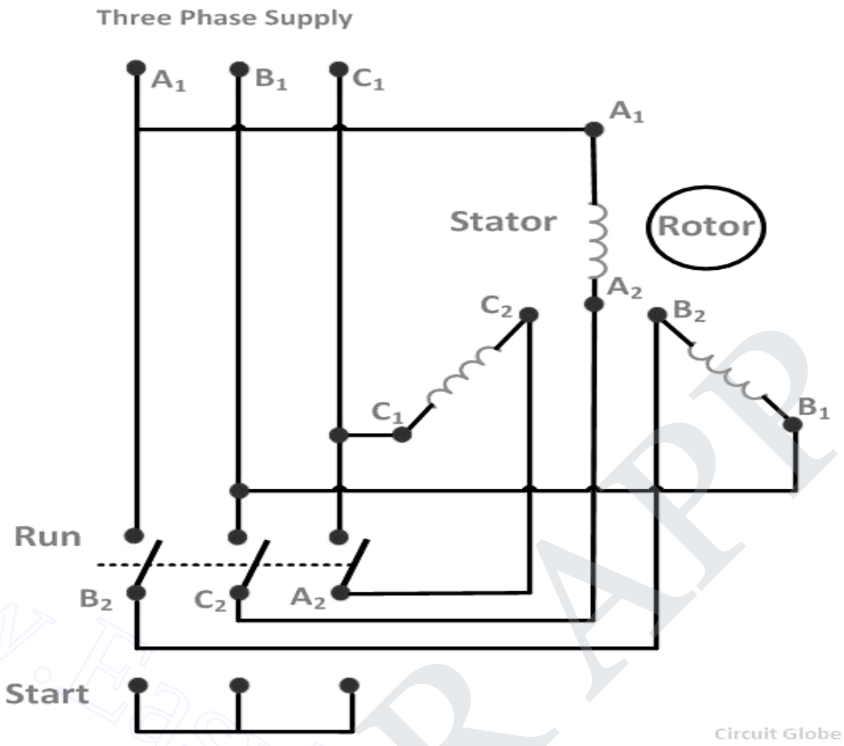
windings can be connected in Star to get reduced voltage, hence the starting current is also reduced.



Operation

The Star-Delta starter uses triple pole double throw (TPDT) switch hat connects stator windings of 3ϕ induction motor either in Start or Delta. During starting the switch is in Start position. Now the switch connects stator windings in Star. The phase voltages of Star connected stator windings is reduced by the factor 1 /√3 when compared to the lien voltage. Since the voltage applied to the stator is reduced, the starting current is also reduced.

Once the motor picks up 80% of rated speed the changed over switch can be thrown over to the Run position. Now the switch connects stator windings in Delta. In Delta connection the phase voltage are not reduced and it is equal to the line voltage. So entire supply voltage is applied across the motor. The motor starts rotating with rated speed. The switch can also be operated automatically with the help of relays. This starter is the cheapest of all starters because no special device like rheostat or transformer is included in the circuit. The starter works by simply connecting the stator windings in Star and Delta.

This starter is normally used for 3ϕ induction motor with delta connected stator windings. This starter is used in places where the motor is not started with heavy load.

Expression for Starting Torque

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$$I_{st} \text{ per phase} = \frac{1}{\sqrt{3}} I_{sc} \text{ per phase}$$

Now starting torque $T_{st} \; \alpha \; I_{st}^2$
Full load torque

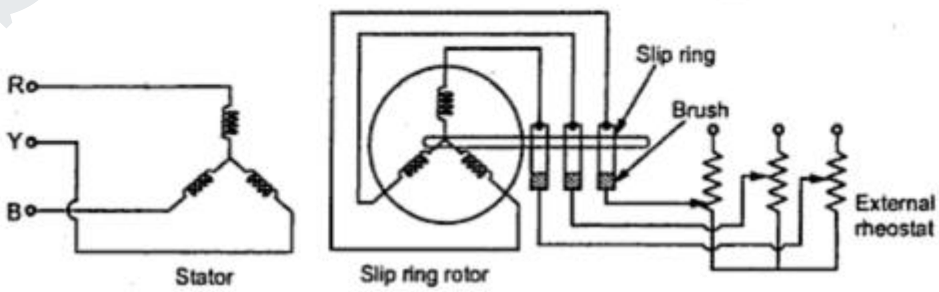
$$\frac{T_{st}}{T_f} = \left(\frac{I_{st}}{I_f}\right)^2 x \;\; S_f = \left(\frac{I_{sc}}{\sqrt{3} I_f}\right)^2 x \;\; S_f$$

$$\text{Therefore} \quad \frac{T_{st}}{T_f} = \frac{1}{3} \; x \left(\frac{I_{sc}}{I_f}\right)^2 x \;\; S_f$$

5. Explain detail about Rotor resistance starter in induction motor.(Apr/May-2015, Nov/Dec-2014)

The 3ϕ slip ring induction motor can be started by all the stator starters used for 3ϕ squirrel cage induction motor. In 3ϕ slip ring induction motor the rotor circuit can be accessed through the slip rings. In 3ϕ slip ring induction motor the rotor circuit has star connected windings. The ends of the three star connected windings are connected to three slip rings. The slip rings can be either short circuited or connected to external resistance. So starter for 3ϕ slip ring induction motor is connected in the rotor circuit.

By adding eternal resistance to the rotor circuit any starting torque up to the maximum torque can be achieved; and by gradually cutting out the resistance a high torque can be maintained throughout the starting period. The added resistance also reduces the starting current, so that a starting torque in the range of 2 to 2.5 times the full load torque can be obtained at a starting current of 1 to 1.5 times the full load current.



The starting current in the rotor winding is

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$$(I_2)_{st} = \frac{E_r}{\sqrt{(r_2 + R_{ext})^2 + (x_2)^2}}$$

Where R_{ext} = Additional resistance per phase in the rotor circuit.

It's a switch that connects several resistances, one at a time, to a motor to allow the motor to start slowly. The resistances are switched as individual resistances from the highest to the lowest. As each resistance is switched in, the motor receives a certain amount of current, as the motor reaches the speed that switch setting would allow, the next resistance is switched in, replacing the first resistance.

The motor speeds up a little more, until zero resistance is reached and the motor is running at full speed.

Advantages:

(i) It is inexpensive,

(ii) It is good for relatively small motors.

Disadvantages:

(i) Arcing between contacts,

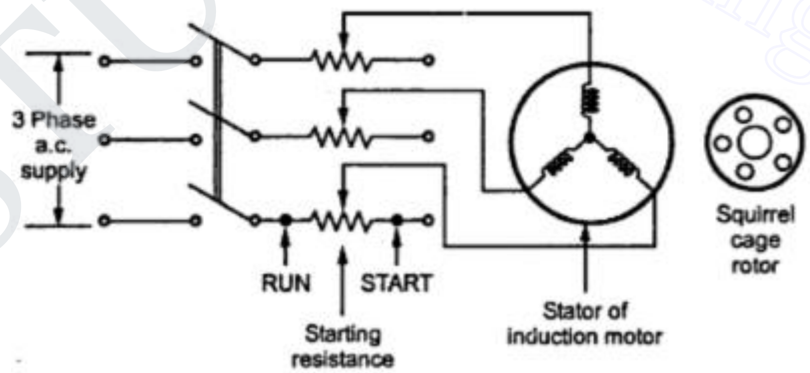
(ii) Motor speed up is not a smooth transition.

(iii) The shock of each speed increase can cause damage to the motor

(iv) This method is only applicable for slip ring induction motor.

PART C

6. Explain detail about Stator resistance starter in induction motor.(Apr/May-2015, Nov/Dec-2014)



The above figure shows the basic setup of stator resistance starter. By applying a reduced voltage the starting current may be limited. For this, three rheostats are connected in series to the stator winding of three phase induction motor. Initially the rheostat is kept in maximum position, hence a minimum the voltage is applied to the motor. As the motor gathers speed, the rheostst will be brought to minimum position thereby the full supply voltage is given to the motor. Now motor will run at normal

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speed.

The starter construction is simple and cheap. As the ratio of starting torque to full load torque is X2 as that of direct on line starter, this method is suitable for small motors only.

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UNIT IV CONVENTIONAL AND SOLID STATE SPEED CONTROL OF DC DRIVES

PART – A

1. What are the methods of speed control of dc motors? (Dec 2014)

Armature resistance control, Flux control, Voltage control.

2. What is meant by armature resistance control?(or) Why is armature voltage control used below rated speed? (Dec 2013),(May 2014)

A controller resistance is connected in series with armature. By varying the controller resistance R, the potential drop across the armature is varied. Therefore, the motor speed also varied. This method of speed control only applicable for speed less than no load speed.

3. What is meant by duty cycle? (Dec 2011),(May 2014)

Duty cycle is defined as the ratio between on time of chopper and total time of chopper

$$\alpha = T_{on}/T$$

4. What are the advantages of dc chopper drives? (Dec 2014)

Dc chopper drives has the advantages of high efficiency, flexibility in control, light weight, small size, quick response and regeneration down to very low speed.

5. What are the different methods of speed control of induction motors?

1. Stator voltage control
2. Voltage/frequency control (v/f)
3. Rotor resistance control
4. Slip energy recovery control.

6. Give the limitation of field control? (Nov/Dec-2012, Apr/May-2015)

(a) The Speed control below normal rated speed is not possible as flux can be increased only upto its rated value.

(b) As flux reduces, speed increases. But high speed affects the commutation making motor operation unstable. So there is limit to the maximum speed above normal possible by this method.

7. What are the main applications of Ward Leonard system? (Apr/May-2015)

(i)Full forward and reverse speed can be achieved.

(ii)A wide range of speed control is possible.

(iii)Power is automatically regenerated to the ac line to the mg set when speed is reduced.

(iv)Short time overload capacity is large.

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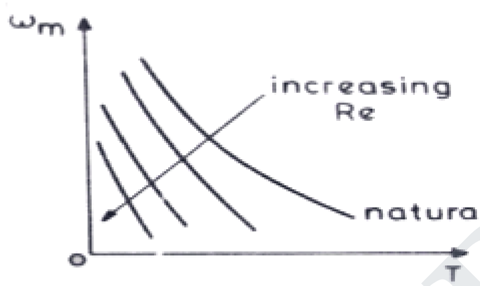
8. What are the various parameters that control the speed of the motor applications? (Nov/Dec-2014)

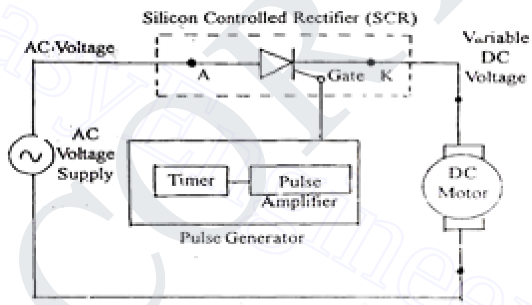
$N = 120f(1-s)/p$

The slip s, Frequency f and number of poles p.

9. Draw the speed-torque characteristics of DC series motor by armature resistance method. (May/June-2013)



10. Draw the block diagram of phase controlled rectifier fed DC drives. (May/June-2013)



11. Write down any advantages of solid state speed control. (May/June-2011)

(i) Simple operation, (ii)Time response is faster, (iii)Operating efficiency is high,(iv)Small size,(v)Less weight and(vi)Low initial cost

12. What is armature diverter speed control of D.C series motor? (Apr/May-2014)

In this method, a variable resistance is connected in parallel with armature, which is known as armature diverter. The speed control of DC series motor using armature diverter is known as armature diverter method.

13. Name the basic methods of speed control of D.C motor. (Nov/Dec-2014)

The DC motor speed controlled by

1. Armature voltage control (below base speed)
2. Flux control (above base speed)

14. Draw the basic circuit for chopper controlled separately excited dc motor drive. (Nov/Dec-2013)

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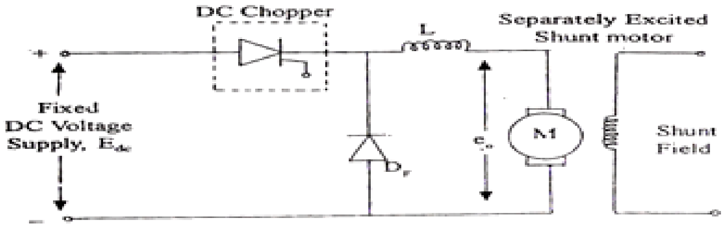


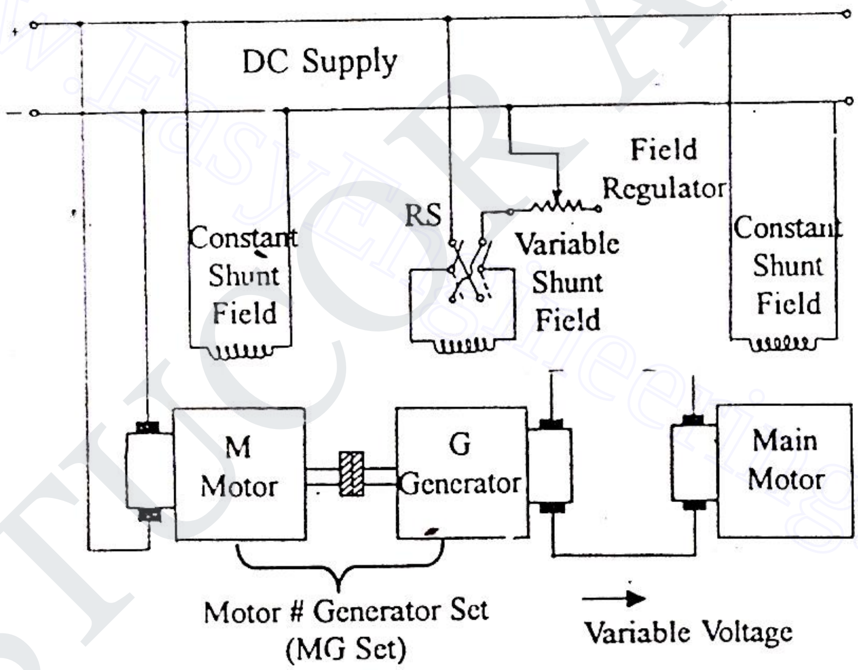
15. Give the applications of controlled rectifier circuit. (May/June-2016)

(i)Machine tools, (ii) Paper mills, (iii)Electric traction and (iv) Textile mills

PART – B

1. Describe with diagram Ward-Leonard speed control system for DC motor (Apr/May-2015, Nov/Dec-2014, May/June-2014, May/June-2013, Nov/Dec-2012)

The speed equation of DC motor shows that by varying the supply voltage, the speed can be controlled. The speed of DC motor is directly proportional to the voltage applied to it. The speed equation is given by,



$$N = K(V/\Phi)$$

Where N- Speed of the motor,

V- applied voltage

Φ - Flux

The Ward-Leonard method of speed control of DC motor uses voltage control, i.e., the speed is controlled by varying the supply voltage (V). In this method the variable voltage is obtained from 'Motor-Generator set'.

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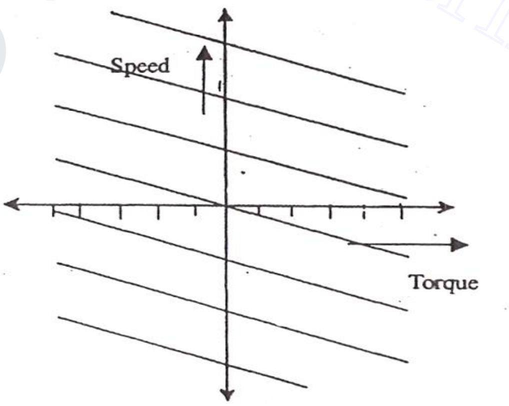
Construction and Operation:

The shunt field of the Main motor (DC shunt motor) is connected with fixed the DC supply line. Here DC motor (M) and DC Generator (G) forms the Motor # Generator St (i.e MG set). The armature of motor M is connected with the fixed DC supply lined Shunt field of it is also connected with fixed DC supply. So motor M rotate with constant speed. This motor is mechanically coupled with Generator (G). This forms MG set. The armature of the Generator now rotates with the constant speed. The armature of generator (G) is electrically connected with Main motor. The MG set supplies variable voltage to the main motor.

The speed control is obtained by the inserting a field regulator (Rheostat) in the field circuit of the generator (G). by adjusting the field regulator, the flux is varied. Since the generator is rotating at constant speed, the voltage produced by it depends on flux. When the flux is varied by adjusting the field regulator, the variable voltage is produced by generator (G). This variable voltage is applied to armature of main motor. So the speed of the main motor (DC shunt motor) is varied due to variable voltage. Thus the speed is controlled by voltage control in Ward – Leonard Method.

The reversing switch RS is used to reverse the connection of field terminals. As a result voltage generated is also reversed. This reversed voltage when applied to the main motor gives rotation in the opposite direction. Therefore in this method, the speed control is possible in the bo



Advantages

1. It is possible to achieve lowest limit of speed variation of 5 to 7% of its base speed.
2. Smooth speed control over very wide range is possible.
3. Rapid starting and reversing of the motor without losses in the rheostats are possible.

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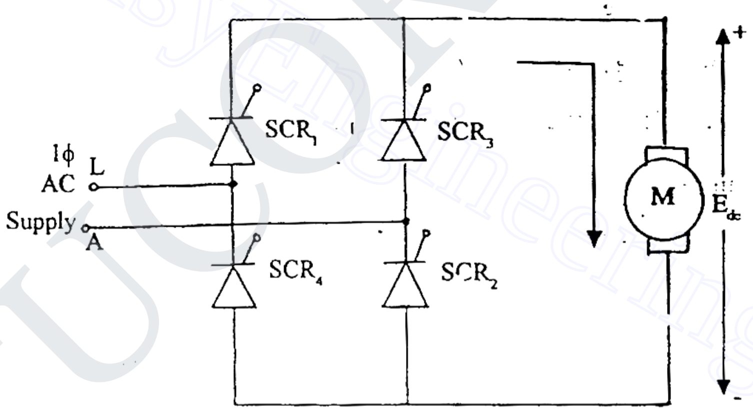
4. By using RS switch, speed control in both direction is possible.
5. The rheostat is in the field circuit of the generator, so very small current flows through it. As a result power loss is loss.
6. Regenerative braking is also possible with this method. This is achieved by suddenly decreasing the generated voltage of the generator, to a value less than the back emf of the main motor. Hence the main motor works as generator. As a result power will be supplied back to the network.
7. In this method speed of the motor is independent of the load on the motor.

Disadvantages

1. The initial cot is high because three machines are required.
2. The efficiency of the speed control is low because there is two stages of power conversion namely, mechanical to electrical (MG set) and electrical to mechanical (Main motor)

2. With neat diagram describe working of single phase fully controlled rectifier drive. **(Nov/Dec-2013, May/June-2014, May/June-2012)**



Construction:

The arrangement of four SCR in a manner as Bridge connection. This connection is also known as B-2 connection. The SCR is so connected that, tow of it is forward biased during one half cycle and other tow is reverse biased. This shown that two SCRs are used to rectify each half cycle. In this circuit both the half cycle is rectified by applying triggering pulse and hence it is known as Full – wave rectifier.

Operation:

During positive half cycle of input AC voltage the terminal L is positive and terminal A is negative. As a result SCR_1 and SCR_2 are forward biased and SCR_3 and SCR_4 are reverse biased. So SCR_1 and SCR_2 conducts when triggered by firing pulse

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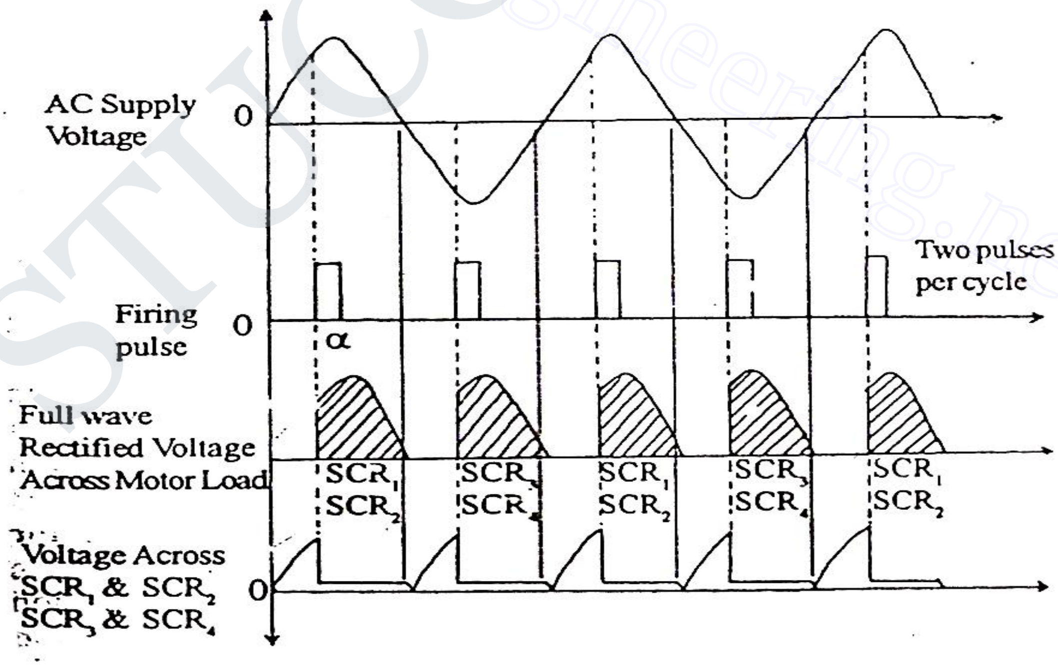
and SCR_3 and SCR_4 never conducts because it is reverse biased. Now during certain angle α of the positive half cycle SCR_1 and SCR_2 were given triggering pulses so current flows through the path L-SCR_1 – Motor – SCR_2 – N. So the part of the positive half cycle, after the application of firing pulse at firing angle (α), appears across the motor load.

During negative half cycle of input AC voltage the terminal A is positive and terminal L is negative. As a result SCR_3 and SCR_4 are forward biased and SCR_1 and SCR_2 are reverse biased. So SCR_3 and SCR_4 conducts when triggered by firing pulse and SCR_1 and SCR_2 never conducts, because it is reverse biased. Now during certain angle α of the negative half cycle after the application of firing pulse at firing angle (α), appears across the motor load in the positive direction.

The above two cases shows that both the half cycle produces the current in same direction through the motor. So the output voltage is rectifier DC voltage. By varying the firing angle, the conduction angles of SCRs are varied. By varying the conduction angle β($\alpha$to π) of the SCR, the average value of output DC voltage applied to the motor can be varied. By varying the average value of the DC voltage, the speed of the DC motor can be controlled. Thus the speed of DC motor can be varied by varying the firing angle.



It is observed from the above waveform that tows triggering or firing pulses are applied during each cycle of the AC voltage, so this circuit is also known as two pulse converter.

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3. With neat diagram explain chopper fed four quadrant dc drives.(Nov/Dec-2013)

Construction and Operation:

In four quadrant chopper four switches (T1, T2, T3, and T4) are used. The switches may be of power semiconductor switches like IGBT, MOSFET, BJT, SCR etc., and Depends upon the application need the fixed DC supply is given as the input supply. By varying the applied PWM (pulse width modulation) inputs the chopper on and off time can be changed, so the variable dc supply voltage is applied to the motor load. Four numbers of freewheeling diodes connected in parallel with the four switches. These freewheeling diodes are used as a protective device for the switching devices. The four quadrant operation is depends upon the current flow direction through the motor. When the armature (A) is connected with the positive supply the motor is running in the forward direction. When the armature (AA) is connected with the negative supply the motor is running in the reverse direction.

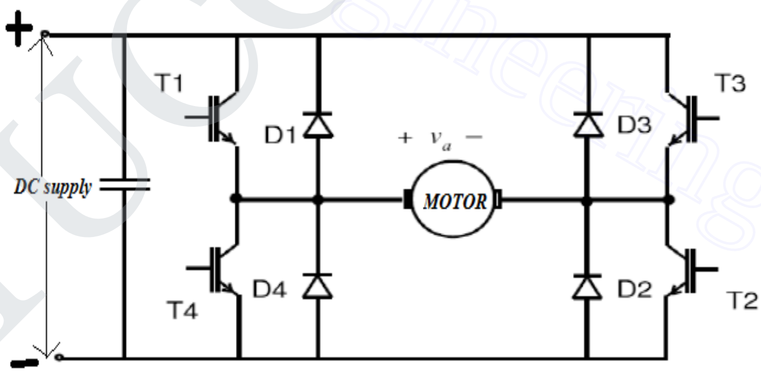
The four quadrant chopper operates in four modes of operations namely,

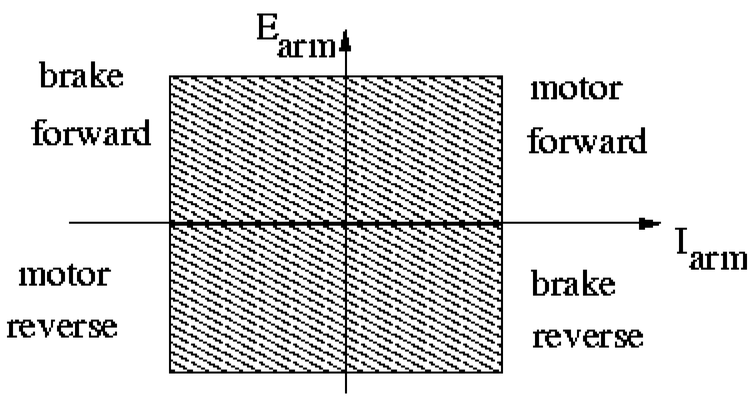
(a) Forward motoring (Quadrant: 1)

(b) Forward braking (Quadrant: 2)

(c) Reverse motoring (Quadrant: 3)

(d) Reverse braking (quadrant: 4)





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(a) Quadrant I: In the first quadrant, the voltage and current are positive making the power is positive. In this case, the power flows from source to load. In this operation T1is ON, T4 is OFF, T2 is continuously ON and T3 is continuously OFF. T1 and T2 are conducting in this mode.

(b) Quadrant 2: In the second quadrant, the voltage is still positive but the current is negative. Therefore, the power is negative. In this case, the power flows from load to source and this can happen if the load is inductive or back emf source such as a dc motor .Here T1 is OFF, T4 is ON,T2 is continuously ON and T3 is continuously OFF. As the inductor current cannot be changed instantaneously, D4 and T2 will be freewheeling the current.

(c) Quadrant 3: In the third quadrant both the voltage and current are negative but the power is positive. In this case, the power flows from source to load. In this operation T3is ON, T2 is OFF, T4 is continuously ON and T1 is continuously OFF. T3 and T4 are conducting in this mode.

(d) Quadrant 4: In the fourth quadrant voltage is negative but current is positive. The power is therefore negative. Here T3 is OFF, T2 is ON,T4 is continuously ON and T1 is continuously OFF . As the inductor current cannot be changed instantaneously, D2 and T4 will be freewheeling the current.

Advantages:

Easy to control, Possible to control in all four regions and Smooth speed control

Disadvantages:

Complex circuit, Cost is high

Applications:

Traction, Lifts, and Conveyors

4. Explain the methods of speed control of dc shunt Motor

Principle

The speed equation shows that the speed of the Dc motor is inversely proportional to Armature Resistance (R_a). If Armature Resistance (R_a) is increased, then the speed (N) is decreased. The method of speed control that is obtained by varying armature circuit resistance by including a rheostat in armature circuit is known as Armature or Rheostatic Control.

$$N \quad \alpha \quad \frac{V - I_a R_a}{\phi}$$

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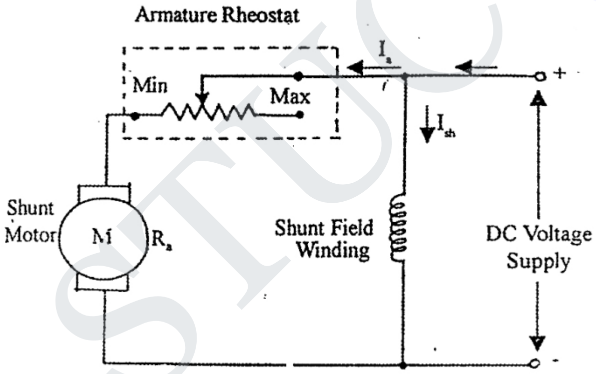
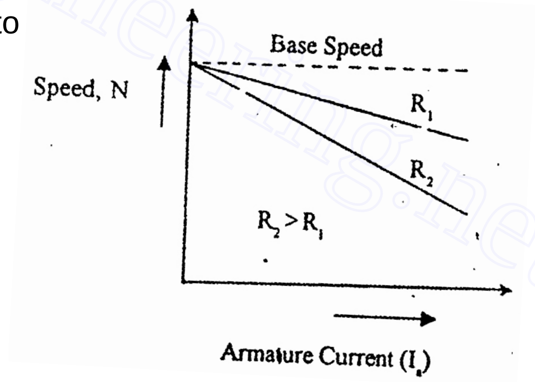
Operation

The Speed of the DC Motor is directly proportional to armature voltage (V). If the Resistance of Rheostat is increased, the voltage applied across Armature is reduced. So speed is controlled by adding variable resistance (armature rheostat in series with the armature. This method is used when speeds below the base speed (no-load rated speed) are required.

The field winding is excited by rated voltage, hence the current flowing in field winding I_{sh} is constant. Initially sliding arm of rheostat is kept in minimum (min) position. Now rheostat is not included in the armature circuit. So the full rated voltage is applied to the armature. Now the DC shunt motor is applied with the rated field current and the rated voltage and hence it runs with rated speed (Base speed). When the slider arm of rheostat is moved towards the maximum position, the voltage applied to the armature decreases.

So the speed is reduced from base speed. When the rheostat is in maximum (Max) position, the speed drops to the minimum value as shown in the characteristics curve. The speed is decreased from base speed to the low speed for the movement of slider arm from min to max position. This shows that this method is used to get speed below the base speed i.e., by increasing resistance the speed can only be reduced, l to





From speed / armature current characteristics it is seen that greater the resistance in the armature circuit, greater is fall in the speed.

Advantages

1. Easy and smooth speed control below the base speed is possible.
2. The rheostat in the armature act as a starter during he starting. So the high current during starting can be avoided.

Disadvantage

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1. The large amount of power is wasted in the armature rheostat. So the efficiency of this method is poor.
2. The Speeds above the base speed is not possible
3. This method results in poor speed regulation, i.e., the range of speed control is very small.

Flux Control method

Principle:

The speed equation of DC motor shows that the speed (N) is inversely proportional to the Flux (ϕ). So by altering the flux, speed control of required range can be obtained. To change the flux the rheostat is included in the field circuit and hence it is knows as field rheostat. In the field circuit if the resistance is increased, then field current decrease, as a result the flux is also deceases. The decreasing flux gives increases in speed and vice versa.

$$N = K(V/\Phi)$$

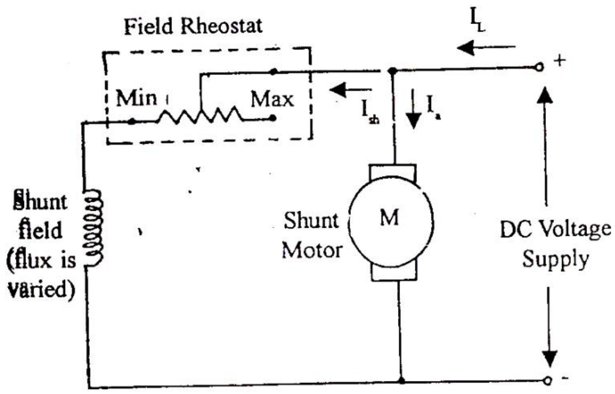
Where N- Speed of the motor,

V- applied voltage

Φ - Flux

Operation:

The speed control of DC shunt motor by flux control method. At the beginning, the field rheostat is kept at the minimum (min0 position. Now field rheostat is not present in the field circuit. So rated field current I_{sh}, flows in the field circuits. The rated supply voltage is applied to the armature. Now the DC Shunt motor runs at base speed because field is provided with rated field current and armature is provided with rated supply voltage.



Now the field resistance is increased by moving slider arms towards maximum (Max) position, due to which shunt field current decrease. The decreases in shunt field current

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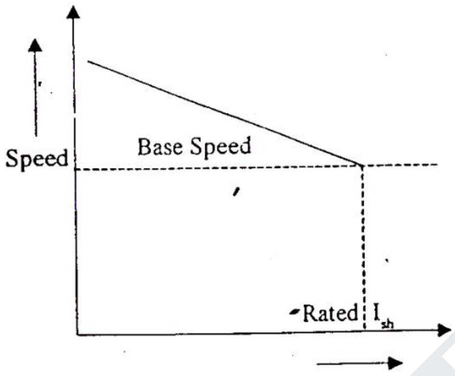
causes flux to decrease. Since the flux decrease, the speed increases. Already the motor is running with base speed. By deceasing the flux speeds above the base speed is possible. So this method used to cases where speed above the rated speed is required.



Advantage

1. This is an easy and convenient method
2. speed control above the base (rated) speed is possible
3. since the field current is very low, the size of the field rheostat and power loss is less

Disadvantage

1. The speed control below the normal speed is not possible. Because flux can be only reduced by inserting Rheostat
2. Since the speed obtained is above the rated speed, the motor operation is unstable.

5.Explain the Speed control of D.C. Series Motor

In DC series motor the armature and field windings are connected in series. In series circuit, the current flowing through each element is same. Soothe same current flows through armature and field. The speed control methods of DC series motor are classifieds into two types namely.

(i) Flux Control method
(ii) Armature Resistance Control

(a) Flux Control Method

In flux control methods the flux can be varied by number of methods. They are,

(i) Field Diverter method
(ii) Armature Diverter method
(iii) Tapped field method
(iv) Series / Parallel arrangement of field coils

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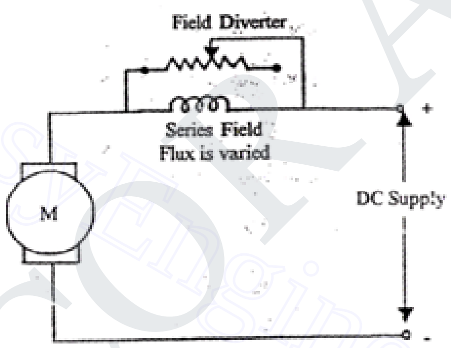
These methods are explained in the below section.

i) Field Diverter Method

In this method variable resistance is connected in parallel with series field winding, which is known as Field diverter. The speed control method by which the speed of the DC series motor is controlled by varying flux with the help of field diverter is known as field diverter method. The diverter and the series field form the parallel circuit. This parallel circuit acts as a current divider. So current flowing through the series field is reduced. As a result flux produced by the series field is also reduced. which makes the speed to increase. If the field diverter resistance is increased then current flowing through series field increases and as a result flux increases. This makes speed to decrease, because speed is inversely proportion to flux increases. The control circuit for field diverter method is shown below. Using this method speed above be speed is possible.



ii) Armature Diverter Method

This method is used for the motors that require constant load torque. In this method, a variable resistance is connected in parallel with armature, which is known as armature diverter. The speed control of DC series motor using armature diverter is known as armature diverter method. The armature diverter and the armature forms the parallel circuit. So the current flowing through the armature is reduced. But as T $\alpha \phi I_a$, but load torque is constant, so the flux is to be increased. So the motor takes more current from the supply. As a result current through the field winding increases. This cause the flux to increases and speed of the motor to decrease. So this method is used to control the speed below the base speed.

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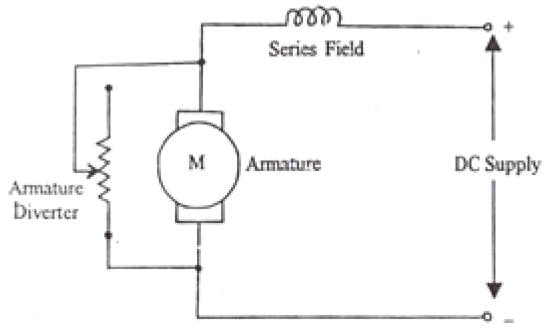
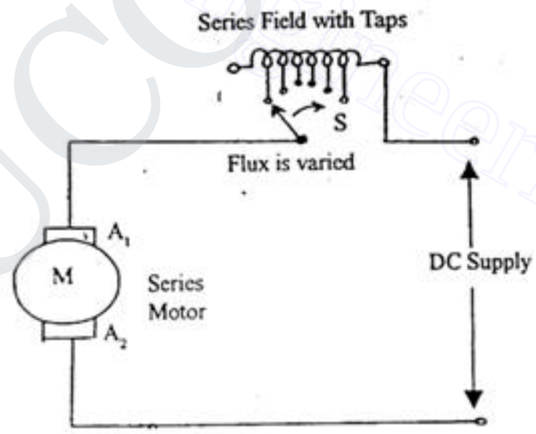


iii) Tapped Field method

In this method, flux change is obtained by changing the number of turns of the series field winding. Here the series field finding is provided with number of taps. The selector switch S is provided with rotor sliding contact to select the numbers of turns through the taps, as per the requirement. When the switch is placed in position as indicated, the entire field winding is inserted in the circuit and the motor runs with base (Normal) speed.

As the switch is moved towards clockwise direction, the number of turns, that is included in the circuit, is reduced. As a result, the flux is reduced which increases the sped of the motor above the base speed. So this method is used to obtain speed above the base speed. This method often used in electric traction.



iv) Series / Parallel Arrangement of Field Coils

In this method the field coils is divided into various parts. These divided parts can be then connected in series and parallel as per the requirement. the field coils connected in series. The series connection of the field coil gives lower speeds. In the series circuit is not divided as a result the flux is more and the speed is less.

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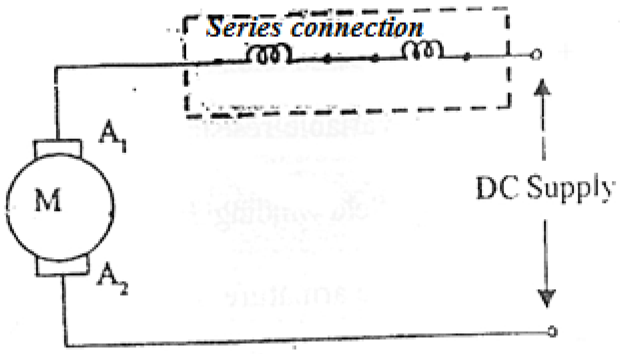
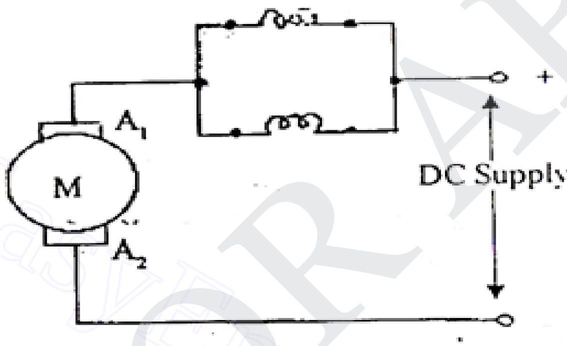
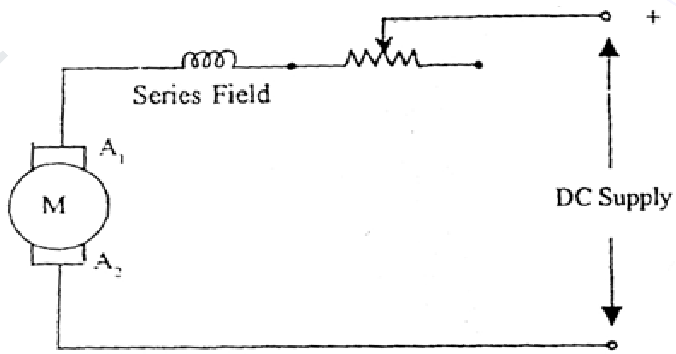


Below has field coils connected in parallel. The parallel connection of field coils is used to obtain higher speed. The parallel circuit acts as a current divider. So the current flowing through the field coils is reduced. So the flux is reduced. This causes increases in speed because speed is inversely proportional to the flux.



(b) Armature Resistance Control

In this method the variable resistance is connected in series with the armature and series field winding. By increasing the resistance the voltage applied across the armature, the speed is reduced. However, it is noted that entire full load current passes through the variable resistance, so the power loss is high.



The speed control of DC drive using solid – state device such as SCR and solid state circuit such as rectifier and chopper is known as Solid-state speed control of DC drives.

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PART C

6. Explain the speed control of a dc shunt motor using three phase fully controlled rectifiers. (Nov/Dec-2014)

1ϕ Full – Wave controlled Rectifier:

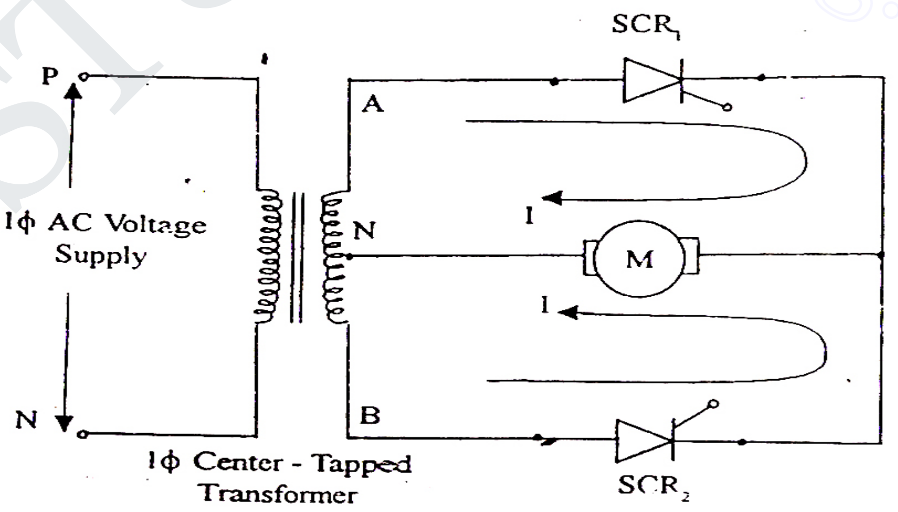
The rectifier that converts fixed AC voltage into variable DC voltage by utilizing full cycle (both the half cycle) of input 1ϕ AC supply is known as 1ϕ Full – Wave rectifier. Since this circuit uses SCR the output DC voltage can be controlled. Hence it is known as controlled rectifier. There are two basic configurations of full – wave controlled rectifiers. Their classification is based on method of connection the SCRs. They are

1. Mid-Point Converter
2. Bridge Converter

i) 1ϕ Full – Wave Mid-Point Controlled Rectifier

Circuit Connections:

This rectifier circuit has two SCR, one SCR is triggered during positive half cycle of input AC wave and the other SCR is triggered during negative half cycle of the input AC wave. The two SCRs are connected across the motor. The AC input voltage is applied to the circuit through special transformer with mid-point terminal (N) in the secondary. The mid- point terminal (N) is tapped from the centre of the secondary of the 1ϕ transformer. This is known as Centre – Tapped Secondary. The anode of the two SCRs are connected with two ends of the secondary and one end of the motor load is connected with mid-point of the transformer and the other end with cathode of the SCRs. This connection is known as mid- point connection or M-2 Connection.



Control circuit of 1phase Full-Wave controlled mid-point rectifier used for speed control of DC Motor.

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Working Principle:

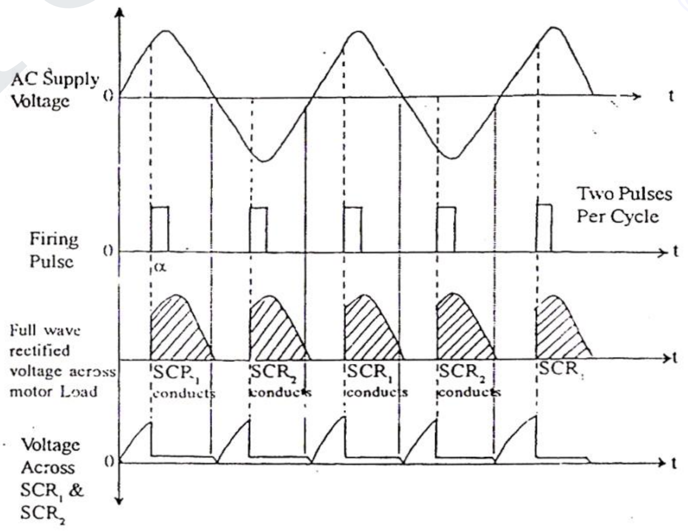
During positive half cycle of input AC supply, the terminal A of centre – tapped transformer is positive with respect to terminal B. The positive terminal A is connected with SCR_1 and negative terminal with SCR_2. So SCR_1 is forward biased and SCR_2 is reverse biased. The SCR_1 can conduct when triggered by firing pulse and SCR_2 never conducts because it is reverse biased. The current now flows in the path A- SCR_1 –

Motor – N. So positive half cycle of input AC supply appears across the motor load, when firing pulse is applied.

During negative half cycle of input AC supply, the terminal B of centre – tapped transformer is positive with respect to terminal A. The positive terminal B is connected with SCR and negative terminal with SCR_1. So SCR_2 is forward biased and SCR_1 is reverse biased. The SCR_2 can conduct when triggered by firing pulse and SCR_1 never conducts because it is reverse biased. The current now flows in the path B – SCR_2 –

Motor – N. so negative half cycle of input AC supply appears across the motor load.

The above two cases shown that both the half cycle produces the current in same direction through the motor. Os the output voltage is rectified DC voltage. B varying the firing angle, the conduction angles of SCRs are varied. By varying the conduction angle ($\beta = \alpha$ to π) of the SCR, the average value of output DC voltage applied to the motor can be varied. By the firing angle, the conducting angle can be varied. By varying the average value of the DC voltage, the speed of the DC m … vary the speed of DC motor.



Waveforms of 1phase Full-Wave Mid-point Controlled Rectifier.

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It is observed from the above waveform that two triggering or firing pulses are applied during each cycle of the AC voltage, so this circuit is also known as two pulse converter.

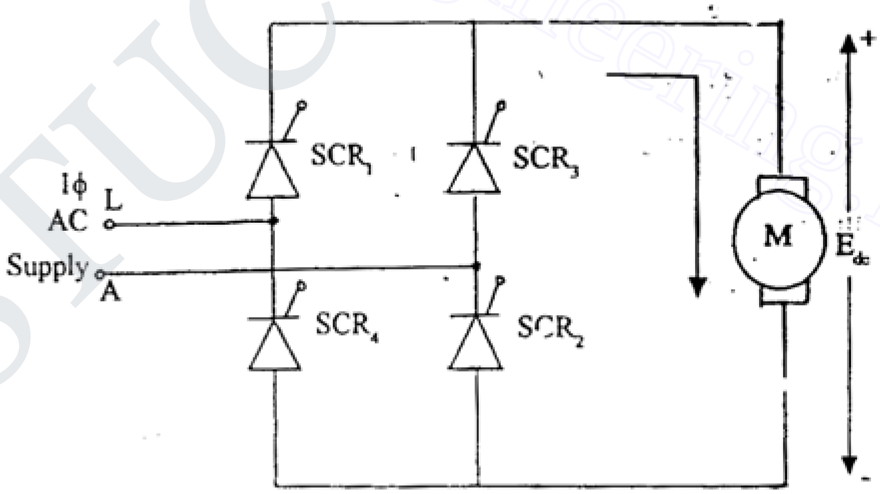
ii) 1ϕFull– Wave Bridge controlled Rectifier

Circuit connections

The arrangement of four SCR in a bridge connection is shown in below figure. This connection is also known as B-2 connection. The SCR is so connected that, tow of it is forward biased during one half cycle and other tow is reverse biased. This shown that two SCRs are used to rectify each half cycle. In this circuit both the half cycle is rectified by applying triggering pulse and hence it is known as full – wave rectifier.

Operation:

During positive half cycle of input AC voltage the terminal L is positive and terminal A is negative. As a result SCR_1 and SCR_2 are forward biased an dSCR_3 and SCR_4 are reverse biased. So SCR_1 and SCR_2 conducts when triggered by firing pulse and SCR_3 and SCR_4 never conducts because it is reverse biased. Now during certain angle α of the positive half cycle SCR_1 and SCR_2 were given triggering pulses so current flows through the path L-SCR_1–Motor –SCR_2–N. So the part of the positive half cycle, after the application of firing pulse at firing angle (α), appears across the motor load.



Control Circuit for 1phase Full Wave Bridge Controlled Rectifier

During negative half cycle of input AC voltage the terminal A is positive and terminal L is negative. As a result SCR_3 and SCR_4 are forward biased and SCR_1 and SCR_2 are reverse biased. So SCR_3 and SCR_4 conducts when triggered by firing pulse and SCR_1 and SCR_2 never conducts, because it is reverse biased. Now during certain

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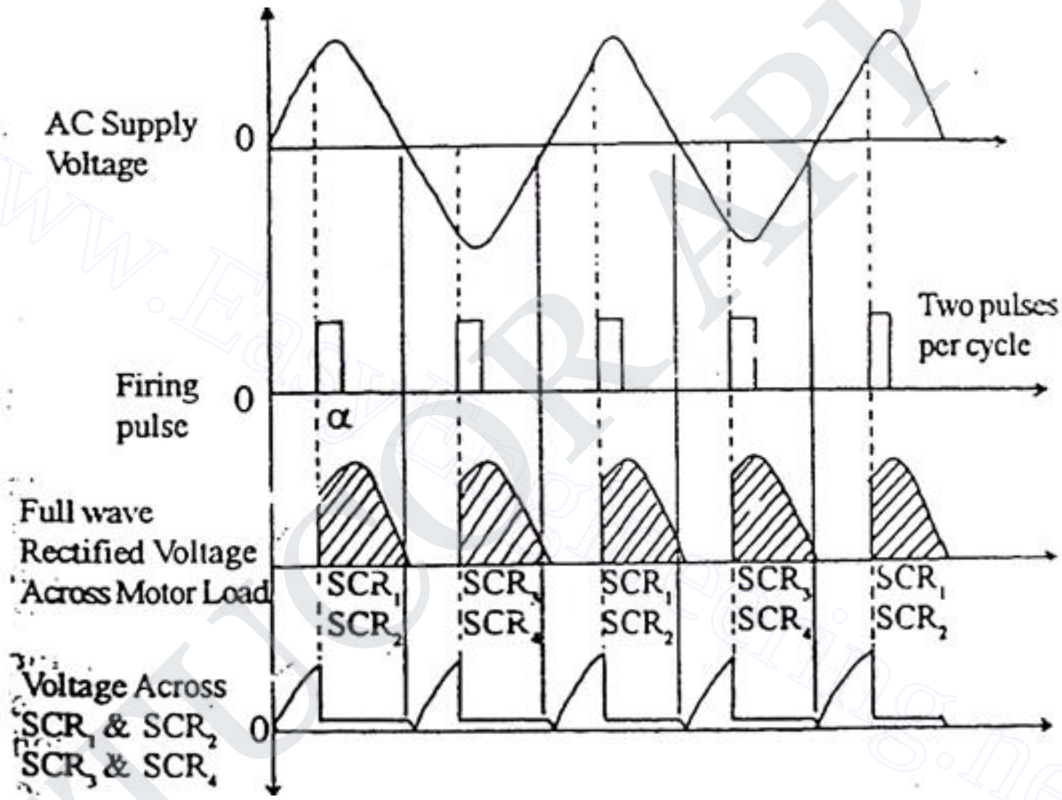
angle α of the negative half cycle after the application of firing pulse at firing angle (α), appears across the motor load in the positive direction.

The above two cases shows that both the half cycle produces the current in same direction through the motor. So the output voltage is rectifier DC voltage. By varying the firing angle, the conduction angles of SCRs are varied. By varying the conduction angle β(αto π) of the SCR, the average value of output DC voltage applied to the motor can be varied. By varying the average value of the DC voltage, the speed of the DC motor can be controlled. Thus the speed of DC motor can be varied by varying the firing angle.



Waveforms of single phase Full – Wave Bridge Controlled Rectifier

It is observed from the above waveform that two triggering or firing pulses are applied during each cycle of the AC voltage, so this circuit is also known as two pulse converter.

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UNIT V – CONVENTIONAL & SOLID STATE SPEED CONTROL OF AC DRIVES

PART – A

1. What are the speed control methods available for speed control of induction motor on stator side? (AU-MAY-08)

i. By controlling supply voltage

ii. By pole changing

iii. By Changing supply frequency

2. What are the speed control methods available for speed control of induction motor on rotor side? (AU-NOV-05)

i. By rotor resistance control

ii. By Cae speed control

iii. By injected voltage method.

3. What are the three possible speeds that can be obtained in caed operation of induction motor? (AU-MAY-07) (AUC-NOV-10)

i. $N_S = \frac{120f}{Pa}$; Where, Pa = No of stator poles in motor A

ii. $N_S = \frac{120f}{Pb}$; Where, P_b = No of stator poles in motor B

iii. $N_S = \frac{120f}{Pa+Pb}$

4. What is slip in an induction motor? (AUC-NOV-09)

The induction motor speed is always less than the speed of synchronous speed of revolving flux. The difference in speed between synchronously revolving flux and the rotor speed is called slip speed. The ratio between the slip speed and synchronous speed of induction motor is called slip. It is denoted

$$\text{Slip, } S = \frac{Ns-N}{Ns}$$

$$\%S = \frac{Ns-N}{Ns} *100$$

5. What is slip power? (AUC-NOV-09)

It is the power wasted in the rotor circuit resistance. In case of slip ring induction motor, the speeded control is achieved by adding external resistance in the rotor circuit. But, with adding external resistance in the rotor circuit, (I2R) losses in the external resistances will be increased. Hence, slip power is wasted in rotor resistance. Without wasting this slip power, the slip power can be usefully utilized in slip power recovery scheme.

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6. What is slip power recovery scheme?(AU-MAY-06,07)(AU-APR-08)(AUC-NOV10)

The power wasted in the external resistance in the rotor circuit in case of slip ring induction motor, is called slip power. This wastage slip power can be usefully fed back to the source by used of slip power recovery scheme. Two types of slip power recovery scheme available are

(i) Static scherbius drive, (ii) Static Kramer's drive

7. What is meant by inverter? (AUC-MAY-10)

A device that converts dc power into ac power at desired output voltage and frequency is called an inverter.

8. What is the function of inverter? (May 2015)

Inverter is a circuit which converts DC to AC with desired output voltage and frequency.

9. Give two advantages & applications of CSI

Advantages

(i) CSI does not require any feedback diodes.

(ii)Communication circuit is simple as it contains only capacitors.

Applications

(i)Induction heating, (ii)Lagging VAR compensation, (iii)Speed control of AC motors, (iv)Synchronous motor sharing

10. What are the advantages of static Kramer's system over static Scherbius system? (May 2008, May 2015)

(i) No commutation problem

(ii) Output frequency can easily tracked.

(iii) The line power factor is almost unity.

11. Compare VSI and CSI (AU-NOV-08) (AUC-MAY-10)

S.No	Voltage source inverter(VSI)	Current source inverter(CSI)
1	In voltage source inverter, input voltage is maintained constant.	In current source inverter, input currents constant but adjustable
2	In VSI, the output voltages does not depend on the load	In CSI, the amplitude of output currents constant but adjustable
3	The magnitude of output current and its waveform depends upon the nature of the load impedance	The magnitude of output voltage and its waveform depends upon the nature of the load impedance
4	It requires feedback diodes	It does not require any feedback

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		diode
5	Commutation circuit complex	Commutation circuit is simple i.e., it contains only capacitors.

PART- B

1. Explain the speed control of induction motor from starter side (AU-MAY-08) (AU-NOV-08, 09) (AUC-MAY-10)

The various methods available for speed control of induction motors from stator side are:

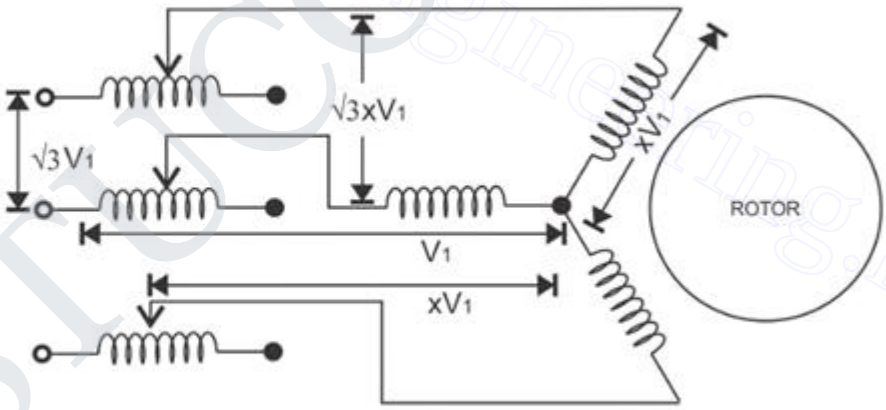
(i) By changing the applied voltage.

(ii)By changing the applied frequency.

(iii)By changing the number of stator poles

(i)By changing the applied voltage:

Slip can be varied by changing the applied stator voltage i.e. motor speed can be varied by varying the supply voltage, because if the voltage is reduced as, torque is reduced as square of the voltage. For example, if the applied voltage is reduced from V to 0.9 V, the torque will be reduced from T to 0.81 T. The torque –speed characteristics at reduced stator voltage say 0.9V.



Since the torque is reduced to 81 percent, the rotor cannot continue to rotate at speed N1, it speed will be reduced. i.e. its slip will increase until the increased rotor current will make up for the reduced stator voltage and produce the required load torque at a a lower speed N2. This method of speed control is rarely used for industrial three-phase motors because of the requirement of additional costly voltage changing auxiliary equipment. For small induction motor used in home appliance, voltage control method of speed changing is often used.

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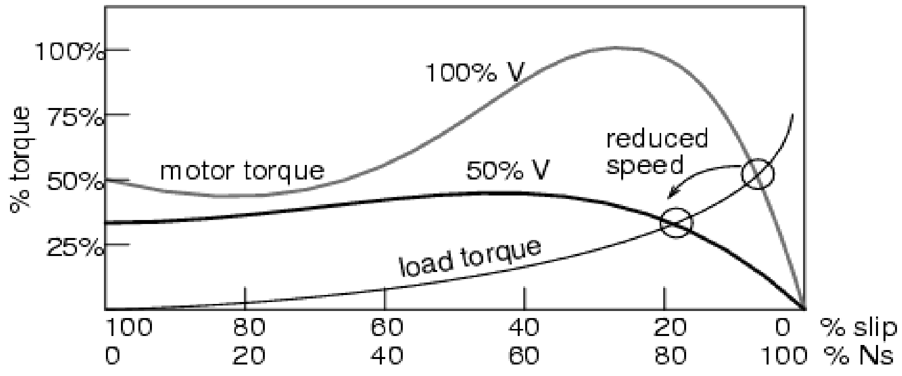
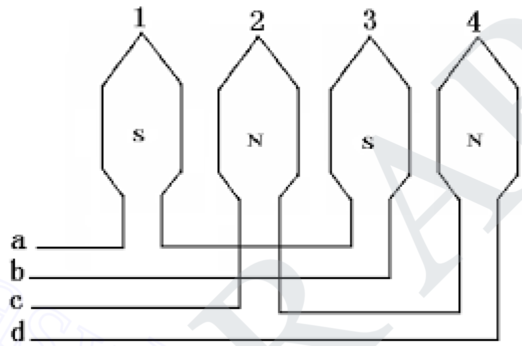


Figure: Speed-torque curves: voltage variation

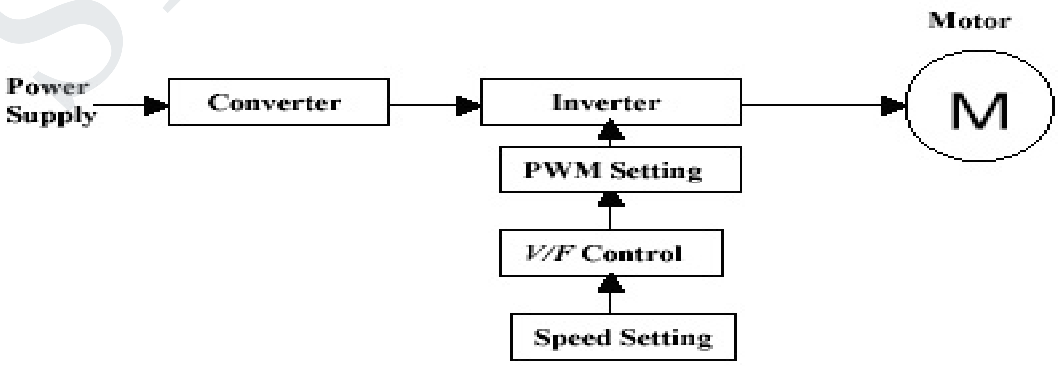
B). BY POLE CHANGING METHOD:



The speed of an induction motor depends upon the number of poles in which the stator is wound. If two independent stator windings are used for different number of poles say for four poles and for two poles are made on the stator, definite rotor speeds can be obtained. The two windings are to be insulated from one another. When any of the windings is used, other winding should be kept open circuited by the switch.

The limitation of this method is only two definite speeds can be obtained. Smooth control of speed over wide range is not possible.

C) BY CHANGING SUPPLY FREQUENCY:



The speed of an induction motor is directly proportional to supply frequency. By gradually changing supply frequency, speed can be increased (or) decreased smoothly. There are, however, several drawbacks in this system. Electricity supply authorities

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supply power at a fixed frequency of 50 HZ, provision for supply at variable frequency can be made by consumers by having separate arrangement. Frequency conversion equipment are, therefore, to be installed by the industries at additional costs. Variable frequency conversion equipment are therefore, to be installed by the industries at additional costs. Variable frequency supply can be obtained from solid-state equipment, rotary converters i.e. motor generator gets.

If speed control is to be achieved by changing frequency, the supply voltage should also simultaneously be changed. This is because if the supply frequency is reduced keeping the applied voltage constant, the flux is increased. If flux is increased, core-losses will reduce the efficiency on the other hand if frequency is increased, flux will decrease, thereby reducing the torque developed.

It is important, therefore, that frequency changing device should change frequency and voltage simultaneously as a direct ratio. i.e. if frequency is increased, the supply voltage must also increase and if frequency is decreased the supply voltage must also decrease proportionately. Three phase supply at the input is first converted into controlled DC. This DC is applied to inverter circuit, whose frequency is controlled by pulses from voltage to frequency converter units. A large smoothing reactor, L is in the circuit to filter the controlled DC.

2. Explain the slip recovery scheme of conventional Kramer and Sherbius system for induction motor drive. (AU-NOV-05, 09) (AU-MAY-07) (AU-APR-08) (AUC-NOV-09) (AUC-APR-11) (AUC-JAN-09) (AUC-MAY-10)

Conventional Kramer system

The Kramer's system of slip power recovery scheme, which is used, is case of large motors of 4000 KW (or) above.

Construction and working:

It consists of a rotary converter C which converts the low-slip frequency a.c. power into D.C. power, which is used to drive a d.c shunt motor D, mechanically coupled to the main motor M. The main motor is coupled to the shaft of the d.c shunt motor D. The slip rings of m are connected to those of the rotary converter C. The d.c output of C is used to drive D. But C and D are excited from the D.C bus bars (or) from an exciter. There is a field regulator which governs the back emf E_b of D and hence the d.c potential at the commutator of C which further controls the slip ring voltage and therefore the speed of M.

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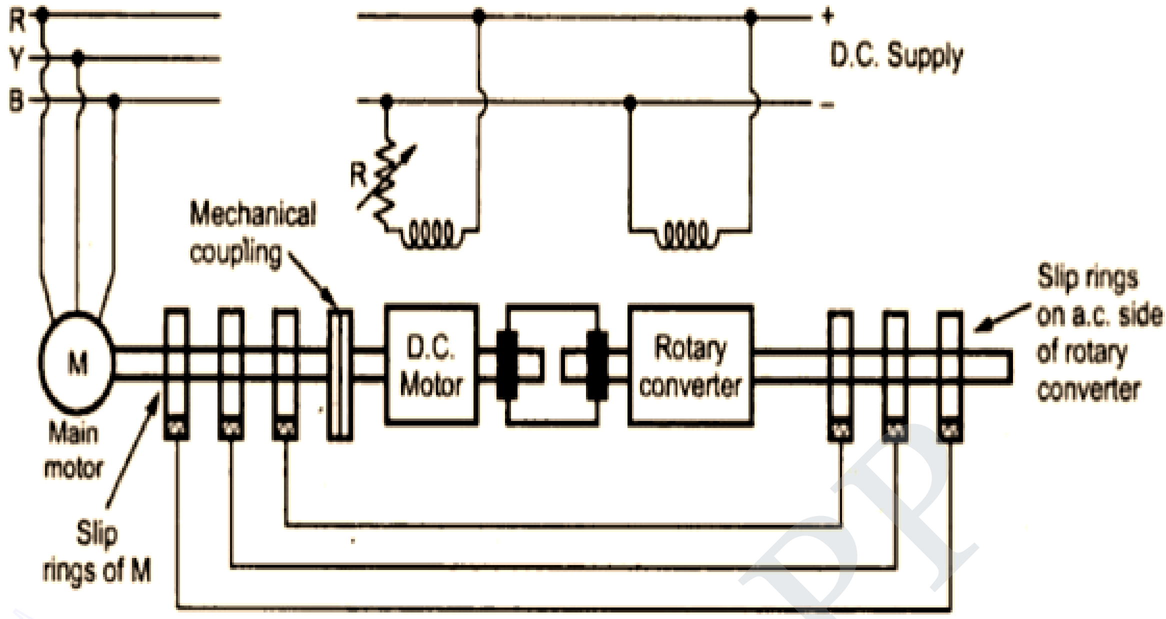

The main advantage is that any speed within working range can be obtained by this method. Another advantage is that if the rotary converter is over-excited, it will take a leading current which compensates for lagging current drawn by main motor m and hence improves the power factor of the system

Conventional Scherbius system:

This is another method of speed control system in which slip power is recovered. The poly-phase winding of machine C is supplied with the low frequency output of machine M through a regulating transformer (RT). The commutator motor C is a variable speed motor and its speed (and hence of M) is controlled by either varying the tapping's on RT or by adjusting the position of brushes on C. This method requires an auxiliary 3 phase or 6 phase a.c. commutator machine which is called Scherbius machine.

The difference between Kramer system and this system is that the Scherbius machine is not directly connected to the main motor, whose speed is to be controlled. The Scherbius machine is is excited at a slip frequency from the rotor of a main motor through a regulation transformer. The taps on the regulating transformer can be varied, this changes the voltage developed in the rotor Scherbius machine, which is injected into the rotor of main motor. This control the speed of the main motor, the scherbius machine is connected directly to the induction motor supplied from main line so that its speed deviates from a fixed value only to the extent of the slip of the auxiliary induction motor.

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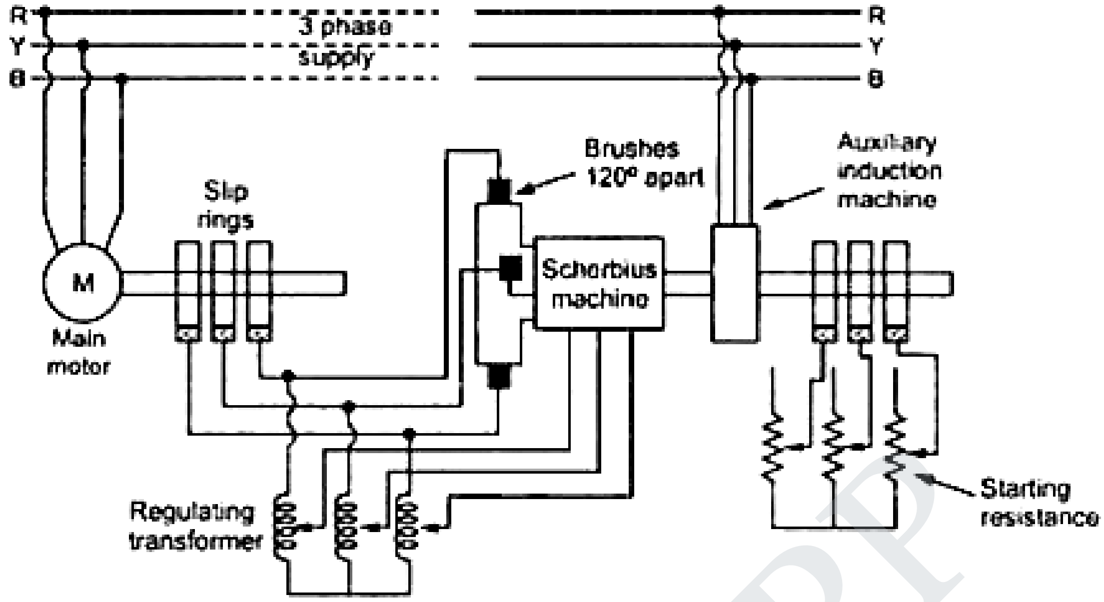

For any given setting of regulating transformer, the speed of the main motor remains substantially constant irrespective of the load variations. Similar to the Kramer system, this method is also used to control speed of large induction motors. The only disadvantage is that these methods can be used only for slip ring induction motors.

3. Explain the slip recovery scheme of Static Sherbius and Kramer system for induction motor drive. (AUC-APR-11) (AUC-JAN-09) (AUC-MAY-10), Dec 2015, Nov 2015

Static Sherbius system:

This is another method of speed control system in which slip power is recovered. The induction motor is started using three rheostats in the rotor circuit. The ac slip power is first rectified by the three-phase diode bridge, then turned back into ac power at line frequency by the thyristor inverter and finally returned to the supply network by means of a transformer , which brings the rotor circuit voltage of the ac supply network. The speed of the induction motor is regulated by the controlling the firing angle of the inverter. The gate pulses are provided by the firing circuits, synchronized with the supply voltage.

Both the rectifier and the inverter are line-commutated by the alternating emfs appearing at the slip rings and supply network respectively. The average counter emf of the inverter may be considered as an injected emf opposing the rectified rotor voltage. The system is started by switching on first S1 and then S2 while switches S3 and S$ remain off. As soon as the motor attains a steady speed, the rectifier –inverter

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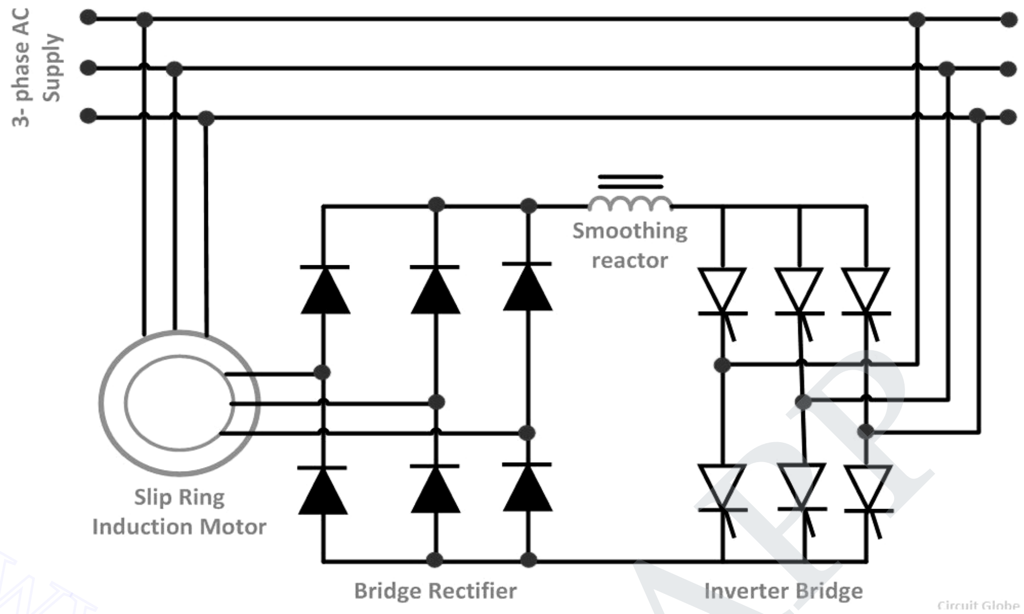
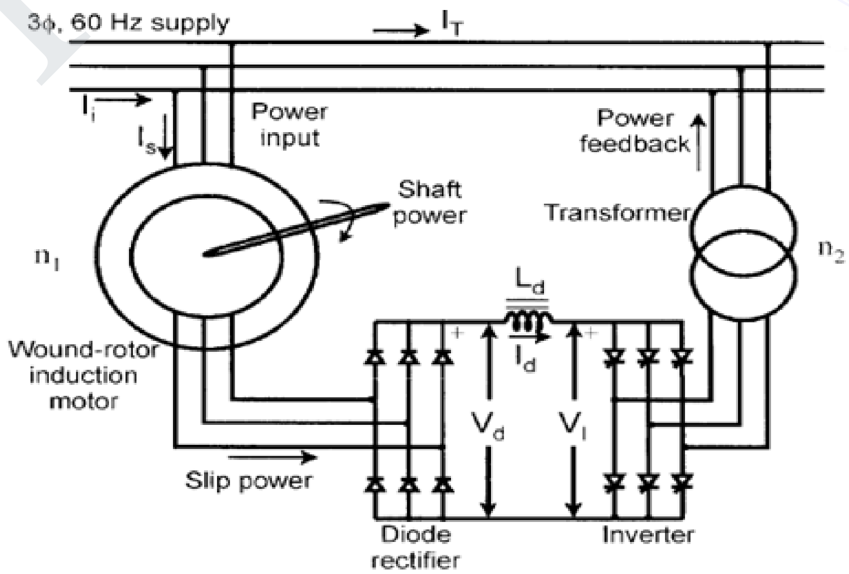
combination as well as the transformer is connected to the supply network switching S2 off and S3 and S4 on.



Static Kramer system

A slip ring induction motors rotor circuit feeds the slip power, rectified by means of a diode bridge, to the armature of a separately excited dc motor, which is mechanically coupled to the induction motor

The system is started by switching on S1 first and then S2, while switches S3 and S4are off. As soon as the motor attains steady speed, the dc motor is energized by switching S2 off and S3 and S4 on. Speed control is achieved by varying the field current of the motor an emf proportional to the back emf of the dc motor may be considered to be injected into the rotor circuit of the induction motor to cause variation in speed of the system.



Static Kramer drive system

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4. Explain the V/f control method of AC drive with neat sketches.

V/F control or Frequency control:

Whenever three phase supply is given to three phase induction motor rotating magnetic field is produced which rotates at synchronous speed given by

$$N_S=\frac{120f}{P}$$

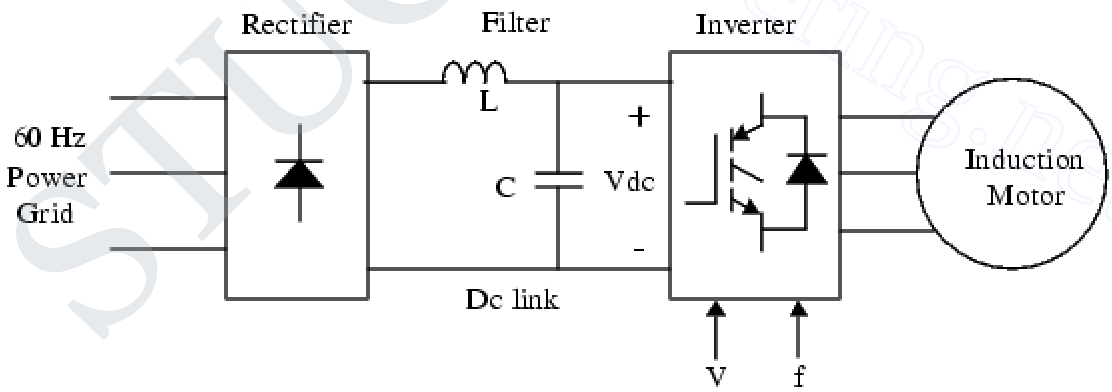
In three phase induction motor emf is induced by induction similar to that of transformer which is given by

$$E=4.44\boldsymbol{\Phi K T f}$$

Where K is the winding constant, T is the number of turns per phase and f is frequency.

Now if we change frequency synchronous speed changes but with decrease in frequency flux will increase and this change in value of flux causes saturation of rotor and stator cores which will further cause increase in no load current of the motor. So, it's important to maintain flux, φ constant and it is only possible if we change voltage. i.e if we decrease frequency flux increases but at the same time if we decrease voltage flux will also decease causing no change in flux and hence it remains constant.

So, here we are keeping the ratio of V/ f as constant. Hence its name is V/ f method. For controlling the speed of three phase induction motor by V/ f method we have to supply variable voltage and frequency which is easily obtained by using converter and inverter set.



If we reduce the supply frequency at rated supply voltage, the air gap flux will tend to saturate and causes excessive stator current to flow in which results in distortion of the flux wave. Thus the region below the rated frequency should be proportional reduction of stator voltage so as to maintain the air gap flux constant. The below figure 2 is the Torque-Speed characteristic at volt/Hz = constant. In Lower frequency region the air gap flux is reduced by stator impedance drop (V_m<V_s).Therefore this region has to be compensated by an additional boost voltage so as to restore T_{em} value. If air gap

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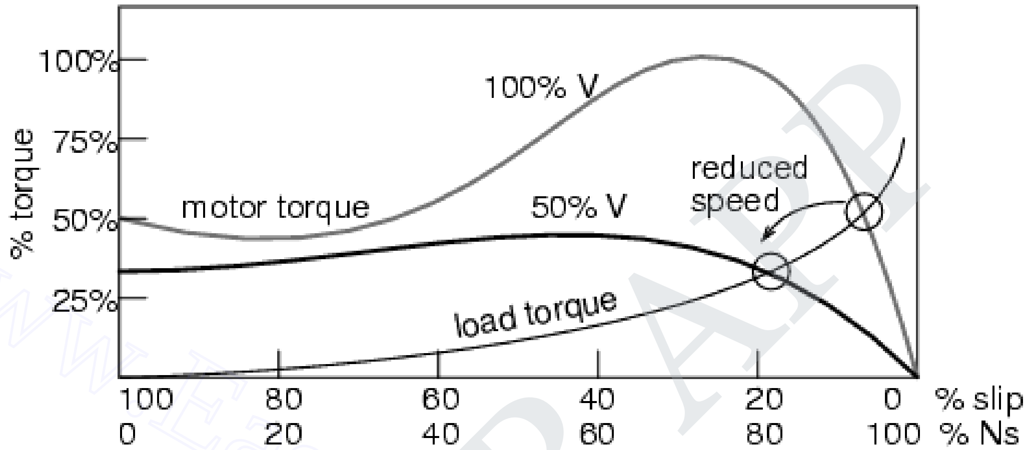
flux is kept constant in constant torque region then the torque sensitivity in ampere of stator current is high by permitting fast transient of the drive. In the variable frequency, variable voltage operation of the drive system, the machine usually has low slip characteristic (i.e low rotor resistance) giving high efficiency. In low starting torque for base frequency the machine can always be started at maximum torque indicated in the below figures. The absence of high inrush of starting current in a direct start drives reduces the stress and improves the life of the machine



From the torque equation of the induction machine, we can see that the torque depends on the square of the applied voltage. The variation of speed torque curves with respect to the applied voltage is shown in Fig. These curves show that the slip at maximum torque remains same, while the value of stall torque comes down with decrease in applied voltage. The speed range for stable operation remains the same. Further, we also note that the starting torque is also lower at lower voltages. Thus, even if a given voltage level is sufficient for achieving the running torque, the machine may not start. This method of trying to control the speed is best suited for loads that require very little starting torque, but their torque requirement may increase with speed.

5. Explain detail about Rotor resistance control of induction motor. (May 2014)

By adding eternal resistance to the rotor circuit any starting torque up to the maximum torque can be achieved; and by gradually cutting out the resistance a high torque can be maintained throughout the starting period. The added resistance also reduces the starting current, so that a starting torque in the range of 2 to 2.5 times the full load torque can be obtained at a starting current of 1 to 1.5 times the full load current.

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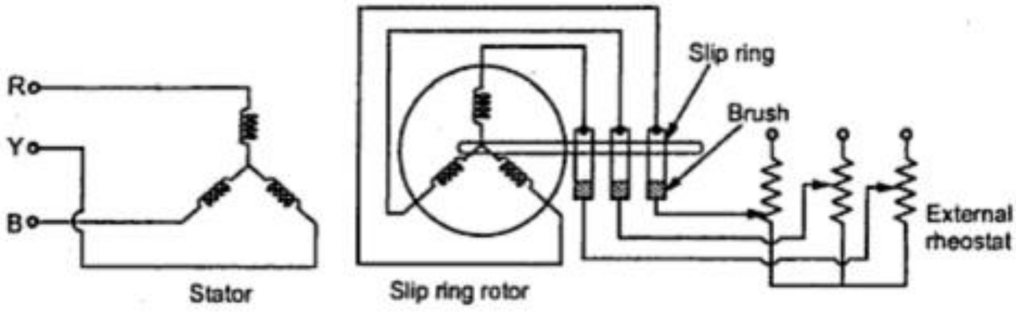


It's a switch that connects several resistances, one at a time, to a motor to allow the motor to start slowly. The resistances are switched as individual resistances from the highest to the lowest. As each resistance is switched in, the motor receives a certain amount of current, as the motor reaches the speed that switch setting would allow, the next resistance is switched in, replacing the first resistance. The motor speeds up a little more, until zero resistance is reached and the motor is running at full speed.

Advantage:

It is inexpensive, and is good for relatively small motors.

Disadvantages:

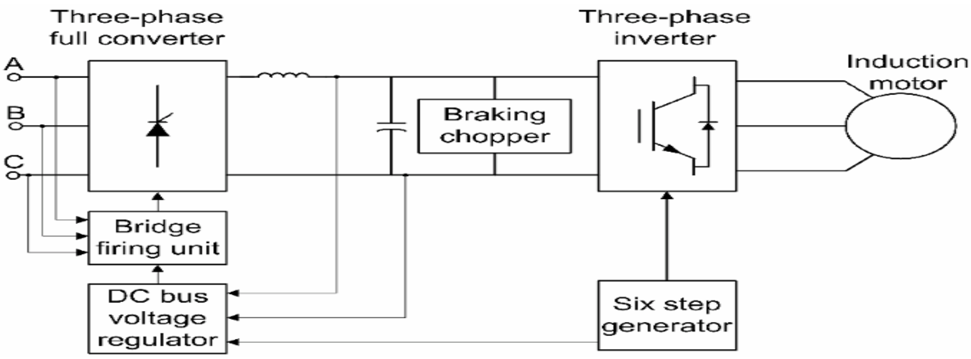
(i)Arcing between contacts,

(ii)Motor speed up is not a smooth.

PART C

6. Explain detail about CSI fed induction motor drive.

The CSI converts the input dc current into an ac current at its output terminals. The output frequency of ac current so depends upon the rate of triggering in the thyristor. These CSI's does not require any feedback diode, which is required by the VSI. Also the computation circuit is simple, it contains only the capacitor. The required dc convert is obtained from the three phase controlled rectifier. The smoothening inductor L will remove the ripples in the currents. Now the dc input current is given to the CSI. The nature of the current is in square wave. Due to this, harmonics will be produced and the torque will be in a pulsating nature. This can be minimised by implementing PWM technique of inversion. By eliminating the harmonics, the torque ripples can be minimised.



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Reg. No. :

Question Paper Code : 27209

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Third Semester

Mechanical Engineering

EE 6351 — ELECTRICAL DRIVES AND CONTROLS

(Common to Mechanical and Automation Engineering, Production Engineering, Manufacturing Engineering, Petrochemical Engineering, Chemical Engineering and Petrochemical Technology)

(Regulations 2013)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Draw the block diagram of an electric drive. 9

2. Mention the factors affecting the selection of Electrical drives. 9

3. A 220V, DC shunt motor having the armature current of 10 A, runs at 1500 rpm. Find the armature current if the source voltage drops to 150V. Assume the load torque as constant.

4. What are the different methods of breaking of DC series motor? 22

5. What is the need for a starter in Electrical motors? 36

6. Mention the advantage of four point starter over three point starter. 41

7. Write the disadvantages of armature resistance method of speed control in DC shunt motor. 56

8. List the applications of chopper fed DC drives.

9. What are the various speed control methods used in AC motors? 66

10. What are the different types of slip power recovery scheme? 67

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PART B — (5 × 16 = 80 marks)

11. (a) Explain the various classes of motor duty with necessary diagrams and examples. 15 (16)

Or

(b) (i) Define an Electric drive and describe the classification of Electric Drives. 9 (8)

(ii) Explain the selection of motor power rating for different loading conditions. (8)

12. (a) Explain the four quadrant operation in motor drives. (16)

Or

(b) (i) Discuss the dynamic breaking of DC shunt motor. 33 (8)

(ii) Describe the speed-torque characteristics of DC shunt and series motor with neat sketch. 23 & 24 (8)

13. (a) Explain the three point starter in detail. 37 (16)

Or

(b) Briefly explain the various types of starters used in 3ϕ induction motor. 41 (16)

14. (a) (i) Explain the Ward-Leonard method of speed control in DC shunt motor. 50 (12)

(ii) A 220V, DC shunt motor having a field flux of 0.8 wb, runs at a speed of 900 rpm. Find the speed of the motor, if the field flux reduced to 0.6 wb by field resistance control method. (4)

Or

(b) (i) Explain the voltage control strategies employed in DC chopper drives. (8)

(ii) A 220V, 1200 rpm, 1ϕ full converter fed separately excited DC motor having a armature resistance and current of 0.25 Ω and 40 A respectively. For the delay angle of 30°, find the speed of the motor. Consider motor constant, $K_a\phi = 0.18\, N/rpm$. (8)

15. (a) Explain the rotor resistance control employed in 3ϕ Induction motor. (16) 75

Or

(b) Explain the concept of slip power recovery scheme in static scherbius method of speed control of Induction motor. 70 (16)

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Reg. No. :

Question Paper Code : 77126

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2015.

Third Semester

Mechanical Engineering

EE 6351 — ELECTRICAL DRIVES AND CONTROLS

(Common to Mechanical and Automation Engineering, Production Engineering, Manufacturing Engineering, Petrochemical Engineering, Chemical Engineering and Petrochemical Technology)

(Regulation 2013)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is an individual electric drive? Give some examples. 11
2. How heating occurs in motor drives? 18
3. Why DC shunt motor is termed as a constant speed motor? 22
4. What are the different types of electric braking? 22
5. Why starters are required? 36
6. What is the objective of rotor resistance starter? 45
7. Give the Limitation of field control. 48
8. What are the main applications of Ward-Leonard system? 50
9. What is the function of an inverter? 67
10. What are the advantages of static Kramer system over static scherbius system? 67

PART B — (5 × 16 = 80 marks)

11. (a) (i) What is an electrical drive system? How are electric drive classified? List its advantage and disadvantages. 9 (8)

(ii) Explain Heating and cooling curves of an electric drive. 18 (8)

Or

(b) What are the factors that influence the choice of electrical drives? (16)
13

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12. (a) List out the advantages and disadvantages of electrical braking over mechanical braking. Discuss any one method of electrical braking of DC Machines. 30 (16)

Or

(b) (i) Explain the Speed-Torque characteristics of three phase induction motor with neat diagrams. (6)

(ii) Explain about the quadrantal diagram of speed-torque characteristics for a motor driving hoist load. (10)

13. (a) Explain the theory of three point and four point starters. 37&39 (16)

Or

(b) Explain DOL, auto transformer, star-delta starters for AC motors. (16) 41

14. (a) (i) Discuss the Ward-Leonard speed control system with a neat diagram. Also mention its advantages and disadvantages. (8) 50

(ii) Explain the single phase half wave converter drive speed control for DC drive with waveforms. (8)

Or

(b) A 220V, 70A dc series motor has combined resistance of armature and field resistance of 0.12 ohm. Running on no load with field winding connected to a separate source it gave the following Magnetization characteristics at 600 rpm:

I_f A	10	20	30	40	50	60	70	80
V_t V	64	118	150	170	184	194	202	210

Motor is controlled by chopper with a source voltage = 220 V.

Calculate

(i) Motor speed for a duty ratio of 0.6 and motor current of 60A

(ii) Torque for a speed of 400 rpm and duty ratio of 0.65. (16)

15. (a) Explain the pole changing, stator frequency variation methods for controlling the speed of AC motor. 68 (16)

Or

(b) Explain the slip power recovery control of slip ring induction motor. (16)

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B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2014.

Third Semester

Mechanical Engineering

EE 6351 — ELECTRICAL DRIVES AND CONTROLS

(Common to Mechanical and Automation Engineering, Production Engineering, Manufacturing Engineering, Petrochemical Engineering, Chemical Engineering and Petrochemical Technology)

(Regulation 2013)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Distinguish between group drive and individual drive.

2. Define continuous, short time and intermittent duty. 15

3. Define pulsating and impact loads with examples.

4. What are the advantages of electric braking over other type of braking? 22

5. Why we need starters for starting electric motors? 36

6. What are the advantages of relay based starters compared to conventional starters?

7. What are the various parameters that control the speed of dc motors? 49

8. What is the function of a chopper and give some of the applications.

9. What are the various conventional speed control methods used in induction motors? 66

10. What do you mean by VVVF control and mention some of its advantages.

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PART B — (5 × 16 = 80 marks)

11. (a) Define heating and cooling of a motor. Derive the heating and cooling curve of a motor with necessary assumptions. 18

Or

(b) (i) List out the factors that influence the choice of electric drives. 13

(ii) An electric motor subjected to a load torque variation as given below : (8)

240 Nm for 20 min

140 Nm for 10 min

300 Nm for 10 min

200 Nm for 20 min

If speed of motor is 720 rpm find the power rating of motor.

12. (a) Define various types of electric braking and discuss the various braking characteristics of dc shunt and dc series motors. 30

Or

(b) Derive the torque equation of a 3-phase induction motor from the basics and obtain the speed Vs torque characteristics.

13. (a) With a neat diagram explain the working of a DC motor starter using time delay relays. 37

Or

(b) Explain the working of a three-phase slip ring induction motor starter using frequency sensing relay. 45

14. (a) With a neat diagram explain the construction and working of a Ward Leonard system of speed control and write the advantages and disadvantages. 50

Or

(b) Explain the speed control of a dc shunt motor using three-phase fully controlled rectifiers. 62

15. (a) (i) Explain the pole changing method of speed control for a squirrel cage IM. 68 (10)

(ii) Explain the stator voltage variation method of a wound rotor IM. (6) 68

Or

(b) Explain the speed control of a three-phase IM using three-phase bridge inverter –120° mode of conduction.

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B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2014.

Third Semester

Mechanical Engineering

ME 2205/ME 36/EE 1205 A/080120013/10122 ME 306 — ELECTRICAL DRIVES AND CONTROL

(Common to Production Engineering, Chemical Engineering, Petrochemical Engineering, Petrochemical Technology and Mechanical (sandwich) Engineering)

(Regulation 2008/2010)

(Also common to PTME 2205 Electrical Drives and Control for B.E. (Part-Time) Third Semester – Production Engineering – Regulation 2009)

Time : Three hours

Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What are the basic elements of electric drives? 9
2. What are the factors to be considered for the selection of electrical drives. 8
3. Draw speed-torque characteristic of constant torque type load. 22
4. Draw speed-armature current characteristic of DC series motor. 24
5. What are the types of DC motor starter? 36
6. What is the basic principle of primary resistance starter used in 3-phase induction motor?
7. Define armature control method of DC shunt motor. 48
8. Define duty cycle in DC chopper. 48
9. What are the conventional methods of speed control of three phase induction motor from stator side. 66
10. What is the basic principle in v/f control? 74

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PART B — (5 × 16 = 80 marks)

11. (a) List and explain various classes of motor duty. 15 (16)

Or

(b) Explain the selection of power rating for drive motor with regard to continuous duty load.

12. (a) With circuit diagram explain plugging method of braking of D.C. shunt motor and its torque speed-characteristics. 30 (16)

Or

(b) Describe speed-torque characteristics for DC dynamic braking of three-phase induction motor.

13. (a) Explain construction and operation of 4-point starter. 39 (16)

Or

(b) Explain with diagram construction and working of rotor resistance starter. 45

14. (a) Describe with diagram Ward-Leonard speed control system for DC motor. 50 (16)

Or

(b) With diagram describe working of single phase fully controlled rectifier drive. 52

15. (a) Explain various method of conventional speed control of three-phase induction motor from rotor-side. 75 (16)

Or

(b) Explain working of conventional Kramer slip power recovery system. 70

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Reg. No. :

Question Paper Code : 31561

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2013.

Third Semester

Mechanical Engineering

ME 2205/ME 36/10122 ME 306/EE 1205 A/ 080120013 — ELECTRICAL DRIVES AND CONTROL

(Common to Production Engineering, Chemical Engineering, Petrochemical Engineering and Petrochemical Technology)

(Regulation 2008/2010)

(Also common to PTME 2205 Electrical Drives and Control for B.E. (Part–Time) Third Semester – Production Engineering – Regulation 2009)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Draw the block diagram of an electrical drive. 9
2. Give the examples where continuous duty at constant load is required. 15
3. Draw the mechanical characteristic of a three phase induction motor.
4. What are the methods of braking of electric motors? 22
5. Draw the basic automatic starter arrangement for shunt motor starting.
6. What are the two types of rotors of three phase induction motors?
7. Why is armature voltage control used below rated speed?
8. Draw the basic circuit for chopper controlled separately excited dc motor drive.
9. Name the power modulators (converters) used for V/f control of three phase induction motor.
10. State the applications where stator voltage control is employed for three phase induction motors.

PART B — (5 × 16 = 80 marks)

11. (a) Explain the thermal model of an electric motor for (16)
    (i) heating the electric motor when starting from cold 18
    (ii) cooling the electric motor when it is switched off from the mains. 20

Or

(b) (i) A constant speed drive operating at a speed of 500 rpm has a cyclic loading as given below :
200 Nm for 10 minutes
300 Nm for 20 minutes

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150 Nm for 20 minutes

No load for 10 minutes

Estimate power rating of the motor. (10)

(ii) What are the different classes of motor duty? 15 (6)

12. (a) Explain the modifications to the speed-torque characteristics of a dc shunt motor for the following : 23

(i) with increase in armature resistance (8)

(ii) by field weakening. (8)

Or

(b) A 220 V dc series motor runs at 1200 rpm (clockwise) and takes an armature current of 80 A when driving a load with constant torque. Armature resistance is 0.05 Ω and field resistance is 0.05 Ω. Find the magnitude and direction of motor speed and armature current if the motor terminal voltage is reversed and the number of turns in field winding is reduced to 80%. Assume linear magnetic circuit. (16)

13. (a) A starter is required for a 220 V shunt motor. The maximum and minimum range of current values are 50 A and 30 A respectively. Find the number of sections of starter resistance required and the resistance of each section. The armature resistance of the motor is 0.5 Ω. (16)

Or

(b) Explain the different starting methods for three phase squirrel cage induction motor. 41 (16)

14. (a) Explain the operation of single phase full converter fed separately excited dc motor drive. 52 (16)

Or 54

(b) With neat circuit diagrams, explain chopper fed four quadrant dc drive. (16)

15. (a) Explain the static Scherbius drive which provides speeds below and above synchronous speed. 72 (16)

Or

(b) Explain the constant torque mode and constant power mode of operation of voltage source inverter fed induction motor drive with necessary diagrams. (16)

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B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2013.

Third Semester

Mechanical Engineering

ME 2205/ME 36/10122 ME 306/EE 1205 A/080120013 — ELECTRICAL DRIVES AND CONTROL

(Common to Production Engineering, Chemical Engineering, Petrochemical Engineering and Petrochemical Technology)

(Regulation 2008/2010)

(Also common to PTME 2205 Electrical Drives and Control for B.E. (Part-Time) Third Semester – Production Engineering – Regulation 2009)

Time : Three hours — Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What are types of electrical drives? 9
2. List the factors to be considered for the selection of electrical drives. 9
3. Draw speed-torque characteristics during regenerative braking of induction motor.
4. What are the types of electric braking of electric motor? 22
5. State the basic principle in DOL for 3-phase induction motor. 41
6. What is the basic principle in starting 3-phase induction motor using rotor resistance starter? 45
7. Draw the speed-torque characteristics of DC series motor by armature resistance method.
8. Draw the block diagram of phase controlled rectifier fed DC drives.
9. Draw the block diagram of conventional scherbius system. 70
10. What are the variable frequency AC drive applications? 74

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PART B — (5 × 16 = 80 marks)

11. (a) Explain various classes of motor drives. 15 (16)

Or

(b) Describe the selection of motor rating for continuous duty load. (16)

12. (a) Explain speed-torque characteristics of different types of load with graph. (16)

Or

(b) Explain with speed-torque characteristics of DC series motor under dynamic braking. 33 (16)

13. (a) Describe with diagram working of 3-point starter for DC shunt motor. 37 (16)

Or

(b) With diagram explain auto transformer starter for three phase induction motor. 41 (16)

14. (a) With circuit describe DC motor Ward-Leonard control system. 50 (16)

Or

(b) Explain first quadrant chopper control of separately excited motor for continuous conduction. 54 (16)

15. (a) Explain voltage/frequency control of 3-phase induction motor. 74 (16)

Or

(b) Describe Kramer system slip power recovery system of 3-phase induction motor. 70&72 (16)

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B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2012.

Third Semester

ME 2205/131305/ME 36/10122 ME 306/EE 1205 A/080120013/080210005 — ELECTRICAL DRIVES AND CONTROLS

(Common to Mechanical Engineering, Production Engineering, Chemical Engineering, Petrochemical Engineering and Petrochemical Technology)

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Define cooling time constant of an electrical machine. 9

2. Name the four commonly used methods for the determination of power rating of motors.

3. Write down the equation for the back e.m.f. of DC motor in terms of flux pole and speed.

4. List the types of single phase induction motors.

5. What are the functions of starter of a DC motor? 36

6. What is the advantage of three phase slip ring induction motor?

7. Enumerate the limitations of field control in DC Motors. 48

8. What is a DC chopper?

9. What are the advantages of V/f control of three-phase induction motors?

10. Mention the advantages of slip power recovery scheme of controlling the speed of induction motor.

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PART B — (5 × 16 = 80 marks)

11. (a) (i) Explain what is meant by a group drive. What are its advantages and disadvantages? 9 (8)

(ii) The enclosure of a 10 kW motor is equivalent to a cylinder of 70 cm diameter and 100 cm length. The motor weighs 500 kg assuming that the specific heat is 700 J/kg/°C and that the peripheral surface of the enclosure of the motor alone is capable of heat dissipation of 12.5 W/m²/°C. Calculate the heating time constant of the motor and its final temperature rise. Assume the efficiency of the motor as 90 percent. (8)

Or

(b) (i) Show that, for an electric motor, the relationship between temperature rise and time is an exponential function. 18 (8)

(ii) A motor has a thermal heating time constant of 45 minutes. When the motor runs continuously on full load, its final temperature rises to 80 degree Celsius.

(1) What would be the temperature rise after 1 hour, if the motor runs continuously on full load?

(2) If the temperature rise on 1 hour rating is allowed to be 75 degree Celsius, find what would be the new steady state temperature at this rating. (8)

12. (a) (i) Explain, with necessary circuit diagram, the reverse current braking and the braking characteristics of the following : 30

(1) DC shunt motor. (5)

(2) DC series motor. (5)

(ii) A 250 V, DC shunt motor has an armature resistance of 0.05 Ω and with rated field excitation has a back emf of 245 V at a speed of 1200 rpm. It is coupled to an overhauling load with a torque of 200 N-m. Determine the lowest speed at which the motor can hold the load by regenerative braking. (6)

Or

(b) (i) Sketch the speed-torque characteristics of a three phase induction motor and explain its motoring mode, generating mode and braking mode of operation. (8)

(ii) A 15 kW, 415 V, three-phase, 4 pole, 50 Hz induction motor has a speed of 1455 r.p.m. at full load. At this load, the mechanical losses are 600 watt and the stator losses are 750 watt. Find

(1) Full load slip

(2) Total input power to the motor

(3) Current drawn at full load, if the power factor is 0.8 lagging

(4) Net torque developed at output at full load. (8)

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13. (a) (i) Explain the function and working of 'Overload Release' in a three point starter for shunt motors. 37 (6)

(ii) A 250 V, 37 kW, DC shunt motor is allowed to exert a maximum of 150 percent of the full-load torque during the starting period. The resistance of armature is 0.2 ohm and the full-load efficiency is 84 percent. Number of sections of resistances in the starter is 7. Determine :

(1) the upper and lower limits of current during starting

(2) the values of resistances of each section of the starter. (10)

Or

(b) (i) With the help of a neat circuit diagram, explain the working of star-delta starter. 44 (8)

(ii) A three phase induction motor has a ratio of maximum torque to full load torque as 2.5 : 1. The rotor resistance and standstill reactance per phase are 0.4 ohm and 4 ohm respectively. Determine the ratio of starting torque to full load torque, if a star-delta starter is used. (8)

14. (a) (i) Explain the Ward-Leonard method of speed control of DC motor with a neat sketch showing the circuit. State also the advantages of this method. 50 (10)

(ii) A DC series motor naving an armature-resistance of 1 ohm, runs at a speed of 800 r.p.m. at 200 V with a current of 15 A. Find the speed at which it will run, when a 5 ohm resistance is connected in series at the same supply and taking the same current. (6)

Or

(b) (i) Describe the working of step down DC chopper, with the help of a suitable circuit diagram and wave-form diagrams. State the relation between output and input voltages. How is the speed of a DC motor controlled using a step down chopper? (10)

(ii) A 100 V shunt motor has armature resistance and field resistances of 0.4 ohm and 100 ohm respectively. At a particular constant-torque load, it takes a current of 25 A at the speed of 1200 r.p.m. A chopper is used to control the speed of the motor. Find T_{ON} to reduce the speed to 800 r.p.m. at a chopper frequency of 500 Hz. (6)

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15. (a) Sketch and explain the circuit, using thyristor controller, to control the speed of a three phase induction motor by varying the stator voltage. Mention the merits and demerits of this method. Also sketch and explain the torque-speed characteristics when stator voltage control is used. (16)

68

Or

(b) Explain the following solid state methods of controlling speed of three phase induction motors, with suitable schematic diagrams :

(i) Cycloconverter static Scherbius drive (8)

(ii) Static Kramer drive. (8)

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Reg. No.

Question Paper Code : 51848

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2016

Third Semester

Mechanical Engineering

ME 2205 / ME 36 / EE 1205 A/080 120013/10122 ME 306 – ELECTRICAL DRIVES AND CONTROL

(Common to Production Engineering, Chemical Engineering, Petrochemical Engineering, Petrochemical Technology and Mechanical Engineering (Sandwich))

(Regulations 2008/2010)

(Also common to 10122 ME 306 – Electrical Drives and Control for B.E. (Part-Time) Second Semester – Mechanical Engineering – Regulations 2010)

Time : Three Hours **Maximum : 100 Marks**

Answer ALL questions.

PART – A (10 × 2 = 20 Marks)

List any four classes of insulation used in motors with their maximum temperature ratings.

What are the different classes of motor duty ratings ?

What are cumulative and differential compound motors ?

What is meant by plugging ?

A starter is needed for a DC motor. Justify.

Why is it that DC series motors should not be started on no load ?

What are the factors controlling the speed of a DC motor ?

Bring out the advantages of DC chopper controlled DC drives with that of line commutated converter controlled DC drives.

How the direction of rotation of a three phase induction motor be reversed ?

What is an inverter ?

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PART – B (5 × 16 = 80 Marks)

11\. (a) (i) List the advantages of electric drives.

(ii) Brief the procedures for selection of power rating for drive motor with regards to thermal limits and load variation factors.

OR

(b) Briefly explain about the classes of motor duty based on load time variations with diagrams.

12\. (a) Explain the various electrical braking methods employed for braking of dc motors.

OR

(b) (i) Briefly explain the speed torque characteristics of an Induction motor with a neat sketch .

(ii) Draw and explain the speed torque characteristics of DC series and shunt motor.

13\. (a) Draw a neat sketch of a 3 point starter for a DC shunt motor and explain its operation. Also explain the protective devices therein.

OR

(b) (i) Explain with a circuit diagram the starting of an induction motor by star delta starting.

(ii) Brief the starting of slip ring induction motors by rotor resistance starter.

14\. (a) (i) With a neat sketch of fully controlled thyristor bridge circuit explain the speed control of a separately excited DC motor and plot its speed torque characteristics.

(ii) Describe with a neat sketch the field current control of a DC motor.

OR

(b) (i) Explain the Ward Leonard method of speed control of DC motors.

(ii) Distinguish between single quadrant and two quadrant operation of the chopper.

15\. (a) (i) Explain the V/f method of speed control of induction motor.

(ii) Brief the speed control of an induction motor by rotor resistance.

OR

(b) Discuss a slip power recovery scheme applicable for a 3Φ slip ring induction motor for operation below synchronous speed. Also derive an expression for no load speed.

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Reg. No. :

Question Paper Code : 80369

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2016.

Third Semester

Mechanical Engineering

EE 6351 — ELECTRICAL DRIVES AND CONTROLS

(Common to Mechanical and Automation Engineering, Production Engineering, Manufacturing Engineering, Petrochemical Engineering, Chemical Engineering and Petrochemical Technology)

(Regulations 2013)

Time : Three hours

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is an electrical drive?
2. Define the term 'short time rating'.
3. What are the various components of load torque?
4. What do you understand by electric braking?
5. Why dc motors should not be started without starters?
6. What type of protection is provided in the starters used for 3 phase induction motor?
7. List the various methods of conventional and solid state speed control of D.C. motors.
8. Compare armature control and field control.
9. Why the V/f is kept constant while controlling the speed of a 3 phase induction motor?
10. Mention the advantages of squirrel cage induction motor over a D.C. motor.

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PART B — (5 × 13 = 65 marks)

11. (a) (i) What are the various factors which decide the choice of an electronic drive for industrial applications? (6)

(ii) Discuss different classes of duty cycles. (7)

Or

(b) Draw the pattern of temperature rise characteristic under steady state for

(i) Short time duty

(ii) Intermittent duty and explain the equivalent current method of estimating motor rating. (13)

12. (a) Describe various methods of braking used for shunt, series and compound motors. (13)

Or

(b) (i) For drives, classify the types of load torques available and sketch few speed torque curves of typical leads. (7)

(ii) Explain the four quadrant operation of a motor driving a hoist. (6)

13. (a) Discuss, with circuit diagrams, the star delta starter and auto transformer starter on the basis of starting torque and starting current.

Or

(b) Describe with suitable diagrams the function of (i) 2 point starter and (ii) 3 point starter.

14. (a) Describe with a help of a neat circuit diagram explain Ward-Leonard control of D.C. motors. (13)

Or

(b) Explain the speed control of D.C. shunt motors using D.C. choppers. (13)

15. (a) Describe the variable voltage variable frequency method of speed control of 3 phase induction motors for full range of speed control. (13)

Or

(b) Explain slip power recovery scheme with neat diagram. (13)

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PART C — (1 × 15 = 15 marks)

16. (a) A 220 V dc shunt motor takes 22 A at rated voltage and runs at 1000 rpm. Its field resistance is 100 ohms and armature circuit resistance is 0.1 ohms. Compute the value of additional resistance required in the armature circuit to reduce the speed to 800 rpm when the load torque is proportional to speed. (15)

Or

(b) A motor has a thermal time constant of 45 minutes. When the motor runs continuously on full load, its final temperature rise is 80° C (i) what is the temperature rise after 1 hour if the motor runs continuously on full load? (ii) If the temperature on one hour rating is 80° C, find the maximum steady state temperature at this rating?

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Reg. No. :

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B.E/B.Tech. DEGREE EXAMINATION, APRIL/MAY 2017.

Third Semester

Mechanical Engineering

EE 6351 — ELECTRICAL DRIVES AND CONTROLS

(Common to Manufacturing Engineering/Mechanical and Automation Engineering/Petrochemical Engineering/Production Engineering/ Chemical Engineering/Petrochemical Technology, Petrochemical Engineering)

(Regulations 2013)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What are the factors that influence the choice of electric drives?

2. Define heating time constant and cooling time constant.

3. List the types of single phase induction motor.

4. Draw the mechanical characteristics of shunt and series motor.

5. What is the necessity of starter for AC motors?

6. What are the protective devices in a DC motor Starter?

7. Why chopper based dc drives give better performance than rectifier controlled drives?

8. List the limitations of field control method.

9. What are the advantages of slip power recovery scheme of controlling the speed of induction motor?

10. What is meant by V/f control?

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PART B — (5 × 13 = 65 marks)

11. (a) Draw and explain how to classify the drives according to their duty cycle and give examples. (13)

Or

(b) (i) The enclosure of a 10 kW motor is equivalent to a cylinder of 70 cm diameter and 100 cm length. The motor weighs 500 kg assuming that specific heat is 700 J/kg/°C and that the peripheral surface of the enclosure of the motor alone is capable of heat dissipation of 12.5 W/m²/°C. Calculate the heating time constant of the motor and its final temperature rise. Assume the efficiency of the motor as 90% (5)

(ii) Show that for an electric motor, the relationship between temperature rise and time is an exponential function. (8)

12. (a) Explain the torque slip and speed torque characteristics of three phase induction motor. (13)

Or

(b) What are the different electrical braking methods used in electrical drives? Explain the methods applied to dc shunt motor. (13)

13. (a) With neat diagram, explain any three types of AC starters. (13)

Or

(b) What is the necessity of DC starters? Explain with neat sketches, the principle of operation of 3 point starter. (13)

14. (a) (i) Explain the Ward-Leonard system for speed control of dc motors. State the advantages and disadvantages of the system. (8)

(ii) Explain the Flux control method of speed control for dc shunt motor. (5)

Or

(b) Describe the working of step down dc chopper, with the help of suitable circuit diagram and waveforms. State the relation between output and input voltages. How the speed of a dc motor is controlled using a step down chopper? (13)

15. (a) Explain with neat sketch the conventional Kramer and Scherbius method of variable speed drive system used for slip power recovery scheme. (13)

Or

(b) Discuss the salient aspects of speed control scheme for ac voltage controller fed three phase induction motor. (13)

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PART C — (1 × 15 = 15 marks)

16. (a) A starter required for a 220 V shunt motor. The maximum allowable current is 55 A and the minimum current is about 35 A. Find the number of starter resistance required and the resistance of each section. The armature resistance of the motor is 0.4 ohm. (15)

Or

(b) Explain the different types of braking of three phase induction motors. (15)

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