SUBJECT NAME: ELECTRIC DRIVES

Class : 4th Year/ VII Semester

UNIT-I Characteristics of Electric Drives

1.Aim : To discuss the basics and types of Electric drives.

Objectives : To discuss the basics of Electric drives in terms of

- Basic Concept of Electric Drives.
- Motor-Load torque equation.
- Types of Electric Drives.
- Various classes of duty.
- Heating and cooling of Electric Drives.

2.Pre-Test: MCQ Type

1.Load torques can be classified into how many types?
a) Three
b) Two
c) Four
d) Five

Ans: b

2. What is the condition for the steady-state operation of the motor?
a) Load torque > Motor torque
b) Load torque <<<< Motor torque
c) Load torque = Motor torque
d) Load torque < Motor torque

Ans: c

3.Electric Drives-Introduction

An Electric Drive can be defined as, a system which is used to control the movement of an electrical machine. This drive employs a prime mover such as a petrol engine, otherwise diesel, steam turbines otherwise gas, electrical & hydraulic motors like a main source of energy.

These prime movers will supply the mechanical energy toward the drive for controlling motion.
An electric drive can be built with an electric drive motor as well as a complicated control system to control the motor's rotation shaft.

At present, the controlling of this can be done simply using the software. Thus, the controlling turns into more accurate & this drive concept also offers the ease of utilizing.

The types of electrical drives are two such as a standard inverter as well as a servo drive. A standard inverter drive is used to control the torque & speed. A servo drive is used to control the torque as well as speed, and also components of the positioning machine utilized within applications that need difficult motion.

3.1 Block Diagram of Electric Drive

The block diagram of an electric drive is shown below, and the load in the diagram signifies different kinds of equipment which can be built with an electric motor such as washing machine, pumps, fans, etc. The electric drive can be built with source, power modulator, motor, load, sensing unit, control unit, an input command.

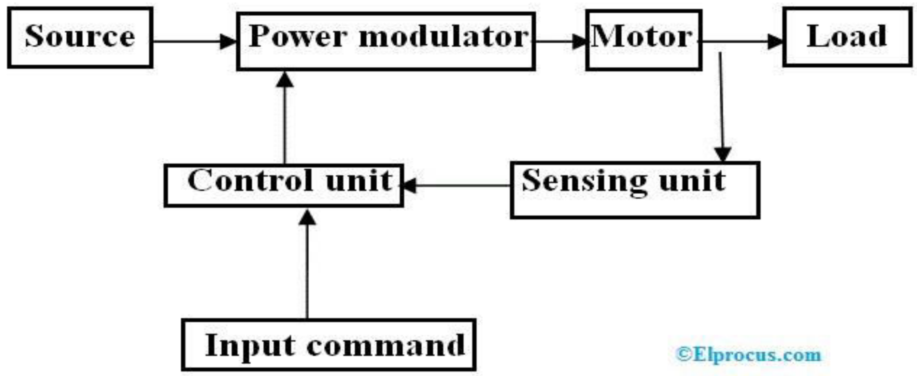


Fig.1.Electric Drive Block Diagram

Power Source

The power source in the above block diagram offers the necessary energy for the system. And both the converter and the motor interfaces by the power source to provide changeable voltage, frequency and current to the motor.

Power Modulator

This modulator can be used to control the o/p power of the supply. The power controlling of the motor can be done in such a way that the electrical motor sends out the speed-torque feature which is necessary with the load. During the temporary operations, the extreme current will be drawn from the power source.

The drawn current from the power source may excess it otherwise can cause a voltage drop. Therefore the power modulator limits the motor current as well as the source.

The power modulator can change the energy based on the motor requirement. For instance, if the basis is direct current & an induction motor can be used after that power modulator changes the direct current into alternating current. And it also chooses the motor’s mode of operation like braking otherwise motoring.

Load

The mechanical load can be decided by the environment of the industrial process & the power source can be decided by an available source at the place. However, we can choose the other electric components namely electric motor, controller, & converter.

Control Unit

The control unit is mainly used to control the power modulator, and this modulator can operate at power levels as well as small voltage. And it also works the power modulator as preferred. This unit produces the rules for the safety of the motor as well as power modulator. The i/p control signal regulates the drive's working point from i/p toward the control unit.

Sensing Unit

The sensing unit in the block diagram is used to sense the particular drive factor such as speed, motor current. This unit is mainly used for the operation of closed loop otherwise protection.

Motor

The electric motor intended for the specific application can be chosen by believing various features such as price, reaching the level of power & performance necessary by the load throughout the stable state as well as active operations.

3.2 Classification of Electrical Drives

Usually, these are classified into three types such as group drive, individual drive, and multi-motor drive. Additionally, these drives are further categorized based on the different parameters which are discussed below.

- Electrical Drives are classified into two types based on supply namely AC drives & DC drives.
- Electrical Drives are classified into two types based on running speed namely Constant speed drives & changeable speed drives.
- Electrical Drives are classified into two types based on a number of motors namely Single motor drives & multi-motor drives.
- Electrical Drives are classified into two types based on control parameter namely stable torque drives & stable power drives.

Advantages of Electrical Drives

The advantages of electrical drives include the following.

- These dries are obtainable with an extensive range of speed, power & torque.
- Not like other main movers, the requirement of refuel otherwise heat up the motor is not necessary.
- They do not contaminate the atmosphere.
- Previously, the motors like synchronous as well as induction were used within stable speed drives. Changeable speed drives utilize a dc motor.
- They have flexible manage characteristics due to the utilization of electric braking.
- At present, the AC motor is used within variable speed drives because of semiconductor converters development.

Disadvantages of Electrical Drive

The disadvantages of electrical drives include the following.

- This drive cannot be used where the power supply is not accessible.
- The power breakdown totally stops the entire system.
- The primary price of the system is expensive.
- The dynamic response of this drive is poor.
- The drive output power which is obtained is low.
- By using this drive noise pollution can occur.

Applications of Electrical Drives

The applications of electrical drives include the following.

- The main application of this drive is electric traction which means transportation of materials from one location to another location. The different types of electric tractions mainly include electric trains, buses, trolleys, trams, and solar-powered vehicles inbuilt with battery.
- Electrical drives are extensively used in the huge number of domestic as well as industrial applications which includes motors, transportation systems, factories, textile mills, pumps, fans, robots, etc.
- These are used as main movers for petrol or diesel engines, turbines like gas otherwise steam, motors like hydraulic & electric.

Thus, this is all about the fundamentals of electrical drives. From the above information, finally, we can conclude that a drive is one kind of electrical device used to control the energy which is sent to the electrical motor. The drive supplies energy to the motor in unstable amounts & at unstable frequencies, thus ultimately controls the speed and torque of the motor.

3.3 Classification of Electric Drive:

Classification of Electric Drive are normally classified into three groups, based on their development, namely group, individual and multi motor electric drives.

(1) Group Drive:

If several groups of mechanisms or machines are organised on one shaft and driven or actuated by one motor, the system is called a **group drive** or **shaft drive**.

The various mechanisms connected may have different speeds. Hence the shaft is equipped with multi stepped pulleys and belts for connection to individual loads. In this type of drive a single machine whose rating is smaller than the sum total of all connected loads may be used, because all the loads may not appear at the same time. This makes the drive economical, even though the cost of the shaft with stepped pulleys may seem to be high.

This method is rarely used in modern drive systems and has become of historical interest, because of the following disadvantages:

1. The efficiency of the drive is low, because of the losses occurring in several transmitting mechanisms.
2. The complete drive system requires shutdown if the motor requires servicing or repair
3. The location of the mechanical equipment being driven depends on the shaft and there is little flexibility in its arrangement.
4. The system is not very safe to operate.
5. The noise level at the work spot is high.

(2) Individual drive:

If a single motor is used to drive or actuate a given mechanism and it does all the jobs connected with this load, the drive is called an **individual drive**. For example, all the operations connected with operating a lathe may be performed by a single machine. If these operations have to be performed at different speeds, transmission devices may be required. The efficiency may become poor over several operations, due to power loss. In some cases it is possible to have the drive motor and driven load in one unit.

(3) Multimotor drive

In a **multimotor drive** each operation of the mechanism is taken care of by a separate drive motor. The system contains several individual drives, each of which is used to operate its own mechanism. This type of drive finds application in complicated machine tools, travelling cranes, rolling mills, etc. Automatic control methods can be employed and each operation can be executed under optimum conditions.

3.4 Torque Equation of Motor Load System:

A motor generally drives a load (machine) through some transmission system. While motor always rotates, the load may rotate or may undergo a translational motion. Load speed may be different from that of motor, and if the load has many parts, their speeds may be different and while some may rotate, others may go through a translational motion. It is, however, convenient to represent the Torque Equation of Motor Load System by an equivalent rotational system shown in Fig. 2

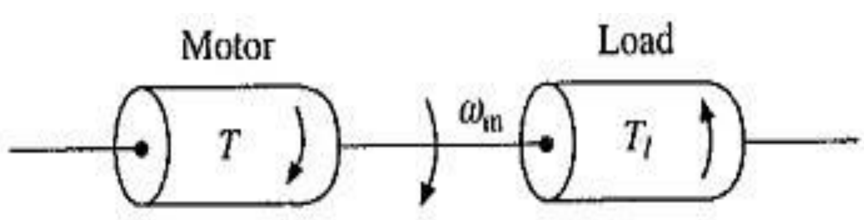


Fig. 2.1 Equivalent motor-load system

Various notations used are:

J = Polar moment of inertia of motor-load system referred to the motor shaft, kg-m^2.

ω_m = Instantaneous angular velocity of motor shaft, rad/sec.

T = Instantaneous value of developed motor torque, N-m.

T_1 = Instantaneous value of load (resisting) torque, referred to motor shaft, N-m.

Load torque includes friction and windage torque of motor.

Torque Equation of Motor Load System of Fig. 2.1 can be described by the following fundamental torque equation:

$$T - T_l = \frac{d}{dt}(J\omega_m) = J\frac{d\omega_m}{dt} + \omega_m \frac{dJ}{dt} \qquad (2.1)$$

Equation (2.1) is applicable to variable inertia drives such as mine winders, reel drives, industrial robots. For drives with constant inertia, (dJ/dt) = 0. Therefore

$$T = T_l + J\frac{d\omega_m}{dt} \qquad (2.2)$$

equation (2.2) shows that torque developed by motor is counter balanced by a load torque T_1 and a dynamic torque $J(d\omega_m/dt)$. Torque component $J(d\omega_m/dt)$ is called the dynamic torque because it is present only during the transient operations.

Drive accelerates or decelerates depending on whether T is greater or less than T_1. During acceleration, motor should supply not only the load torque but an additional torque component $J(d\omega_m/dt)$ in order to overcome the drive inertia. In drives with large inertia, such as electric trains, motor torque must exceed the load torque by a large amount in order to get adequate acceleration.

In drives requiring fast transient response, motor torque should be maintained at the highest value and Torque Equation of Motor Load System should be designed with a lowest possible inertia. Energy associated with dynamic torque $J(d\omega_m/dt)$ is stored in the form of kinetic energy given by $(J\omega^2_m/2)$.

During deceleration, dynamic torque $J(d\omega_m/dt)$ has a negative sign. Therefore, it assists the motor developed torque T and maintains drive motion by extracting energy from stored kinetic energy.

3.5 Heating and Cooling Curves of Electrical Drives:

An accurate prediction of Heating and Cooling Curves of Electrical Drives rise inside an electrical motor is very difficult owing to complex geometrical shapes and use of heterogeneous materials. Since conductivities of various materials do not differ by a large amount, a simple thermal model of the machine can be obtained by assuming machine to be a homogeneous body. Although inaccurate, such a model is good enough for a drive engineer whose job is only to select the motor rating for a given application ensuring that temperatures in various parts of motor body do not exceed the safe limits.

Let the machine, which is assumed to be a homogeneous body, and the cooling medium has following parameters at time t:

P_1 = Heat developed, joules/sec or watts.

P_2 = Heat dissipated to the cooling medium, joules/sec or watts.

W = Weight of the active parts of machine, kg.

h = Specific heat, Joules per kg per °C.

A = Cooling surface, m^2.

d = Coefficient of heat transfer or specific heat dissipation, joules/sec/m^2/°C.

θ = Mean temperature rise, °C.

During a time increment dt, let the machine temperature rise be dθ. Since,

$$\text{Heat absorbed (or stored) in the machine} = \begin{pmatrix}\text{Heat developed inside the machine} - \text{Heat} \\ \text{dissipated to the surrounding cooling medium}\end{pmatrix}$$

$$Whd\theta = p_1 dt - p_2 dt \tag{4.1}$$

$$p_2 = \theta dA \tag{4.2}$$

Substituting in Eq. (4.1) and rearranging the terms

$$C\frac{d\theta}{dt} = p_1 - D\theta \tag{4.3}$$

$$C = Wh \tag{4.4}$$

$$D = dA \tag{4.5}$$

C is the thermal capacity of the machine, watts/°C, and D the heat dissipation constant, watts/°C. Heat dissipation mainly occurs through convection. Typical values of D are in the range of 40 of 600 $W/m^2/°C$. The first order differential equation (4.3) has a solution.

$$\theta = \theta_{ss} + Ke^{-t/\tau} \tag{4.6}$$

$$\theta_{ss} = \frac{p_1}{D} \tag{4.7}$$

$$\tau = \frac{C}{D} \tag{4.8}$$

Constant of integration K is obtained by substituting the temperature rise at t = 0 in Eq. (4.6). When the initial temperature rise is θ_1, Eq. (4.6) has a solution

$$\theta = \theta_{ss}(1 - e^{-t/\tau}) + \theta_1 e^{-t/\tau} \tag{4.9}$$

τ, which has the dimension of time, is known as the heating (or thermal) time constant of the machine. In Eq. (4.9) as $t = \infty$, $\theta = \theta_{ss}$. Thus θ_{ss} is the steady state temperature of the machine when it is continuously heated by power P_1. At this temperature, all the heat produced in machine is dissipated to the surrounding medium.

Let the load on machine be thrown off after its temperature rise reaches a value θ_2. Heat loss will reduce to a small value P'_1 and cooling operation of the motor will‾ begin. Let the new value of heat dissipation constant be D′. If time is measured from the instant the load is thrown off, then

$$C\frac{d\theta}{dt} = p'_1 - D'\theta \tag{4.10}$$

Solving this first order differential equation subjected to the initial condition, $\theta = \theta_2$ at t = 0, gives

$$\theta = \theta'_{ss}(1 - e^{-t/\tau'}) + \theta_2 e^{-t/\tau'} \tag{4.11}$$

$$\theta'_{ss} = \frac{p'_1}{D'} \tag{4.12}$$

$$\tau' = \frac{C}{D'} \tag{4.13}$$

θ'_{ss} is again steady state temperature rise for new conditions of operation and τ' is known as the **Cooling (or thermal) Time Constant** of the machine.

If motor were disconnected from the supply during Heating and Cooling Curves of Electrical Drives then $P'_1 = \theta'_{ss} = 0$, suggesting that the final temperature attained by the motor will be ambient temperature. Substituting in Eq. (4.11) gives

$$\theta = \theta_2 e^{-t/\tau'} \tag{4.14}$$

Eqs. (4.9) and (4.14) suggest that both heating time constant τ and cooling time constant τ' depend on the respective heat dissipation constants D and D′, which in turn depend on the velocity of cooling air.

In self cooled motors, where cooling fan is mounted on motor shaft, the velocity of cooling air varies with motor speed, thus varying cooling time constant τ'. Cooling time constant at standstill is much larger than when running. Therefore, in high performance, and medium and high power variable speed drives, motor is always provided with separate forced cooling, so that motor cooling be independent of speed.

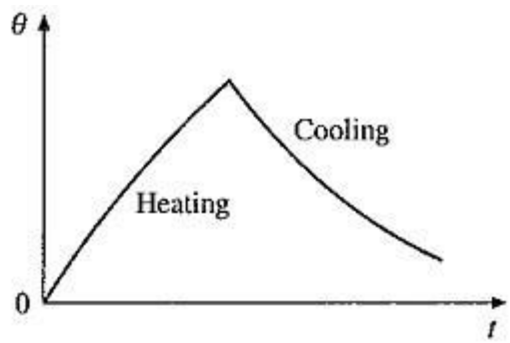


Fig. 4.1 Heating and cooling curves

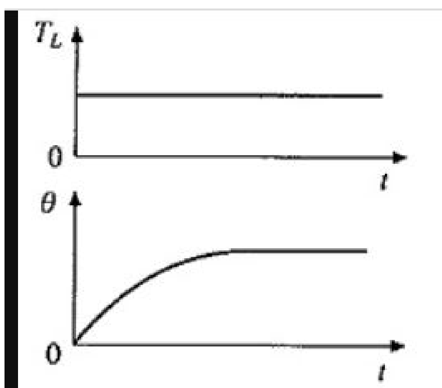
Figure 4.1 shows the variation of motor temperature rise with time during Heating and Cooling Curves of Electrical Drives. Thermal time constants of a motor are far larger than electrical and mechanical time constants. While electrical and mechanical time constants have a typical range of 1 to 100 ms and 10 ms to 10 s, the thermal time constants may vary from 10 min to couple of hours.

3.6 Classes of Motor Duty in Electrical Drives:

IS: 4722-1968 categorise various load time variations encountered in practice into eight standard Classes of Motor Duty in Electrical Drives:

1. *Continuous duty.*
2. *Short time duty.*
3. *Intermittent periodic duty.*
4. *Intermittent periodic duty with starting.*
5. *Intermittent periodic duty with starting and braking.*
6. *Continuous duty with intermittent periodic loading.*
7. *Continuous duty with starting and braking.*
8. *Continuous duty with periodic speed changes.*

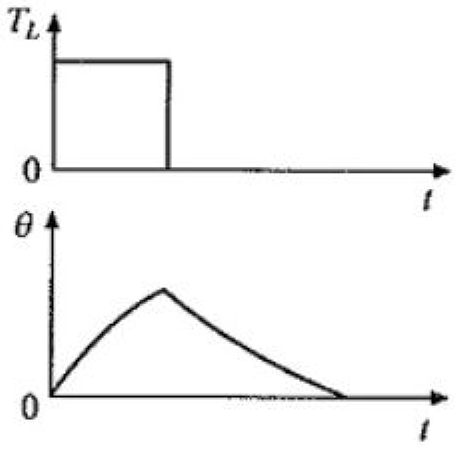
1. Continuous Duty:



(a)

It denotes the motor operation at a constant load torque for a duration long enough for the motor temperature to reach steady-state value. This duty is characterised by a constant motor loss. Paper mill drives, compressors, conveyers, centrifugal pumps and fans are some examples of Classes of Motor Duty in Electrical Drives.

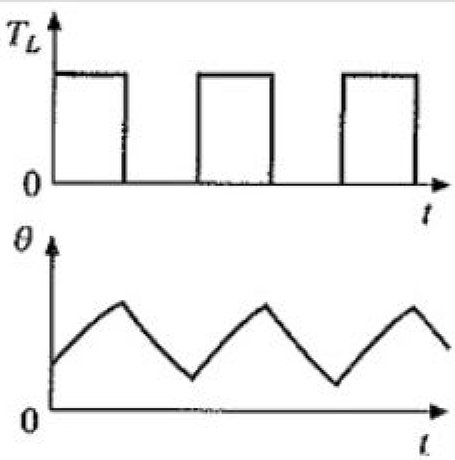
2. Short Time Duty:



(b)

In this, time of drive operation is considerably less than the heating time constant and machine is allowed to cool off to ambient temperature before the motor is required to operate again. In this operation, the machine can be overloaded until temperature at the end of loading time reaches the permissible limit. Some examples are: crane drives, drives for household appliances, turning bridges, sluice-gate drives, valve drives, and many machine tool drives for position control.

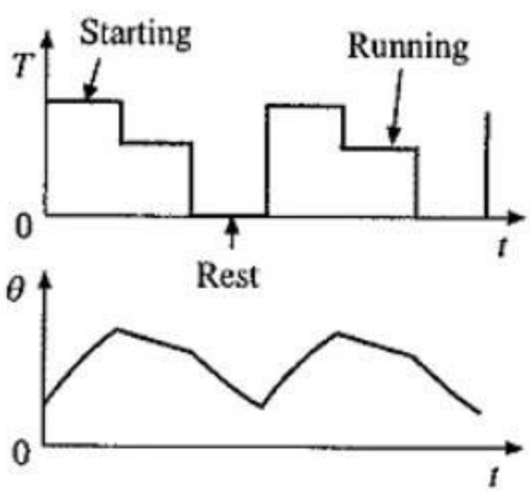
3. Intermittent Periodic Duty:



(c)

It consists of periodic duty cycles, each consisting of a period of running at a constant load and a rest period. Neither the duration of running period is sufficient to raise the temperature to a steady-state value, nor the rest period is long enough for the machine to cool off to ambient temperature. In this Classes of Motor Duty in Electrical Drives, heating of machine during starting and braking operations is negligible. Some examples are pressing, cutting and drilling machine drives.

4. Intermittent Period Duty with Starting:

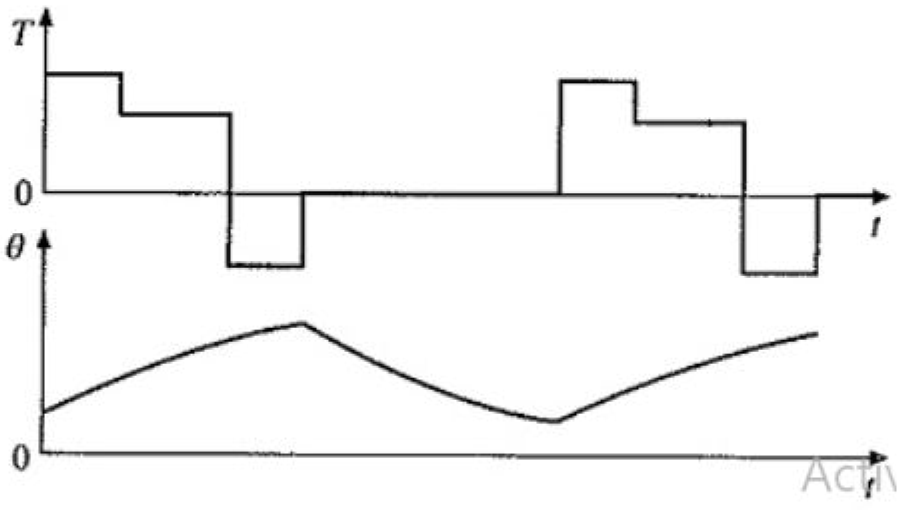


(d)

This is intermittent periodic duty where heat losses during starting cannot be ignored. Thus, it consists of a period of starting, a period of operation at a constant load and a rest period; with operating and rest periods, being too short for the respective steady-state temperatures to be attained.

In this duty, heating of machine during braking is considered to be negligible, because mechanical brakes are used for stopping or motor is allowed to stop due to its own friction. Few examples are metal cutting and drilling tool drives, drives for fork lift trucks, mine hoist etc.

5. Intermittent Periodic duty with Starting and Braking:



(e)

This is the intermittent periodic duty where heat losses during starting and braking cannot be ignored. Thus, it consists of a period of starting, a period of operation with a constant load, a braking period with electrical braking and a rest period; with operating and rest periods being too short for the respective steady state temperatures to be attained.

Billet mill drive, manipulator drive, ingot buggy drive, schrewdown mechanism of blooming mill, several machine tool drives, drives for electric suburban trains and mine hoist are some examples of this duty.

6. Continuous Duty with Intermittent Periodic Loading:

It consists of periodic duty cycles, each consisting of a period of running at a constant load and a period of running at no load, with normal voltage across the excitation winding. Again the load period and no load period being too short for the respective temperatures to be attained. This Classes of Motor Duty in Electrical Drives is distinguished from the **intermittent periodic duty** by the fact that a period of running at a constant load is followed by a period of running at no load instead of rest. Pressing, cutting, shearing and drilling machine drives are the examples.

7. Continuous Duty with Starting and Braking:

Consists of periodic duty cycle, each having a period of starting, a period of running at a constant load and a period of electrical braking; there is no period of rest. The main drive of a blooming mill is an example.

8. Continuous Duty with Periodic Speed Changes:

Consists of periodic duty cycle, each having a period of running at one load and speed, and another period of running at different speed and load; again both operating periods are too short for respective steady-state temperatures to be attained. Further there is no period of rest.

4. MCQ POST-TEST

1. What is heating time constant of the machine?
a) The ratio of the thermal capacity and heat dissipation constant value
b) The ratio of the thermal capacity and heat dissipation constant value
c) The ratio of the thermal capacity and heat dissipation constant value
d) The ratio of the thermal capacity and heat dissipation constant value

Ans: a

2. Continuous duty denotes ……………….

a) Operation at constant load of sufficient duration for thermal equilibrium to be reached

b) operation at constant load for sufficient duration with starting period and rest period.

c) operation at constant load with starting period, period of braking followed by rest period.

d) operation at constant load followed by period of operation at no-load.

Ans : a

3. What type of force handles for active torques?
a) Strong nuclear forces

b) Weak nuclear forces
c) Gravitational forces
d) Electrostatic forces

Ans : c

5.CONCLUSION

Electric drives are widely used in various industries. Converters employed in DC drives and AC drives gives smooth and wide range of speed control without much expensive.

Under steady state operation of Motor-Load system Motor shaft torque is equal to load torque.

The Electric drives are classified into different types based on their operation and types of load.

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SUBJECT NAME: ELECTRIC DRIVES

Class : 4th Year/ VII Semester

UNIT-II DC DRIVES

1.Aim : To discuss the concept of DC drives and performance of DC drives.

Objectives : To explain the performance of DC drives in terms of

- Concept of Electric Drives.
- Performance characteristics and equations of DC motor.
- Speed control methods.
- Converter fed DC drives.
- Chopper fed DC drives.
- Simulation of Converter fed DC drive using PSIM.
- Applications of DC drives.

2.Pre-Test : MCQ Type

1. In a DC shunt motor, the electromagnetic torque developed is proportional to ______

a) I_a
b) I_a^2
c) I_a^3
d) $I_a^{.5}$

Answer:

a) I_a

2. Which of the following rule is used to determine the direction of rotation of D.C motor?

a) Coloumb's Law
b) Lenz's Law
c) Fleming's Right-hand Rule
d) Fleming's Left-hand Rule

Answer d.
Fleming's left-hand rule**.**

3. The efficiency of the DC motor at maximum power is

a)90%

b)100%
c)Around 80%
d)Less than 50%
Answer d.
Less than 50%

4. Choppers converts

a) AC to DC
b) DC to AC
c) DC to DC
d) AC to AC

Answer c.
DC to DC

5. The average output voltage is maximum when SCR is triggered at ωt =

a) π
b) 0
c) π/2
d) π/4
Answer b.
0

3.PRE-REQUESTIES

1.DC Motors
2.Power Electronics

4.Concept of Electric Drives

An electric motor together with its control equipment and energy transmitting device forms an ***electric drive.***

Example:

A motor and conveyer-belt without any material on its belt.

An electric drive together with its working machine constitutes an ***electric –drive system.***

Example:

A motor and conveyer-belt with material on its belt.

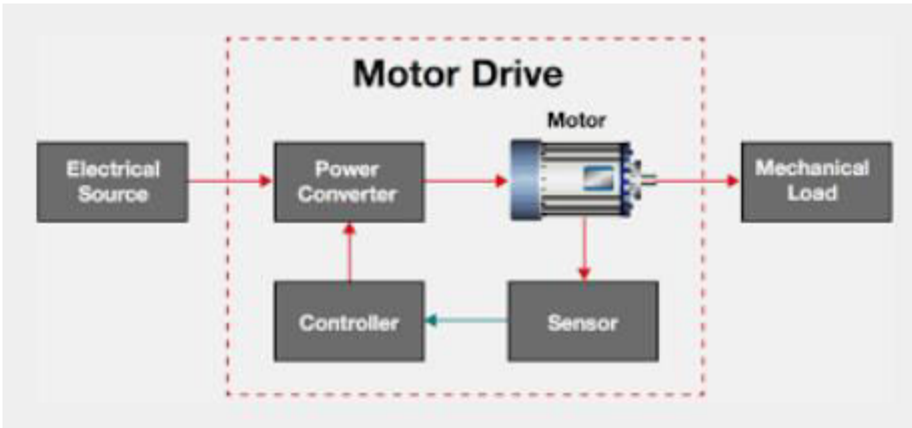


Fig.1. An Electric Drive System

4.1.DC Drives

DC motors are widely used in adjustable-speed drives and position control applications. Speed control methods of DC motors are comparatively less expensive than AC motors.

There are two methods to control the speed of DC motors:

1. Armature voltage control method
2. Field-flux control method

Armature voltage control method: Speeds below base speed are controlled.

Field-flux control method: Speeds above base speed are obtained

Depending on the type of available source and converters DC drives are classified as:

1. Single-phase DC drives
2. Three-phase DC drives
3. Chopper fed DC drives

4.2.Basic performance equation of Separately –excited DC motor

The equivalent circuit of a Separately –excited DC motor coupled with a load is shown in Fig.2. Under steady state conditions load torque T_L oppose the motor torque $T_{e.}$

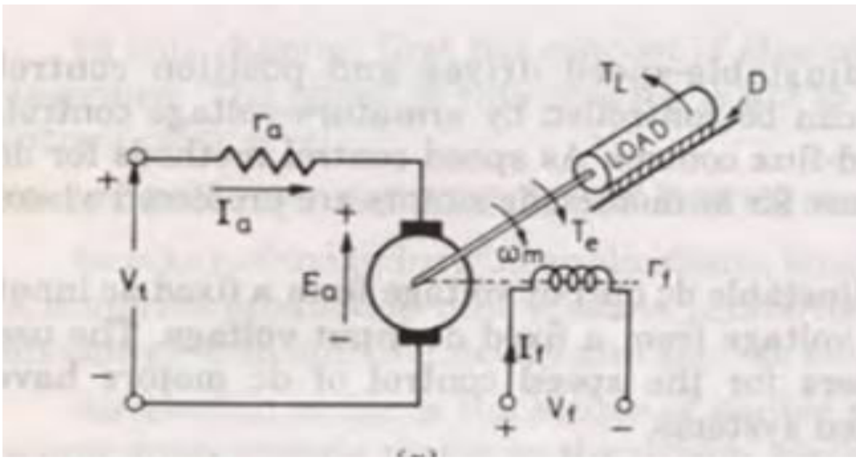


Fig.2. Equivalent circuit of a Separately excited DC motor

For field circuit, $V_f = I_f \, . \, r_f$ …………………(1)

For armature circuit $V_t = E_a + I_a \,.r_a$ …………………(2)

Motor back emf , $E_a = K_a\Phi \; \omega_m = K_m . \; \omega_m = V_t - I_a \,.r_a$ …….(3)

$\omega_m = V_t - I_a \,.r_a \; / \; K_m = V_t - I_a \,.r_a \; / \; K_a\Phi$ ………………….(4)

$T_e = K_a\Phi \; I_a = K_m \, I_a$ …………………..(5)

Where,

V_t = motor terminal voltage, V

I_a = armature current , A

Φ= field flux/pole , Wb

$K_m = K_a\Phi$, torque constant , Nm/A.

r_a = armature resistance, Ω

ω_m = angular speed of motor, rad/sec.

r_f = field circuit resistance, Ω

From equation (4), it is seen that the speed can be controlled by varying the voltage V_t , Known ***as armature –voltage control***, and by varying the Φ, known as the ***field-flux control.***

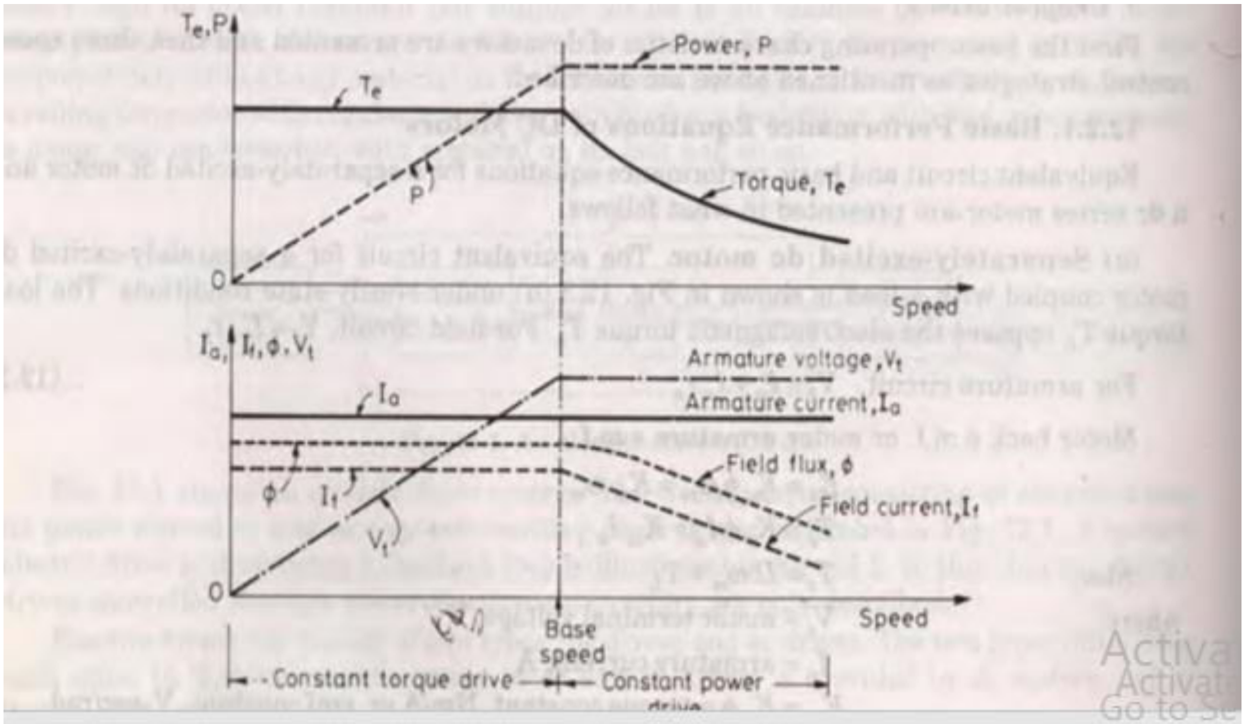


Fig.3. Characteristics of a Separately excited DC motor

Characteristics of a Separately excited DC motor is shown in Fig.3.

Base speed of the motor is defined as the speed at which the motor runs at its rated voltage, rated armature current and rated field current.

(1) ***Armature voltage control*** : armature voltage (V_t) is varied to obtain the speed below base speed. The armature current and field flux (Φ) are kept constant at their rated values. From equation (5), it is seen that when I_a and Φ are constant the torque remains constant at its rated value to meet the required demand. So this armature voltage control method is known as ***constant-torque drive*** method The armature voltage (V_t) is varied from its zero voltage to rated voltage the power $P= V_t . I_a$ increases from its zero value to rated power.

(2) ***Field-flux (Φ) control***: this method of speed control is employed for the speeds above base speed. From equation (4) it is seen that speed and field flux are inversely proportional. During flux control method, armature voltage and armature current are kept constant at rated values. So power remains constant and this method of control is termed as ***constant power-drive*** method. Field flux is decreased to increase the speed above base speed, the torque is directly proportion to flux so torque decreases with decrease in flux.

4.3.Single –phase Full Converter Drives

This converter fed DC drive has two full converters and a separately excited DC motor. One full converter feeding the armature circuit and the other feeding the field circuit. The converters convert the AC voltage into DC voltage and by varying the firing angle(α) of the converters the output voltage of the converters can be varied. Fig.4. shows the single-phase full converter fed separately excited DC motor.

Full converter fed DC drives offers two quadrant operation of the drive, first quadrant operation is the ***motoring mode*** and second quadrant operation is the ***regenerative braking*** of the motor. Fig.5. shows the two- quadrant diagram.

The motoring mode control is the first quadrant operation. During this mode, armature voltage is controlled by controlling the firing angle(α) of the armature side converter. The firing angle(α) can be varied from 0º to 90º for rectification of AC voltage into DC voltage and the output DC voltage of the converter can be varied from its maximum value to zero value. Thus the voltage fed to the armature is controlled varying the firing angle of the converter.

During regenerative braking control power must flow from motor to the AC source. This is possible only when the back emf of the motor is reversed. The SCRs present in the full converters are unidirectional devices so polarity of the back emf is reversed by reversing the direction of field current by making the firing angle(α_1) above 90º for the field side converter.

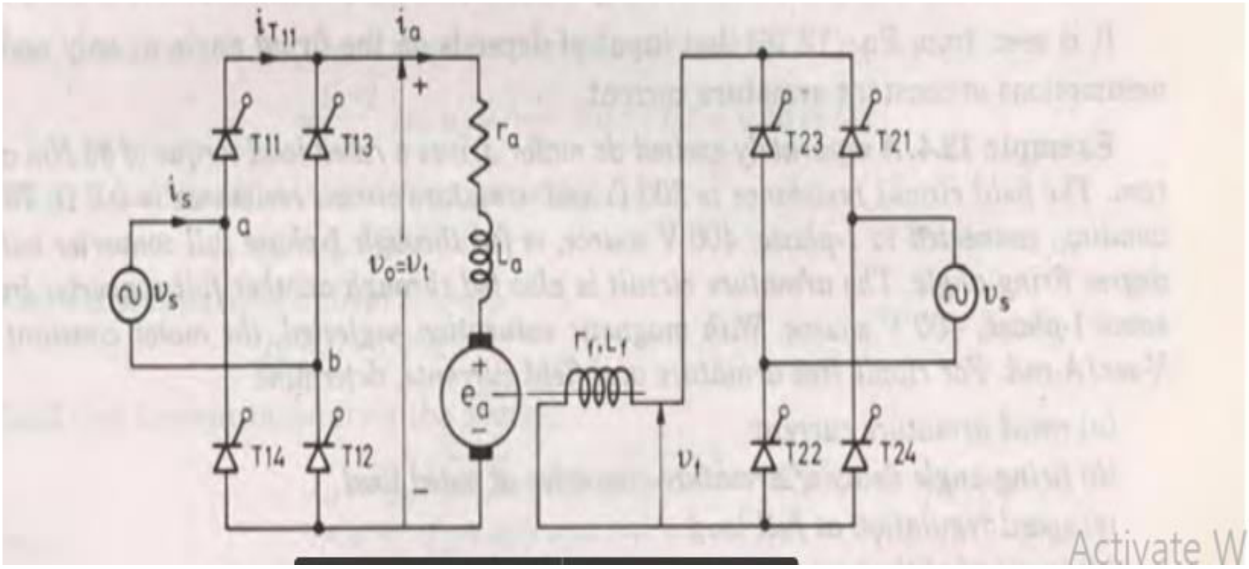


Fig.4. Single-phase full converter fed Separately excited DC motor

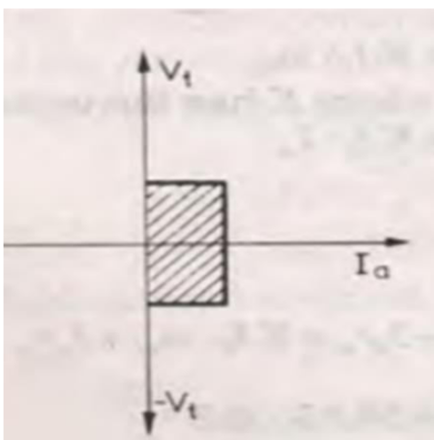


Fig.5.Two –quadrant diagram

The input AC voltage of the converter, output voltage and output current waveforms are shown in Fig.6.

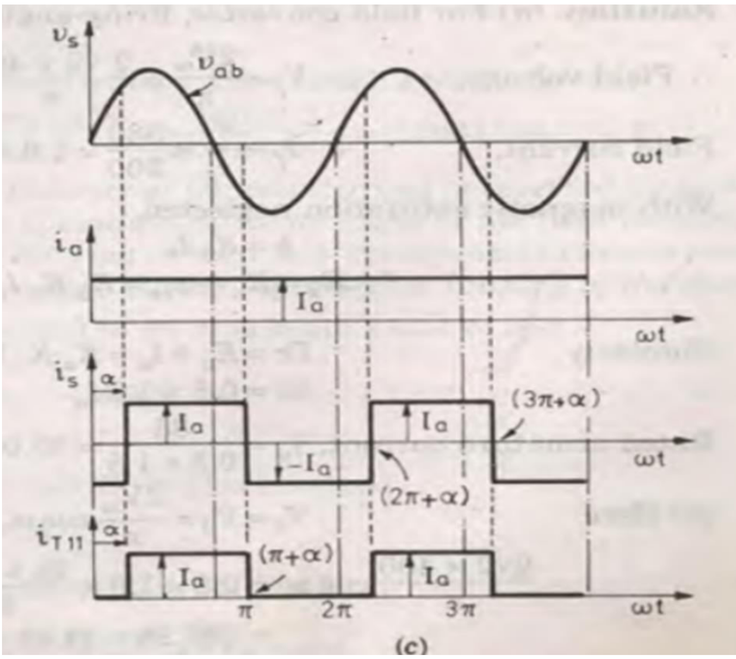


Fig.6.Waveforms

The output voltage of the armature circuit converter 1,

$V_o = V_t = 2V_m/\pi \cos\alpha$ for $0 \le \alpha \le \pi$ ……..(6)

$V_f = 2V_m/\pi \cos\alpha_1$ for $0 \le \alpha_1 \le \pi$ ……..(7)

rms value of source current, $I_{sr} = \sqrt{I_a^2 \cdot \frac{\pi}{\pi}} = I_a$

rms value of thyristor current, $I_{tr} = \left[I_a^2 \cdot \frac{\pi}{2\pi}\right]^{1/2} = \frac{I_a}{\sqrt{2}}$

From Eq. (12.9), input supply $\text{pf} = \frac{V_t \cdot I_a}{V_s \cdot I_{sr}} = \frac{2V_m}{\pi}\cos\alpha_1 \cdot \frac{I_a \cdot \sqrt{2}}{V_m \cdot I_a}$

$$= \frac{2\sqrt{2}}{\pi}\cos\alpha_1$$

4.4.DC Chopper fed DC Drives

Chopper circuit converts fixed DC voltage into variable DC voltage. Chopper circuit can be interfaced between fixed DC voltage source and DC motor armature circuit. By varying the duty cycle(δ) of the DC chopper, variable voltage can be applied to the armature terminals of the DC motor to obtain the speed control below the speed.

Chopper circuit is adoptable for regenerative braking of DC motor and kinetic energy can be returned to the DC source. Choppers can be used for dynamic braking also.

The following controlled modes are explained in detail.

1.Power control or motoring control.

2.Regenerative –braking control.

4.4.1.Power control or motoring control

The Fig.7. shows the circuit for motoring control of Chopper fed DC series motor which is the first quadrant operation. By modifying chopper circuit configuration all four quadrant operation of DC motor drive is possible. Chopper fed DC drives are widely employed in traction systems.

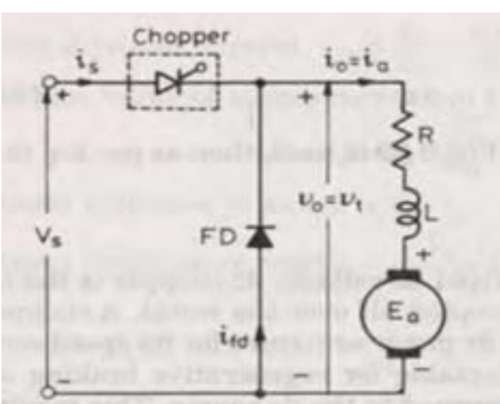


Fig.7.motoring mode operation

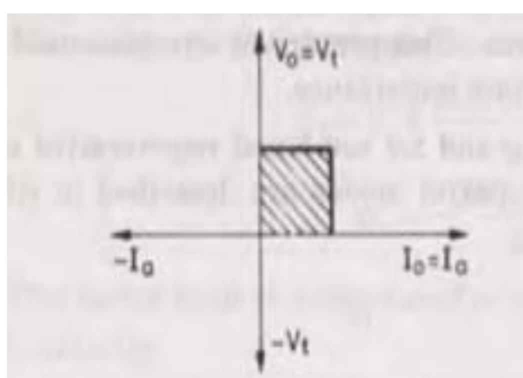


Fig.8. forward motoring mode operation

of chopper fed DC series motor *First -quadrant*

In the above circuit configuration ***when the chopper (CH) is ON***, the motor armature terminal is connected with the DC source. The current is conducted by the chopper from source to armature of the DC motor. The output voltage of chopper $V_O = V_t$ is fed to the motor armature. $I_o=I_a$ is chopper output current flows through the armature winding. R and L are the armature winding output voltage of the chopper is controlled by varying the duty cycle(δ) according to the speed requirement.

When the chopper is OFF and the CH operates like an open switch, the motor armature terminals are disconnected from the DC source. Now the stored energy in the inductance and back emf of the motor drives the armature current through the freewheeling diode FD. During this period rmature terminals are short circuited by FD. Now the output voltage $V_O = 0$, but I_o flows through armature circuit continuously.

The average motor voltage , $V_O = V_t = T_{on}/T .V_s = \delta. V_s$

Where V_s is the input DC voltage

And $\delta = T_{on}/T$, is the duty cycle of the chopper, T_{on} is the ON time of the chopper, T_{off} is OFF time of the chopper, T is the total time period.

$T = T_{on} + T_{off}$

Chopping frequency of the circuit is, $f = 1/T$

The duty cycle δ can be varied by varying the ON time and OFF time of the chopper. Thus the output voltage and in-turn speed of the DC motor drive is controlled during the motoring mode operation to obtain the speeds below base speed.

The input fixed DC voltage , output DC voltage and output currents are shown by waveforms in Fig.9.

The input fixed DC voltage , output DC voltage and output currents are shown by waveforms in Fig.9. The ON time and OFF time of chopper also indicated in the waveforms given.

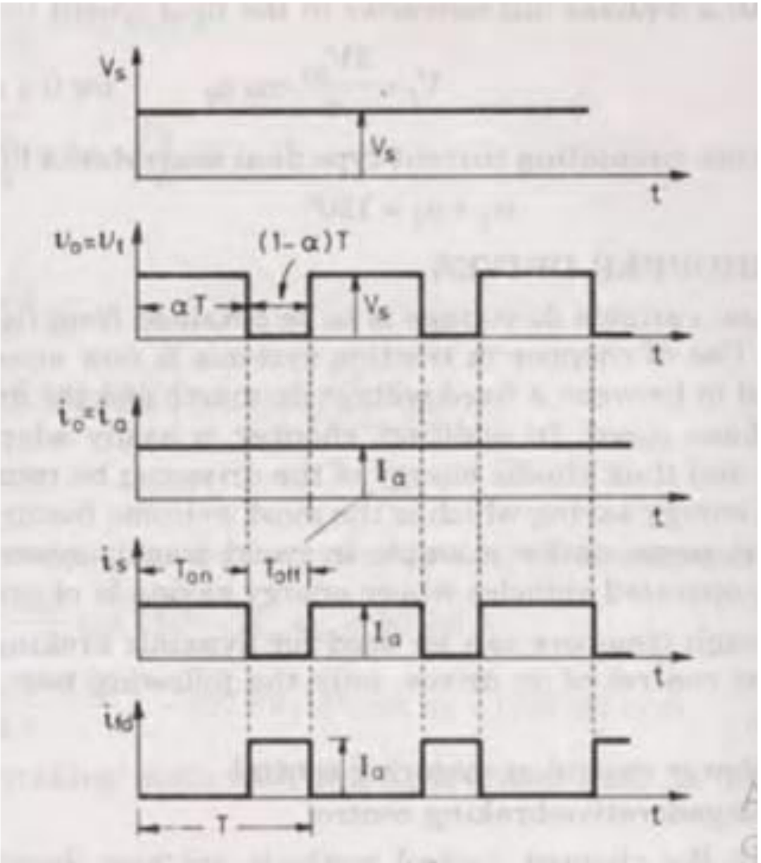


Fig.9. Waveforms

4.4.2.Regenerative Braking Control.

The chopper circuit configuration for Regenerative Braking mode is shown in Fig.10. During this mode of operation the motor acts as a generator, kinetic energy of the motor and the load is returned to the supply. For active loads like downward motion of electric train in a hill or descending hoist, assume the back emf E_b of the motor is greater than supply voltage V_s.

With the chopper circuit configuration shown in Fig.10., when the chopper is ON , chopper CH short circuits the armature terminals of the motor and the current $I_o=I_a$ is conducted by the chopper to the armature .The current is driven by the back emf of the motor and stored energy in the inductance. The ouput voltage $V_o = 0$.

When the CH is OFF, being E_b is greater than $V_{s,}$ diode D conducts and the stored energy in the armature inductance is transferred to the source, during T_{off} $V_t = V_s$.

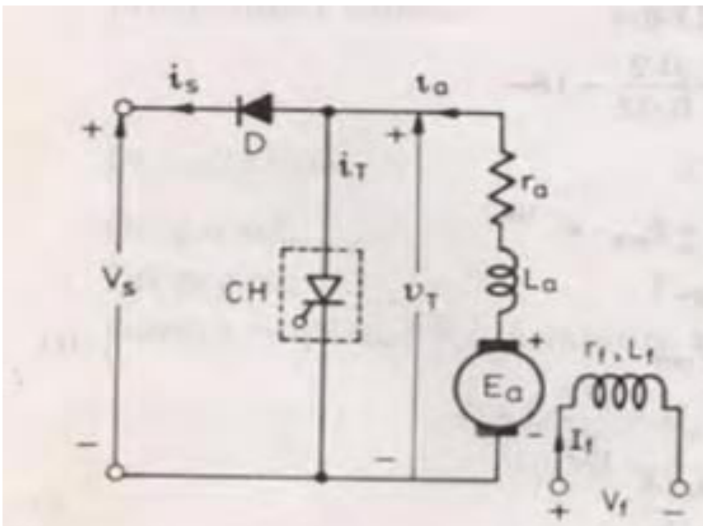


Fig.10. Copper circuit configuration for Regenerative braking control of Separately Excited DC motor.

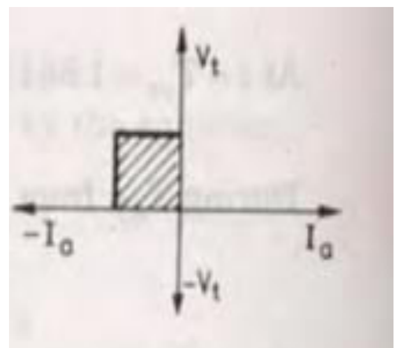


Fig.11. Quadrant diagram

Regenerative braking control is the second quadrant operation which is shown in Fig.11.

The average output voltage of chopper is

$$V_t = T_{off} / T.\ V_s = (1\text{-}\delta).\ V_s$$

Power generated by the motor = $V_t \,.\, I_a = (1\text{-}\delta).\ V_s \,.\, I_a$

Motor emf generated, $E_a = K_m\, \omega_m = V_t + I_a\, r_a$

$$= (1 - \alpha)\, V_s + I_a\, r_a$$

Motor speed during regenerative braking,

$$\omega_m = \frac{(1 - \alpha)\, V_s + I_a r_a}{K_m}$$

The voltage and current waveforms are shown in Fig.12.

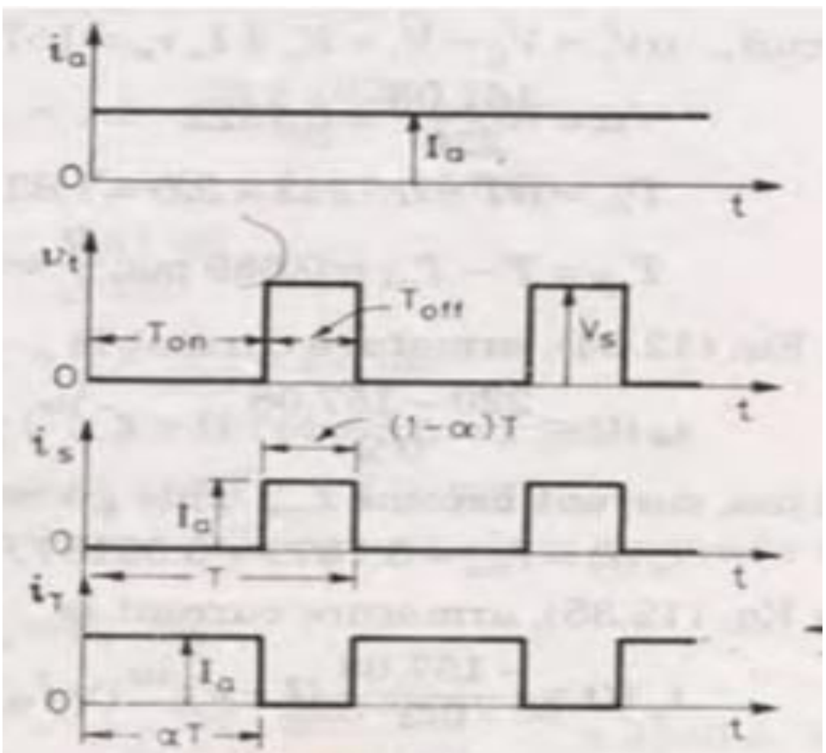
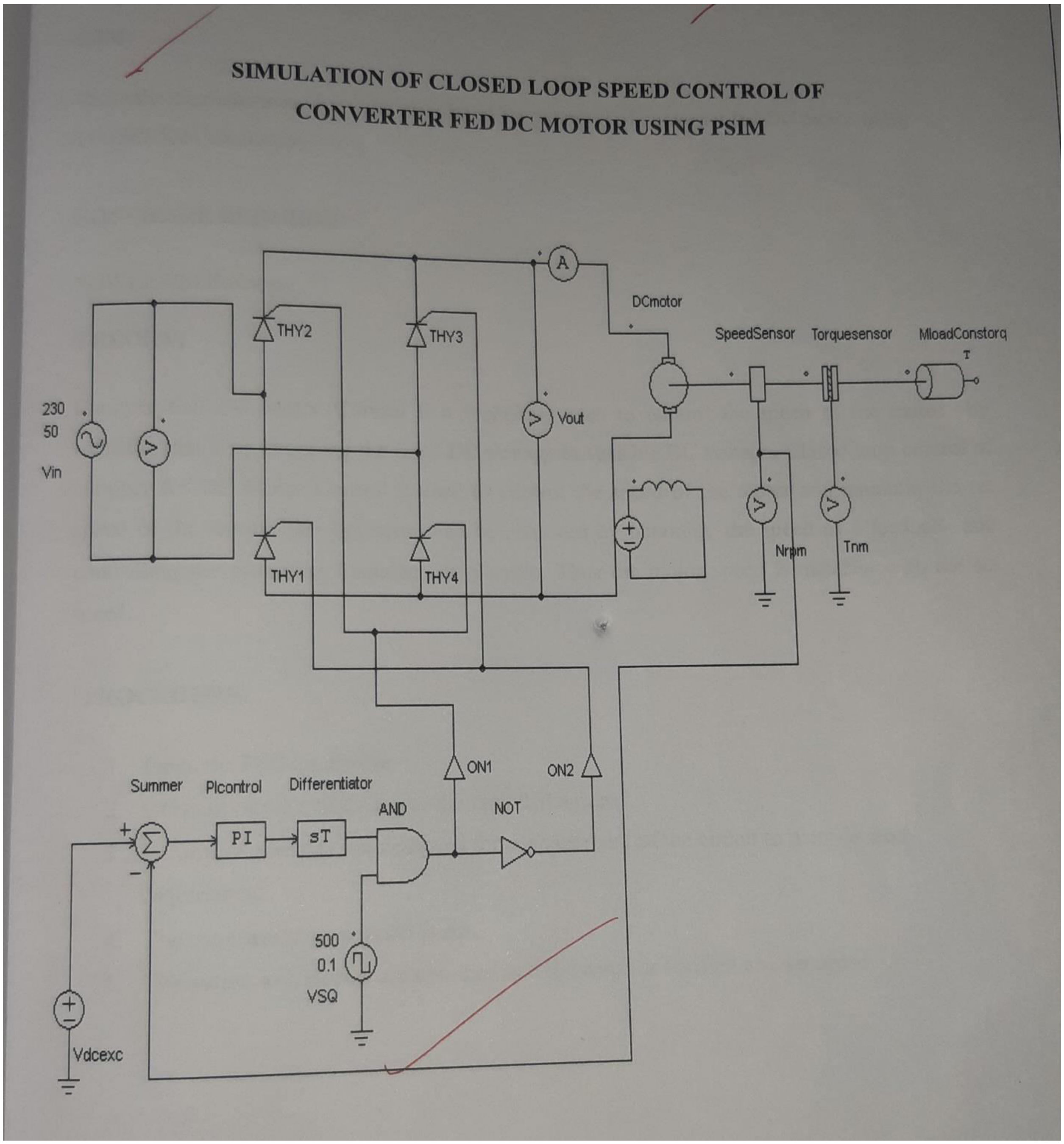


Fig.12.Waveforms

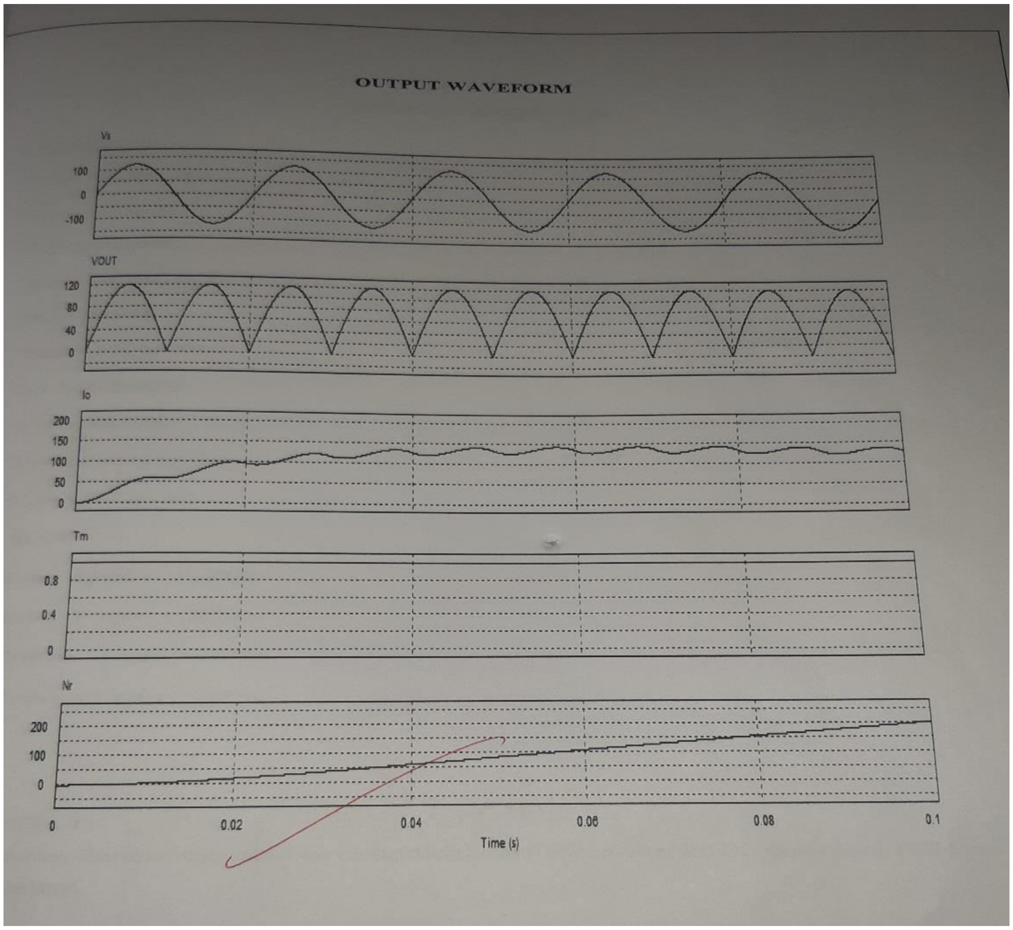
5.1Simulation of DC drives

5.1.1. Converter fed DC drive is simulated using PSIM.



5.1.2. Simulation results

The simulation results are presented interms of converter input AC voltage, DC output voltage of converter, output current, Motor torque and speed waveforms.



5.2.Applications of DC drives:

- Traction systems, Electric locomotives.
- Paper mills
- Lathes, milling machines, boring machines
- Hoists and Cranes
- Spindles and feeds of machine tools
- Roller mills

- Rubber mixers
- Motor braking systems
- Position control mechnisms

6. MCQ POST-TEST

1.To save energy during braking-----------------braking is used?

(A) dynamic
(B) plugging
(C) regenerative
(D) all of the above

Answer:
(C) regenerative

2.How many quadrants does a full converter work?
(A) one
(B) two
(C)three
(D) four

Answer:
(B) two

3.Full-converter can be used in DC motor for regenerative braking in ______________
(A)constant operation
(B)variable operation
(C)Inversion operation
(D) opposite operation

Answer:
(c)

4. Which of the following method is employed when regenerative braking is necessary?
(A)DC chopper
(B)inverter
(C)variable resistor
(D) rectifier

Answer
(A)

7.CONCLUSION

DC drives are widely used in various industries. Converters employed in DC drives gives smooth and wide range of speed control without much expensive. Moreover these drives and controller occupies lesser area and provide precise control of DC drives.

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9.ASSIGNMENTS

1. Discuss the four quadrant operation of Chopper fed DC drives.
2. Explain the inverter operation of single phase converter circuit.