AC/DC drives

Objectives: At the end of this lesson you shall be able to
- **state the classification and working of AC & DC drives**
- **state the applications of AC & DC drives**
- **describe the block diagram, parts of DC drive and advantages and disadvantages of DC drives.**

Electrical drives

An electric drive can be defined as an electromechanical device for converting electrical energy into mechanical energy to feed motion to different machines and mechanisms for various kinds of process control.

Motion control is required in large number of industrial and domestic applications like transportation, systems, rolling mills, paper machines, textile mills, machine tools, fans, pumps, robots, washing machines etc.

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

Classification of electric drives

i According to mode of operation
- Continuous duty drives
- Short time duty drives
- Intermittent duty drives

ii According to means of control
- Manual
- Semi automatic
- Automatic

iii According to number of machines
- Individual drive
- Group drive
- Multi - motor drive

iv According to dynamics and transients
- Uncontrolled transient period
- Controlled transient period

V According to methods of speed control
- Reversible and non - reversible uncontrolled constant speed
- Reversible and non - reversible step speed control
- Variable position control
- Reversible and non - reversible smooth speed control

Advantage of electrical drives

1 They have flexible control characteristics.
2 Drives can be provided with automatic fault detection systems. Programmable logic controller (PLC) and computers can be employed to automatically control the drive operation in a desired sequence.
3 They are available in wide range of torque, speed and power.
4 They are suitable to almost any operating conditions such as explosive and radioactive environments.
5 It can operate in all the four quadrants of speed - torque plane.
6 They can be started instantly and can immediately be fully loaded.
7 Control gear requirement for speed control, starting and braking is usually simple and easy to operate.

Choice (or) selection of electrical drives

- Choice of an electric drive depends on the important factors are.

1 Steady state operating conditions requirements. Nature of speed torque characteristics, speed regulation, speed range, efficiency, duty cycle, quadrants of operation, speed fluctuations if any, rating etc.
2 Transient operation requirements
3 Values of acceleration and deceleration, starting, braking and reversing performance.
4 Requirements related to the source. Types of source and its capacity, magnitude of voltage, voltage fluctuations, power factor, harmonics and their effect on other loads, ability to accept regenerative power.
5 Space and weight restriction if any.
6 Environment and location.
7 Reliability

Group electric drive

This drive consists of a single motor, which drives one or more line shafts supported on bearings. The line shaft may be fitted with either pulleys and belts or gears, by means of which a group of machines or mechanisms may be operated. It is also some times called as **shaft drives.**

Advantages

A single large motor can be used instead of number of small motors.

Disadvantages

There is no flexibility. If the single motor used, develops fault, the whole process will be stopped.

Individual electric drive

In this drive each individual machine is driven by a separate motor. This motor also imparts motion to various parts of the machine.

Multi motor electric drive : In this drive system, there are several drives, each of which serves to actuate one of the working parts of the drive mechanisms.

e.g : Complicated metal cutting machine tools

Paper making industries.

Rolling machines etc.

A modern variable speed electrical drive system has the following components

- Electrical machines and loads
- Power modulator
- Sources
- Control unit
- Sensing unit

Electrical machine

Most commonly used electrical machines for speed control applications are the following.

DC machines

Shunt, series, compound, DC motors and switched reluctance machines.

AC machines

Induction, wound rotor, synchronous, permanent magnet synchronous and synchronous reluctance machines.

Special machines

Brush less DC motors, stepper motors, switched reluctance motors are used.

Power Modulators (Controller)

Functions

- It modulates flow or power from the source to the motor is imparted speed - torque characteristics required by the load.
- During transient operation, such as starting, braking and speed reversal, it reduces the motor current with in permissible limits.
- It converts electrical energy of the source in the from of suitable to the motor.
- It selects the mode of operation of the motor (i.e) motoring and braking.

Types of power modulators (Controllers)

- In the electric drive system, the power modulators can be any one of the following.
- Controlled rectifiers (AC to DC converter)
- Inverters (DC to AC converters)
- AC voltage controllers (AC to DC converters)
- DC choppers (DC to DC converters)
- Cyclo converters (Frequency conversion)

Electrical sources

Very low power drives are generally fed from single phase sources. Rest of the drives is powered from a 3-phase source. Low and medium power motors are fed from a 415V supply. For higher ratings, motors may be rated at 3.3KV, 6.6 KV and 11 KV. Some drives are powered from battery.

Sensing unit

- Speed sensing (from motor)
- Torque sensing
- Position sensing
- Current sensing and voltage sensing (from lines or from motor terminals from load)
- Temperature sensing

Control unit

Control unit for a power modulator are provided in the control unit. It matches the motor and power converter to meet the load requirements.

Comparison between DC and AC drives

DC Drives	AC Drives
The power circuit and control circuit are simple	The power circuit and control circuit are complicated
It requires frequent maintenance	Less maintenance
The commutator makes the motor bulky, costly, and heavy	These problems are not there in these motors and are inexpensive, particularly squirrel motors
Fast response and wide speed range of control, can be achieved smoothly by conventional and solid state control	In solid state control the speed range is wide and conventional method is stepped and limited
Speed and design ratings are limited due to commutations	Speed and design ratings have upper limits

Applications

- Paper mills
- Cement mills
- Textile mills
- Sugar mills
- Steel mills
- Electric traction
- Petrochemical industries
- Electrical vehicles

Another one type of electric drive is 'Eddycurrent drive'

Eddy current drives

An eddy current drive consists of a fixed speed motor and an eddy current clutch. The clutch contains a fixed speed rotor and an adjustable speed rotor separated by a small air gap. A direct current in a field coil produce a magnetic field that determines the torque transmitted from the input rotor to the output rotor. The controller provides closed loop speed regulation by varying clutch current, only allowing the clutch to transmit enough torque to operate at the desired speed. Speed feedback is typically provided via an integral AC tachometer.

Eddy current drives are slip - controlled systems the slip energy of which is necessarily all dissipated as heat. Such drives are therefore generally less efficient than AC/DC-AC conversion based drives. The motor develops the torque required by the load and operates at full speed. The power is proportinoal to torque multiplied by speed. The input power is proportional to motor speed and times, operating torque while the output power is output speed and times operating torque. The difference between the motor speed and the output speed is called the **slip speed**. Power proportional to the slip speed times operating torque is dissipated as heat in the clutch.

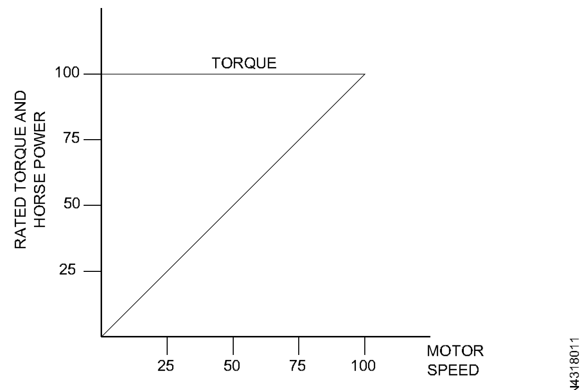
Working principle of DC drives

In DC motors, the speed is proportional to the armature voltage and inversely proportional to the field current . And also, the armature current is proportional to the motor torque. $N \propto \frac{E_b}{I_f}$ and $I_a \propto T$ Therefore, by increasing or reducing the applied voltage, the speed of the motor is varied. However, it is possible up to the rated voltage. If the speed greater than the base speed is required, the field current of the motor has to be reduced.

By reducing the field current, the flux in the motor reduces and it reduces the armature counter emf. Further, this armature current increases the motor torque and the speed will increase. These are the two basic principles employed in DC drives to control the speed of the motor.

In armature controlled DC drives, by varying the armature voltage, variable speed is obtained as in Fig 1.

Fig 1



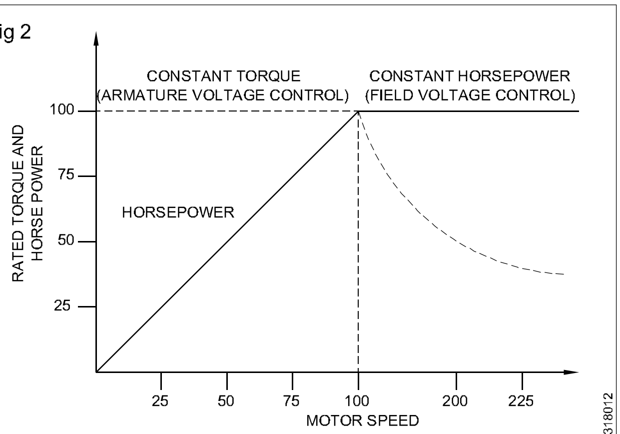
SPEED TORQUE CHARACTERISTIC

Generally, a fixed field supply is provided in these DC drives. As the torque is constant (which describes a load type) over the speed range, the motor output horse power is proportional to the speed. The motor characteristics of this drive are in Fig 1.

Constant torque operation

In case of armature and field controlled drives, the armature voltage to the motor is controlled for constant torque-variable HP operation up to the base speed of the motor. And for the above base speed operation, drive switches to the field control for constant HP- reduced torque operation up to maximum speed as in Fig 2 In this case, reducing the field current increases the speed of the motor up to its maximum speed as in Fig 2.

Fig 2



N V_B T-CHARECTERISTICS

In most instances the shunt field winding is excited, with a constant - level voltage from the controller . The SCR (silicon controller rectifier), also known as thyristor, which converts the alternating current (AC) of the power source to variable DC output which is applied to the armature of a DC motor. Speed control is achieved by regulating the armature voltage to the motor.

A thyristor bridge is a technique commonly used to control the speed of a DC motor by varying the DC voltage. Important to note that the voltage applied to a DC motor can not be greater than the rated name plate voltage.

The tachometer (feedback device) converts actual speed in to an electrical signal that is summed with the desired reference signal. The output of the summing junction provides an error signal to the controller and a speed correction is made.

In modern DC drives, SCRs are completely replaced by MOSFET s and IGBTs in order to achieve high speed switching so that distortion to the AC incoming power and currents during switching is eliminated. Hence, the drive becomes more efficient and accurate.

Silicon controlled rectifier (SCRs) are widely used thyristors for large DC motor drives in its power conversion unit. An SCR conducts when a small voltage applied to its gate terminal. Its conduction continues till the starting of negative cycle and it turned OFF automatically once the voltage across the SCR goes through natural zero till next gated signal.

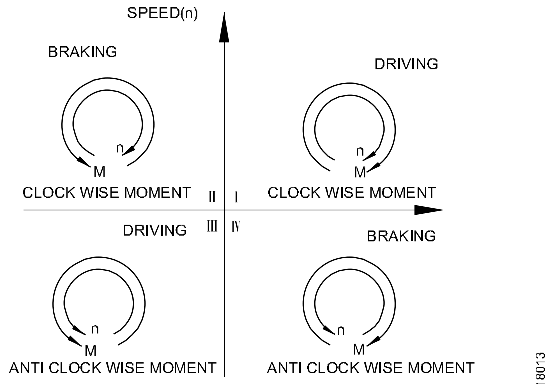
The purpose of using these SCRs in DC drives is to convert the fixed AC supply to variable DC supply that controls the motor speed. Some SCR DC drives are supplied from single phase AC supply and use four SCRs in the form of bridge for the DC rectification. In case of high power DC drives, a three phase supply with six SCRs is used for DC rectification.

In case of four quadrant operation (forward motoring, forward braking, reverse motoring and reverse braking) of the DC drive, a bridge rectifier consisting of 12 SCRs with a three phase incoming supply is used. During each quadrant operation, SCRs are triggered at a phase angle in order to provide required DC voltage to the motor.

Drive operation

The drive applications can be categorized as single - quadrant, two - quadrant, three-quadrant or four- quadrant; the chart's four quadrants (Fig 3) are defined as follows.

Fig 3



ELECTRIC MOTOR SPEED-TORQUE CHART

Quadrant I : Driving or motoring forward accelerating quadrant with positive speed and torque

Quadrant II : Generating or braking, forward braking-decelerating quadrant with positive speed and negative torque.

Quadrant III: Driving or motoring, reverse accelerating quadrant with negative speed and torque.

Quadrant IV : Generating or braking, reverse braking - decelerating quadrant with negative speed and positive torque.

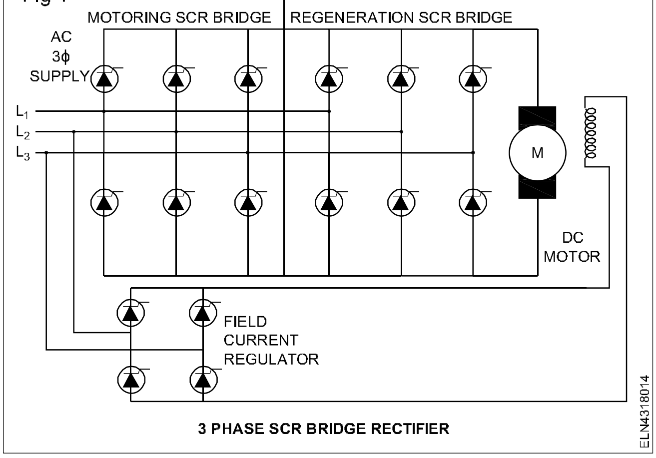
Most applications involve single quadrant loads operating in quadrant I, such as in variable - torque (e.g. centrifugal pumps or fans. etc.

Certain applications involve two - quadrant loads operating in quadrant I and II where the speed is positive but the torque changes polarity Some sources define two - quadrant drives as loads operating in quadrants I and III where the speed and torque is same (positive or negative) polarity in both directions.

Certain high - performance applications involve four - quadrant loads (Quadrants I to IV) where the speed and torque can be in any direction such as in hoists, elevators and hilly conveyors. Regeneration can occur only in the drive's DC link bus when inverter voltage is smaller in magnitude than the motor back - EMF and inverter voltage and back - EMF are the same polarity.

The connection of SCRs for four quadrant operation of the drive) from incoming three phase AC supply to the DC output is in Fig 4. In this, the motoring SCR bridge and regeneration SCR bridge achieve the drive four quadrant operation by receiving the appropriate gate signals from (analog or digital) controller.

Fig 4

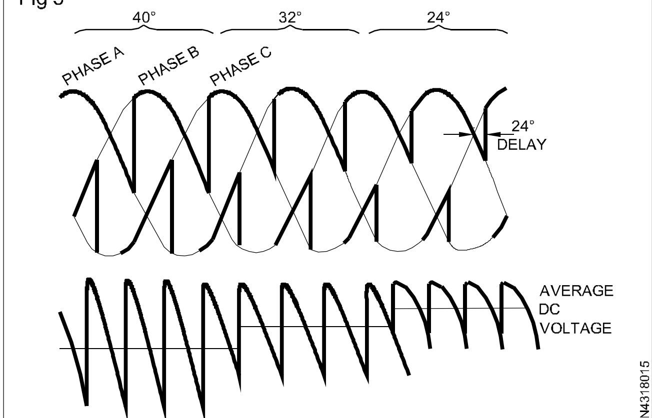


3 PHASE SCR BRIDGE RECTIFIER

If the SCRs were gated with a phase angle of zero degrees, then the drive function as a rectifier which feeds the full rectified rated DC supply to the motor and by varying the firing angle to the SCRs, a variable DC supply is applied to the motor.

The DC output voltage waveform is related to the AC waveform for above circuit is in Fig.5. This average DC output voltage is obtained for 40°, 32° and 24° firing phase angles. By this way, the average output is controlled by varying the firing phase angles to the SCRs.

Fig 5



AC INPUT & DC OUTPUT WAVE FORMS

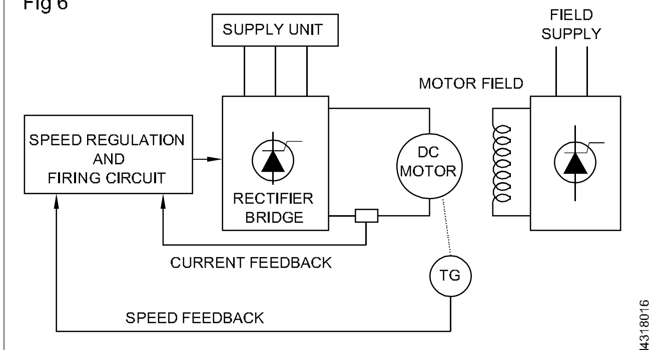
As the field winding also requires the regulated DC supply, only four SCRs are used in the field bridge converter. This is because field never requires a negative current and hence another set of SCRs is not required, which were used in armature for reversing the motor.

Block diagram of DC drive

The block diagram of a DC drive system is in Fig 6

DC drive input : Some thyristor based DC drives operate on a single phase supply and use four thyristors for full wave rectification. For larger motors 3 phase power supply is needed because the waveforms are much smoother. In such cases, six thyristors are needed for full wave rectification.

Fig 6



COMPONENTS OF A DC DRIVE SYSTEM

Rectifier Bridge : The power component of a controlled DC drive is a full wave bridge rectifier which can be driven by three phase or single phase supply. As mentioned above the number of thyristor may vary depends on the supply voltage.

A six - thyristor bridge (in case of three phase converter) rectifies the incoming AC supply to DC supply to the motor armature. The firing angle control of these thyristors varies the voltage to the motor.

Field Supply Unit (FSU) : The power is to be applied to the field winding is much lower than the armature power.

In many cases a two - phase supply is drawn from the three phase input (that supplies power to the armature) and hence the field exciter is included in the armature supply unit.

The function of the field supply unit is to provide a constant voltage to the field winding to create a constant field or flux in the motor. In some cases, this unit is supplied with thyristors to reduce the voltage applied to the field so as to control the speed of the motor above the base speed incase of permanent magnet DC motors, the field supply unit is not included in the drive.

Speed Regulation unit : It compares the operator instruction (desired speed) with feedback signals and sends appropriate signals to the firing circuit. In analog drives, this regulator unit consists of both voltage and current regulators. The voltage regulator accepts the speed error as input and produces the voltage output which is then applied to the current regulator.

The current regulator then produces required firing current to the firing circuit. If more speed is required, additional current is drawn from the voltage regulator and hence thyristors conduct for more periods. Generally, this regulation (both voltage and current) is accomplished with proportional -integral- derivative controllers.

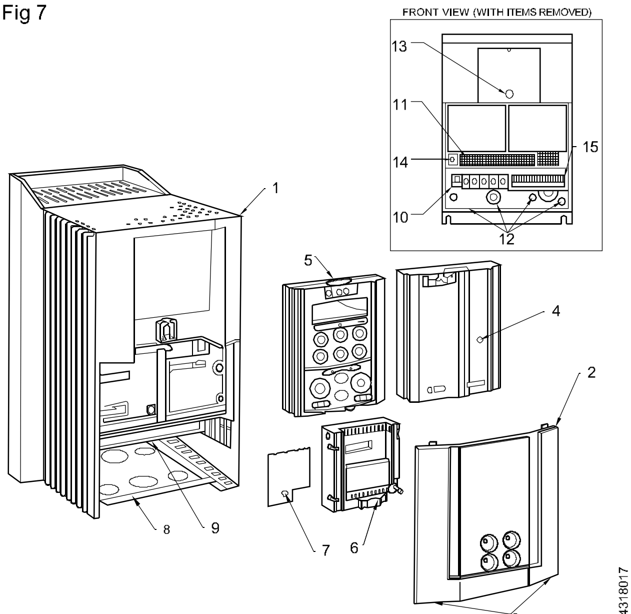
The field current regulator is also provided where speed greater than the base speed is required.

Parts of DC drive

DC drives of various brands with different ratings are available in the market. It is generally assembled in a metallic enclosure. The front panel has the power terminals, control terminals, keypad for controlling the drive etc. It has provision for connecting to PC for programming the drive.

The main parts of DC drive are given below.(Fig 7)

Fig 7



PARTS OF DC DRIVE

1 Main drive assembly

2 Terminal cover

3 Terminal cover retaining screw

4 Blank cover

5 Keypad

6 COMMS technology box (optional)

7 Speed feedback technology card (optional)

8 Gland plate

9 Power terminal shield

10 Power terminals

11 Control terminals

12 Earthing / grounding points

13 Keypad part

14 Programming part

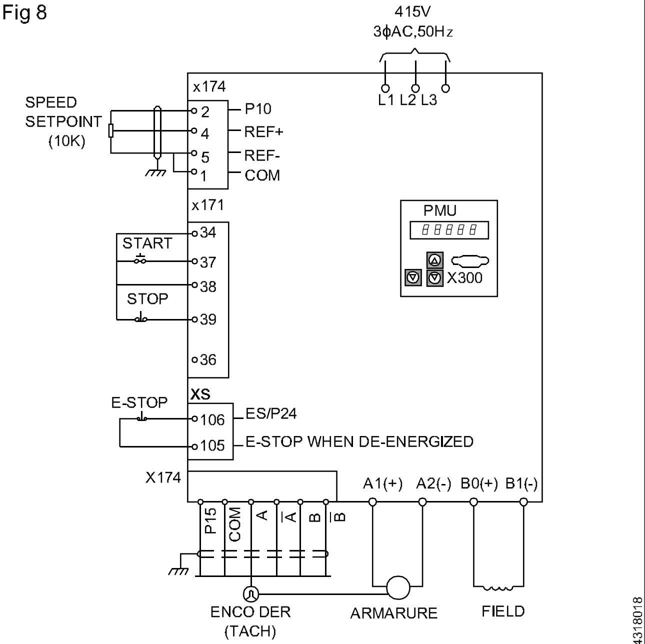
15 Auxiliary power, external contactor, blower and isolated thermistor terminals

Power and control terminals

In DC drive, the front panel has the power terminals L1, L2 and L3 where 3 phase input supply of 415V can be connected.

There are control terminals given for speed adjust potentiometer, Torque adjust potentiometer, START/RUN/ STOP switch, JOG/RUN/ switch, AUTO/MAN switch, FORWARD/REVERSE switch etc. Terminal A1 & A2 and B_0 & B_1 are meant for armature and field connections respectively. Names and locations are illustrated in Fig 8

Fig 8



CONTROL TERMINALS OF DC DRIVE

Advantages of DC drive

- DC drives are less complex with a single power conversion from AC to DC.
- DC drives are normally less expensive for most horsepower ratings.
- DC motors have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose.
- Cooling blowers and inlet air flanges provide cooling air for a wide speed range at constant torque.
- Accessory mounting flanges and kits for mounting feedback tachometers and encoders.
- DC regenerative drives are available for applications requiring continuous regeneration for overhauling loads. AC drives with this capability would be more complex and expensive.
- Properly applied brush and commutator maintenance is minimum.
- DC motors are capable of providing starting and accelerating torques in excess of 400% of rated value.
- Some AC drives may produce audible motor noise which is undesirable in some applications.

Disadvantages of DC drive

- More complicated because of commutators and brushes.
- Heavier than AC motors.
- High maintenance is required.
- Large and more expensive than AC drive.
- Not suitable for high speed operation.