

ELECTRICAL DRIVE SYSTEM

Drives:

Systems employed for motion control are called drives. Motion control is required in industrial as well as domestic applications like transportation system, rolling mills, paper mills, textile mills, machine tools, fans, pumps, robots, washing machines etc. Motion control may be translational, rotational or combination of both. Generally, a drive system is basically has a mechanical load, a transmission system and a prime mover. The prime mover may be I.C. engine, steam engine, turbine or electric motors. However, electric motors are predominantly used employed as prime mover due to certain advantages.

Electric Drives:

‘An Electric is defined as a form of machine equipment designed to convert electrical energy into mechanical energy and provide electrical control of this process’.

Or

Drives employing electric motors as prime movers are called as Electrical Drives. In other words,

A Drive is a combination of various systems combined together for the purpose of motion control.

Basic Elements of the Electric Drive Systems:

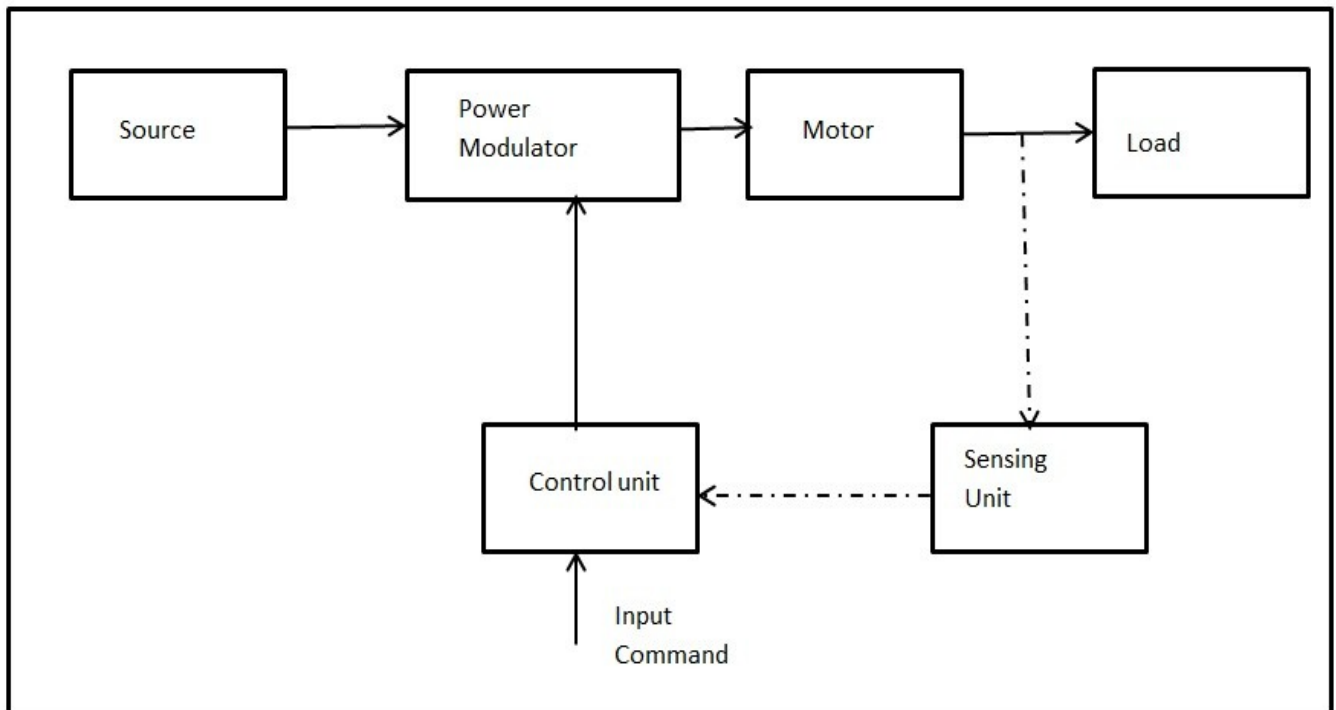


Fig 1.1

A modern electric drive system has five main functional blocks as shown above a mechanical load, a motor, a power modulator, a power source and a controller.

Power source: The power source provides the energy to the drive system. It may be dc or ac (single-phase or three-phase)

Power Converter: The converter interfaces the motor with the power source and provides the motor with adjustable voltage, current and frequency. During transient period such as starting, braking and speed reversal, it restricts source and motor current within permissible limits. Also the converter converts the electric waveform into required signal that requires the motor.

Types of Converter / modulator:

1. Controlled Rectifier(ac to dc)
2. Inverter (dc to ac)
- 3.AC Voltage Regulator (ac to ac)
4. DC Chopper (dc to dc)
5. Cyclo-converter (ac to ac) (Frequency converter)

Controller:

A well designed controller has several functions. The basic function is to monitor system variables, compare them with desire values, and then adjust the converter output until the system achieves a desired performance. This feature is used in speed and position control.

Electric motor:

- i) The basic criterion in selecting an electric motor for a given drive application is it meets power level and performance required by the load during steady state and dynamic operation.
- ii) Environmental factors: In industry such as in food processing, chemical industries and aviation where the environment must be clean and free from arc. Induction motors are used instead of DC motor.
- iii) Cost of Electric Motors.
- iv) the function of Converters.

Mechanical Load:

The mechanical load usually called as machinery such as flow rates in pump, fans, robots, machine tools, trains and drills are coupled with motor shaft.

Advantages of Electrical Drives:

- Do not pollute the environment.
- Unlike other prime movers there is no need to refuel or warm-up the motor.
- They are available with wide range of torque, speed and power.
- Electric braking can be employed. Therefore they are having flexible control characteristics.
- In the past, Induction and synchronous motors were employed mainly in constant speed drives. Variable speed drives uses dc motor.
- Now days AC motors also used in variable speed drives due to development of semiconductor converters.

- The reason is due to the presence of commutator and brushes, DC motors have number of disadvantages.

Torque-speed characteristics of industrial driven units (Mechanical Loads)

Mechanical loads exhibit wide variations of speed-torque characteristics, Generally can be expressed as:

$$T = CT_r \left(\frac{n}{n_r} \right)^k$$

Where : C is proportionality constant

T_r is the loads torque

n_r is speed of load

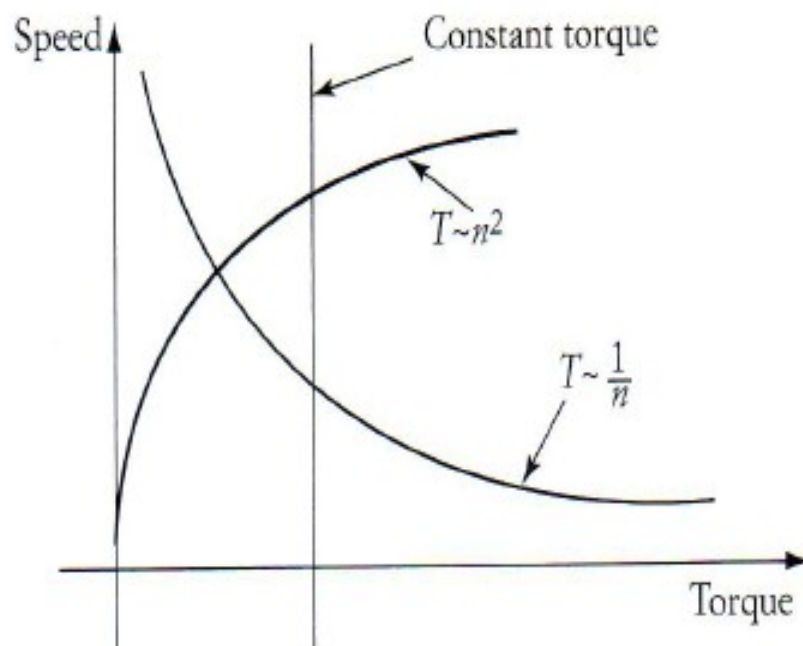
n is operating speed

The mechanical power P of the load torque T is given by :

$$P = T\omega$$

$$\omega = 2\pi f = \frac{2\pi n}{60}$$

Typical Speed - Torque Characteristics of Mechanical Loads



Type of the Mechanical Loads:

1. Torque Independent of Speed (torque constant)

The power linear dependent of speed, Ex: Hoist or the pumping of water or gas against constant pressure.

2. Torque Linearly Dependent on Speed

Ex: Motor driving a dc generator connected to a fixed-resistance load, and the field of the generator is constant.

3. Torque Proportional to the Square of Speed

Ex: fans, centrifugal pumps, and propeller.

4. Torque Inversely Proportional to Speed

Ex: Milling and boring machines. The load usually requires a large torque at starting speed and at low speeds.

Electric Motors Speed - Torque Characteristics**Electric motors have wide variation of speed-torque characteristics**

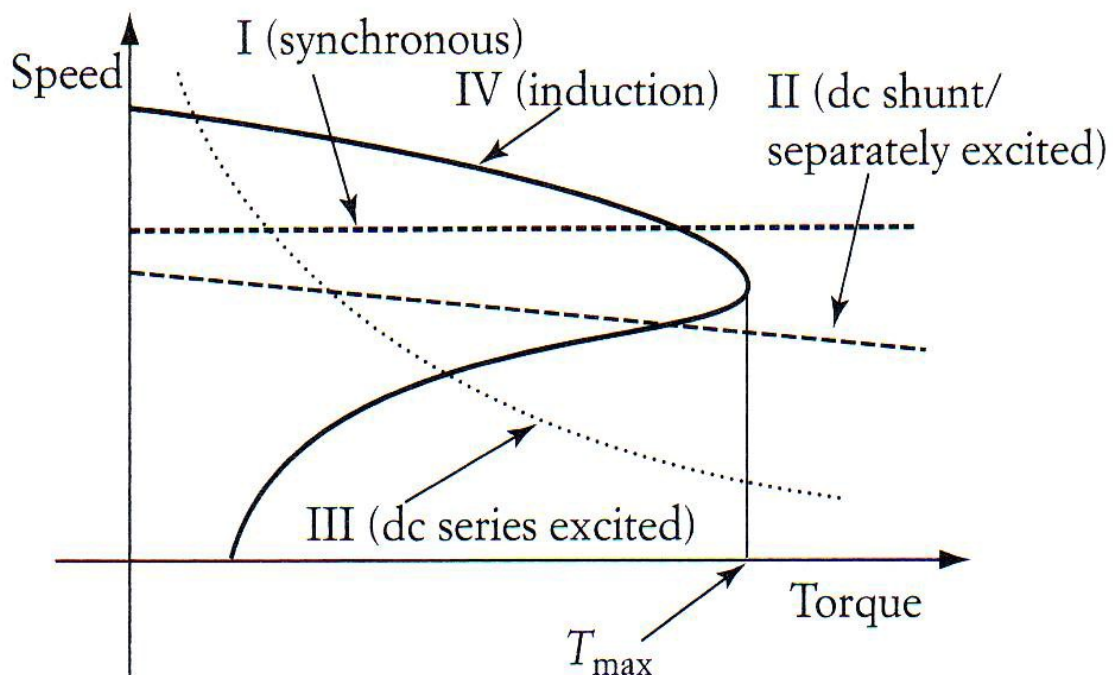
Curve I : Synchronous or reluctance motor(Constant speed)

Curve II : Shunt or separately excited dc motor(speed slightly reduced when the load torque increase)

Curve III : Series dc motor(speed is high at light loading condition and low at heavy loading)

Curve IV : Induction motor(during steady state, they operation at the linear portion of speed-torque characteristic speed is high at light loading, the maximum developed torque is limited to T_{max})

Speed-torque characteristics of electric motors



In electric drive application, electric motors should be selected to match the intended performance of loads. Ex: In constant speed application, the synchronous motor is probably the best option.

Power Supply :

Two major types of power sources are used in industrial applications: alternating current (ac) and direct current (dc). Alternating current sources are common in industrial installations and residences. These sources can either be single-phase or multiphase systems. Single-phase power sources are common in residences, where the demand for electric power is limited. Multiphase power sources are used in high power consumption applications. The most common type of power source in the United States is the three-phase, 60-Hz power source. In Europe, most of the Middle East, Africa, and Asia, the frequency is 50 Hz.

Extensive industrial installations usually have more than one type of power source at different voltages and frequencies. Commercial airplanes, for example, may have a 400-Hz ac source in addition to a 270-volt dc source.

Control of Electric Drives

Electrical drives have become the most essential equipment now days in the electrical motors and other rotating machines. We know that electrical drives mainly accomplishes three kinds of work,

1. Starting
2. Speed control
3. Braking

It can be said that the electrical drives enable us to control the motor in every aspect. But **control of electrical drives** is also necessary because all the functions accomplished by the drives are mainly transient operations i.e the change in terminal voltage, current, etc are huge which may damage the motor temporarily or permanently. That's why the need of controlling the drives rises and there are various methods and equipment's to control different parameters of the drives which are discussed later.

Closed Loop Control of Drives

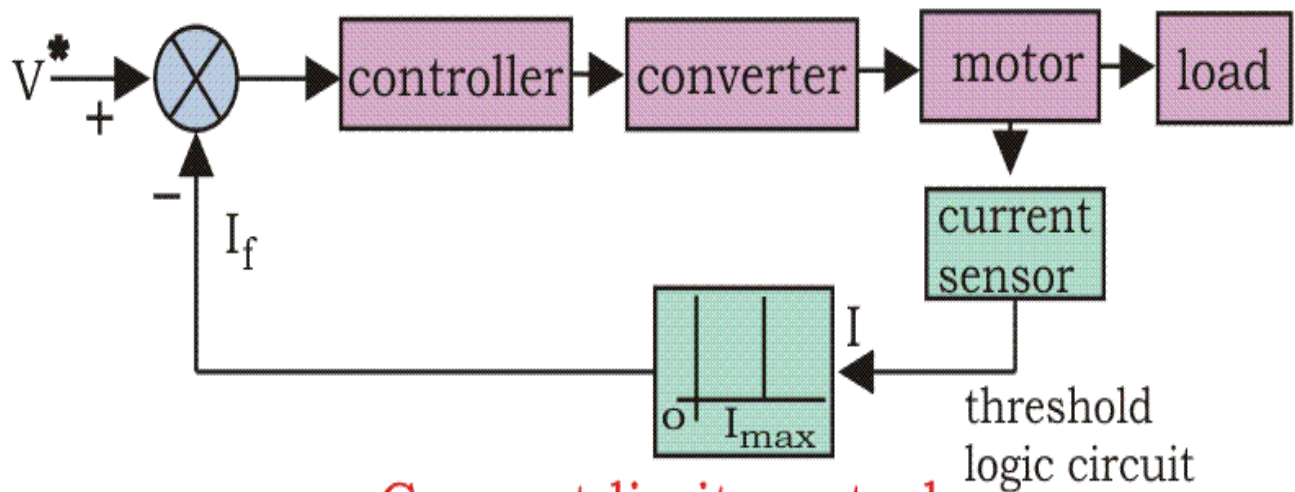
In a control system, there are two types of systems, one is open loop and the other is closed loop control system. In open loop control system the output has no effect on the input, i.e the controlling phenomenon is independent of the output, on the other hand closed loop control system is much more advanced and scientific, here the output is fed back to the input terminal which determines the amount of input to the system, for example if the output is more than predetermined value the input is reduced and vice-versa. In electrical drives feedback loops or closed loop control satisfy the following requirements.

1. Protection
2. Enhancement of speed of response
3. To improve steady -state accuracy

Current Limit Control

During the starting, we know if precautionary measures are not taken there is a chance of huge current flow through the motor circuit. To limit the current and sense the current fed to the motor, current limit controller is installed. The feedback loop does not effect the normal operation of the drive but if the current exceeds the predetermined safe limit, the feedback loop activates and the current is brought down below the safe limit. Once the current is brought down below the safe limit the feedback loop again

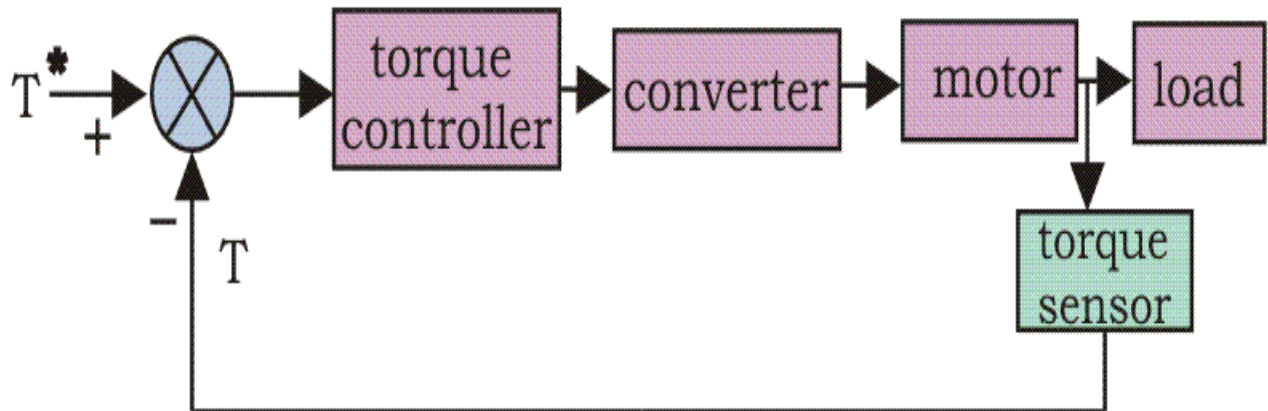
deactivates and in this way the control of current takes place.



Current limit control

Closed Loop Torque Control

This type of torque controller is seen mainly in battery operated vehicles like cars, trains etc. the accelerator present in the vehicles is pressed by the driver to set the reference torque T . The actual torque T follows the T^* which is controlled by the driver via accelerator.

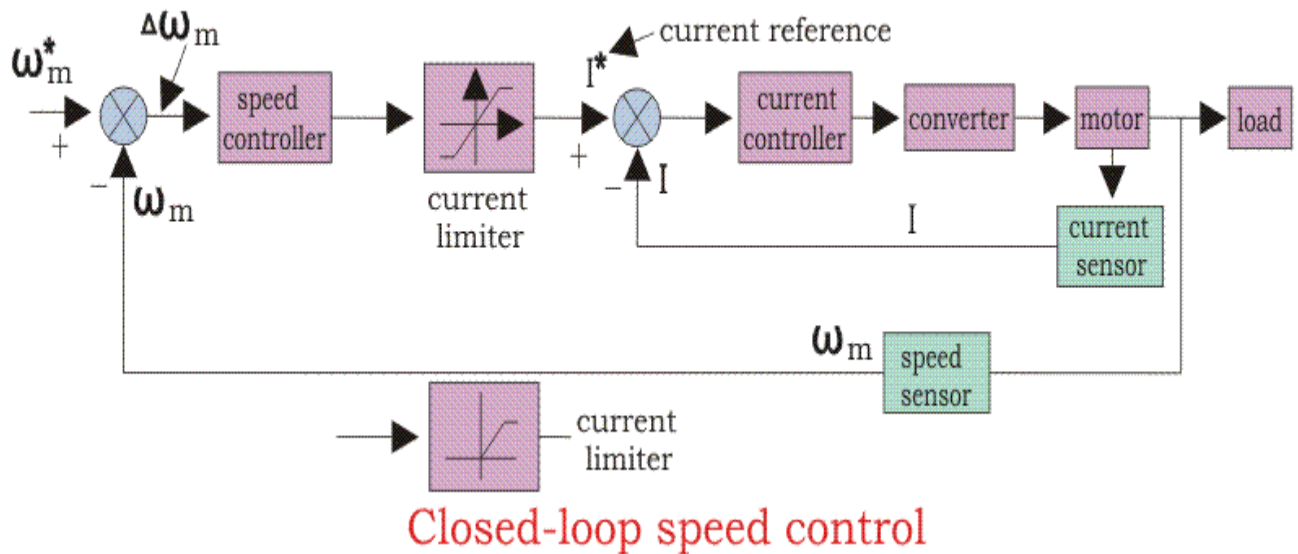


Closed-loop torque control

Closed Loop Speed Control

Speed control loops are perhaps the most widely used feedback loops for drives. If we first see the block diagram of this loop then it will be a

lot easier for us to understand.



We can see from the diagram that there are two control loops, which can be said as an inner loop and outer loop. The inner current control loop limits the converter and motor current or motor torque below the safe limit. Now we can understand the function of the control loop and drive by practical examples. Suppose the reference speed ω_m^* increases and there is a positive error $\Delta\omega_m$, which indicates that the speed is needed to be increased.

Now the inner loop increases the current keeping it under maximum allowable current. And then the driver accelerates, when the speed reaches the desired speed then the motor torque is equal to the load torque and there is a decrease in the reference speed ω_m^* which indicates that there is no need of any more acceleration but there must be deceleration, and braking is done by the speed controller at maximum allowable current. So, we can say that during speed controlling the function transfers from motoring to braking and from braking to motoring continuously for the smooth operation and running of the motor.