# Electric Drive (NEE/NEN-801)

## <u>UNIT-1</u> Fundamental of Electric Drive

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**Electric Drive:-** the electric drive system employed for motion control and their operating condition with respect to mechanical load varied to suit particular requirements is called electric drive.

## Block diagram of electric drive:-

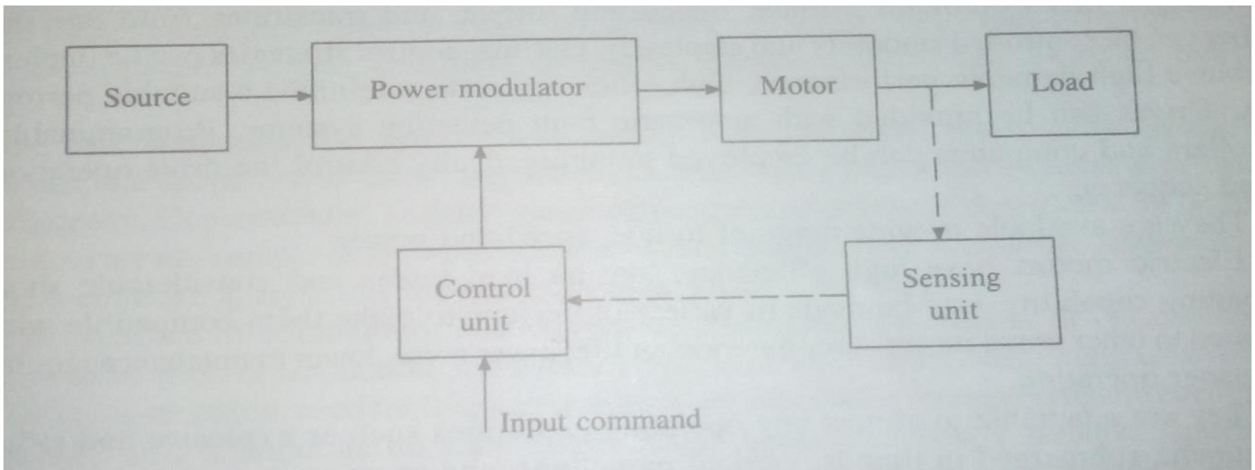


**Fig. 1.1** Block diagram of an electrical drive

Power modulator perform one or more of the following functions-

- Modulates flow of power from the source to the motor in such manner that motor is imparted speed torque characteristics required by the load.
- During transient operation, such as starting braking & speed reversal, it restricts source motor currents with in permeable (allowed) value.
- Converts energy of the source in the form suitable to motor.
- Select the mode of operation of the motor. i e motoring & breaking
  .

**Advantages of electric Drives: -** Electric drive are widely used because of the following advantages-

- They are flexible control characteristics.
- They are amiable in wide range of torque speed power.
- Electric motor has high efficiency, low no load losses & considerable short time over loading capacity.
- They are adoptable to almost any operation conditions.
- Do not pollute the environment.
- Can be operating in all the four quadrants of speed –torque.

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## Part of Electric Drive: Electric Drive has the following Parts:-

**Electric Motors: -** Motor has commonly used in electrical drive are shunt, series, compound, induction motors were employed. Synchronous motors were used in constant speed drive. Variable speed drive applications were used D.C. motors, A.C. motors are now employed in variable speed drives also due to development of semiconductor converts employing thyristors, power transistors, IGBT & GTO.

**Power Modulator: -** Power modulators classifications is following parts-

- converters
- variable impedances
- Switching circuit.

**Converters: -** Convertors convert electrical energy of the source in the form suitable to the motor. Power source fixed voltage A.C. or fixed voltage D.C. need for convertor a rises when nature of available electrical power is different than what is required for the motor.

**Source:** - Source is single phase or three phase 50 Hz ac supply amiable in most locations. Low power drive generally fed to single phase source large power drives are powered from three phase supply.

In case of air craft & space applications drive, 400 Hz ac supply is generally used to achieve high power to weight ratio for motors.

Some drive are powered formed a battery depending up on the sized battery voltage may have typical value 6 V, 12 V 24 V, 48 V, dc supply.

**Control Unit:** - The functions of control unit will be to provide sequencing and interlocking solid state relays are used. Controls for power modulators are provided in the control unit. Nature of control unit for a particular drives depends on the power modulator that is used.

## Choice of Electric Drive: - Choice of electric Drive depends an a number of factors-

- Steady state operation requirement.
- Transient operation requirement.
- Requirement related to the source.
- Capital & running Cost maintence  need life
- Space & weight restrictions.
- Environment & location
- Reliability.

# Electric Drive (NEE/NEN-801)

**Classification of electric Drive: -** Electric Drive may be classified in to three categories-

- Group Drive
- Individual Drive
- Multi-motor Drive

Group drive consists of a single motor which – several mechanism or machines by means of one or more line shafts supported on bearing. it is also called a line shaft drive . the line shaft fitted with multi-stepped pulleys and belts that connect these pulley and the shaft of the driven machines serve to vary their speed.

But, seldom is the group drive used, now a days due to the following disadvantages-

- Any fault that occurs in the driving motors, all the driven equipment idle.
- Considerable power loss takes place in the energy transmitting mechanisms.
- Flexibility of lay out of the different machines is lost , since they have to be located as to suit the lay out of the line shaft .
- The used of line shaft, pulley and belts make the drive untidy in appearance and less safe to operate.
- The level of noise produced at the work site is quit high.

In individual drive, an electric drive is used foe transmitting motion to vary parts or mechanisms belong to single equipments. For example lath machine various part moves helps of gears.

In multi-polar motor drive, separated motors are provided for actuating different parts of the driven mechanism. For example in travelling cranes, there are three motors: one for hoisting, another long travel motion & third for cross travel motion.

## Fundamental Torque Equations:-

The motor load system by an equivalent rotational system shown in fig-

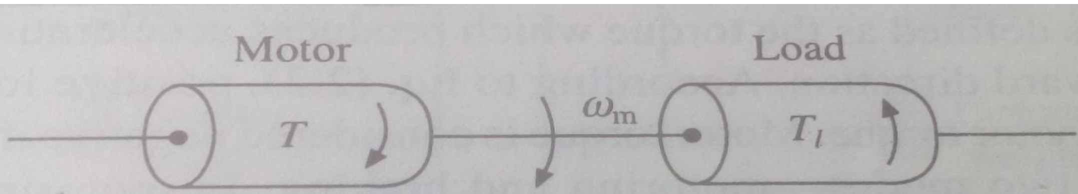



Fig. 2.1 Equivalent motor-load system

Although the load, in general, may not rotate at the same speed as the motor it is convert to represent it in this manner so that all parts of the motor-load system have the same angular velocity . The basic torque equations known as the elution of the motion, for the above loaded system is written as-

$$T_M = T_L + J\frac{dw}{dt}$$

Where $T_M$ & $T_L$ denote motor load torque measured in N-m; J the moment of inertia, W the angular velocity in mechanical radians/sec.

In above equation shows that torque developed by the motor torque ($T_M$) is counter balance by a load torque ($T_L$) & dynamic torque ($J\frac{dw}{dt}$).

- $T_M > T_L$, i.e. $\frac{dw}{dt} > 0$ the drive will accelerating.
- $T_M < T_L$, i.e. $\frac{dw}{dt} < 0$ the drive will decelerating.
- $T_M = T_L$, i.e. $\frac{dw}{dt} = 0$ the drive will continue to run at the same speed if it warte running or will continue to be at rest.

## Speed-Torque conventions & multi-quadrant operation:-

A motor operates in two modes operation motoring & braking. In motoring it convert electrical energy to mechanical energy, which support it motion. In braking, it works as a generator converting mechanical energy to electrical energy and thus opposes the motion. Motor can be provided motoring & braking operations for both forward & reverse directions.

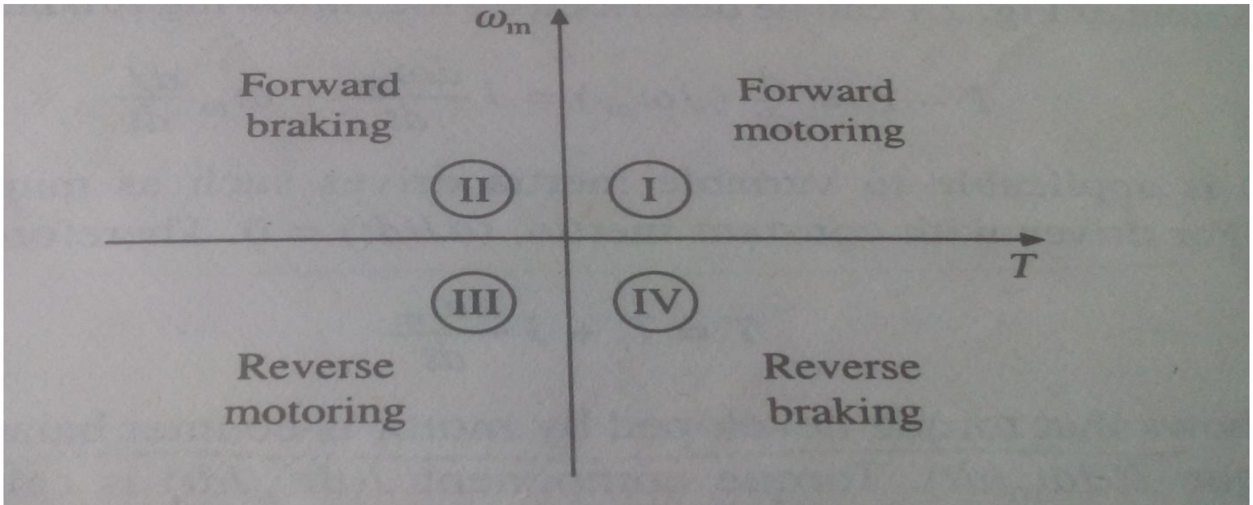



Fig. 2.2 Multiquadrant-operation of drives

In above fig shows the torque & speed co-ordinate for both forward (positive) and reverse (negative) motions. Power developed by a motor is given by the product of speed & torque. In quadrant I developed power is positive, hence machine works as a motor. Supplying mechanical energy operation in quadrant I is there fore called forward motoring. In quadrant II power is negative hence machine works under braking opposing the motion the reform operation in quadrant II is known as forward braking . Similarly operations in quadrant III & IV can be identified as reversed motoring & braking respectively.

Let us consider operation of hoist in four quadrants as shown in fig.-

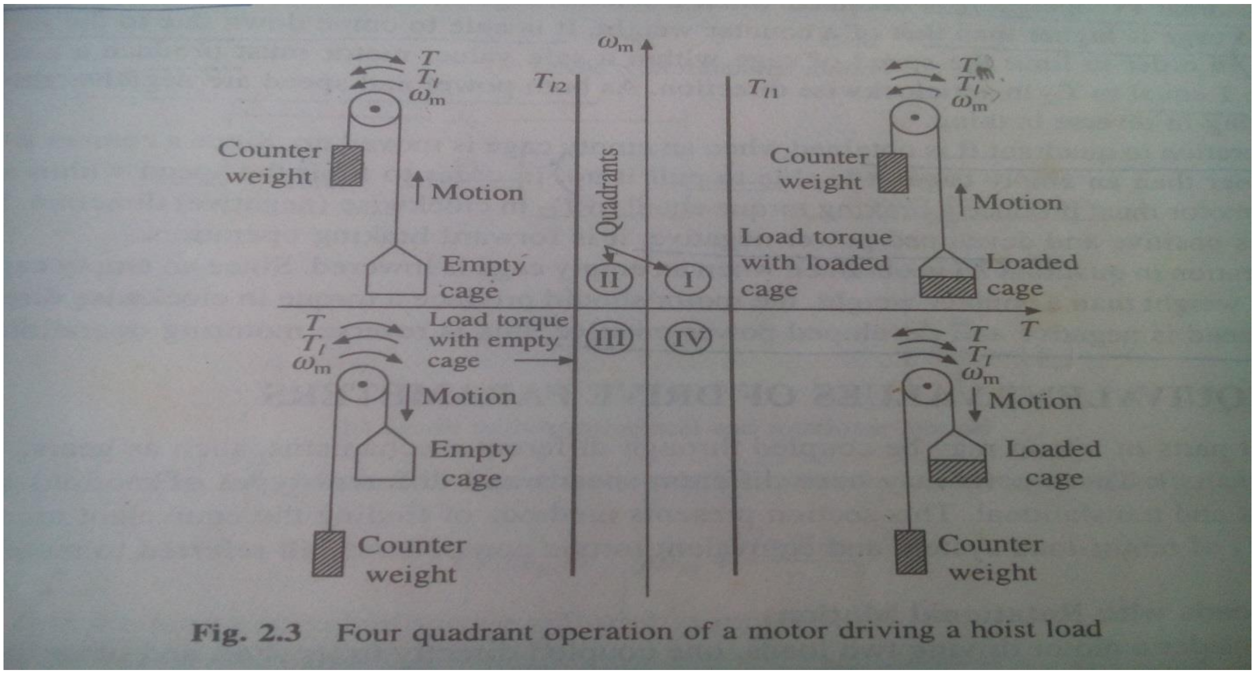



Fig. 2.3 Four quadrant operation of a motor driving a hoist load

The quadrant-I operation of a hoist requires the movement of the cage up-word which corresponds to the positive motor speed which is anti-clock wise direction. If motor produces positive torque in anti-clock wise direction equal to the magnitude of the load torque $T_{l.}$ . Since developed motor power is positive, for-word motoring operation.

Quadrant-IV operation is obtained when loaded cage is lowered. Science the weight of a loaded cage is higher than that of a counter weight. It is able to come down due to the gravity it self and produce a positive torque $T_l$ in anti-clock wise direction. As both power and speed are negative, drive is operating is reverse braking.

Quadrant-II An empty cage is moved up since a counter weight is heavier than empty cage it is able to pull it up motor for produce a braking torque $T_l$ in clock wise direction. Science speed is positive and developed torque is negative.

Quadrant-III An empty cage is lowered since an empty cage has a lesser weight than a counter weight. The motor should produce a torque in anti clock wise direction. Science speed is negative & developed power positive is reverse motoring operation.

## Constant torque & constant power operation:-

**D C Motor**

- **Separately excited DC motor:-** Separately excited d c motor load torque $T_l$ oppose the electromagnetic torque Te. For field circuit-

$$V_f = I_f \; R_f$$

for armature circuit

$$V_t = E_a + I_a R_a$$

Motor back e.m.f. or motor armature e.m.f.

$$E_a = K_a \phi \omega_m$$

$$T_e = K_a \phi I_a = K_m I_a$$

$$T_e = \frac{dw}{dt} + T_l$$

Electromagnetic power

$$P = \omega_m T_e$$

$$E_a = K_m \omega_m = V_t - I_a R_a$$

$$\omega_m = (V_t - I_a R_a) / K_m = (V_t - I_a R_a) / K_a \phi \qquad \text{.... I}$$

In above equation shows that speed can controlled by varying – (i) Armature terminal voltage

(ii) Field flux.

Armature voltage control method is also termed as constant torque drive method because motor torque $T_e = K_a \phi I_a$ remains almost constant. As flux decrease speed increase so that motor emf $E_a$ remains constant is also called constant power drive method. P = ($E_a I_a$)

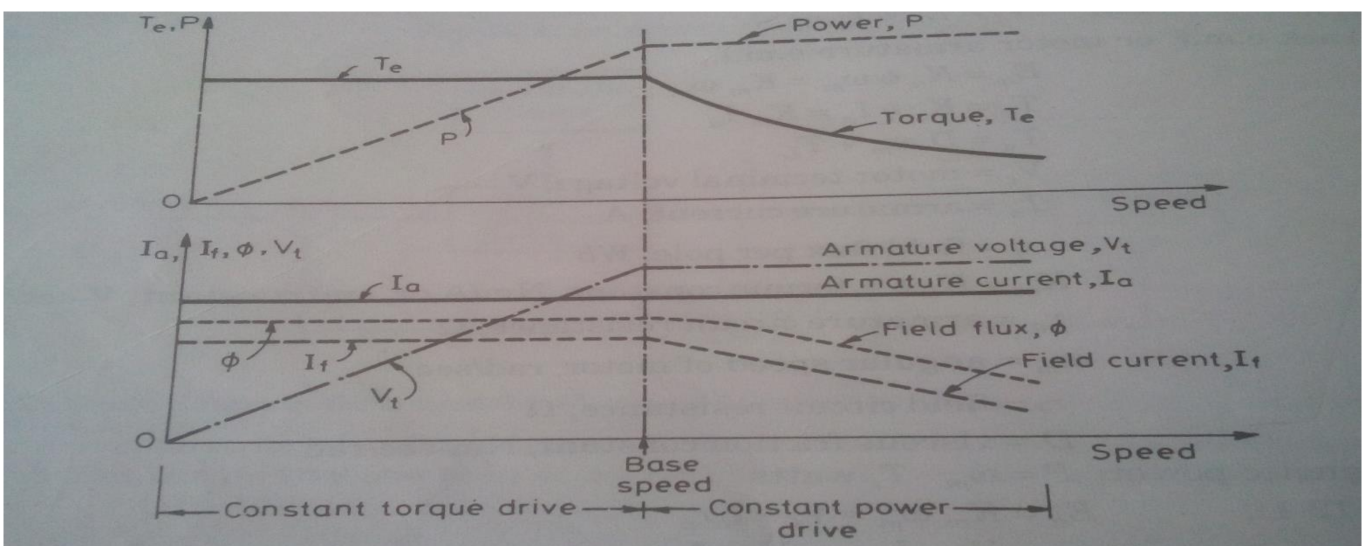



Fig. 12.4. Characteristics of a separately-excited dc motor.

- **D C Series Motor**: **-** In dc series motor, field winding I series with the armature circuit is designed to carry the rated armature current.

$$\mathbf{V}_t = E_a + I_a\,(r_a + r_s) \qquad (\, r_s \text{ – series field resistance }\,)$$

$$T_e = K_a\,\phi\,I_a$$

at no saturation in magnetic circuit

$$\phi = c\,I_a$$

$$T_e = K_a\,c\,I_a^2 = K\,I_a^2$$

$$E_a = K_a\,\phi\,C = K_a\,c\,I_a\,\omega_m = K\,I_a\,\omega_m$$

$$\omega_m = \frac{[Vt - Ia\,(\,ra + rs)]}{K\,Ia}$$

$$\omega_m = (V_t\,/\,K\,I_a\,) - (\,r_a + r_s\,)\,/\,k$$

When $V_t$ is varied with constant $I_a$. Therefore $P = V_t\,I_a$ varies linearly & torque $Te = K\,I_a^2$ remains constant.

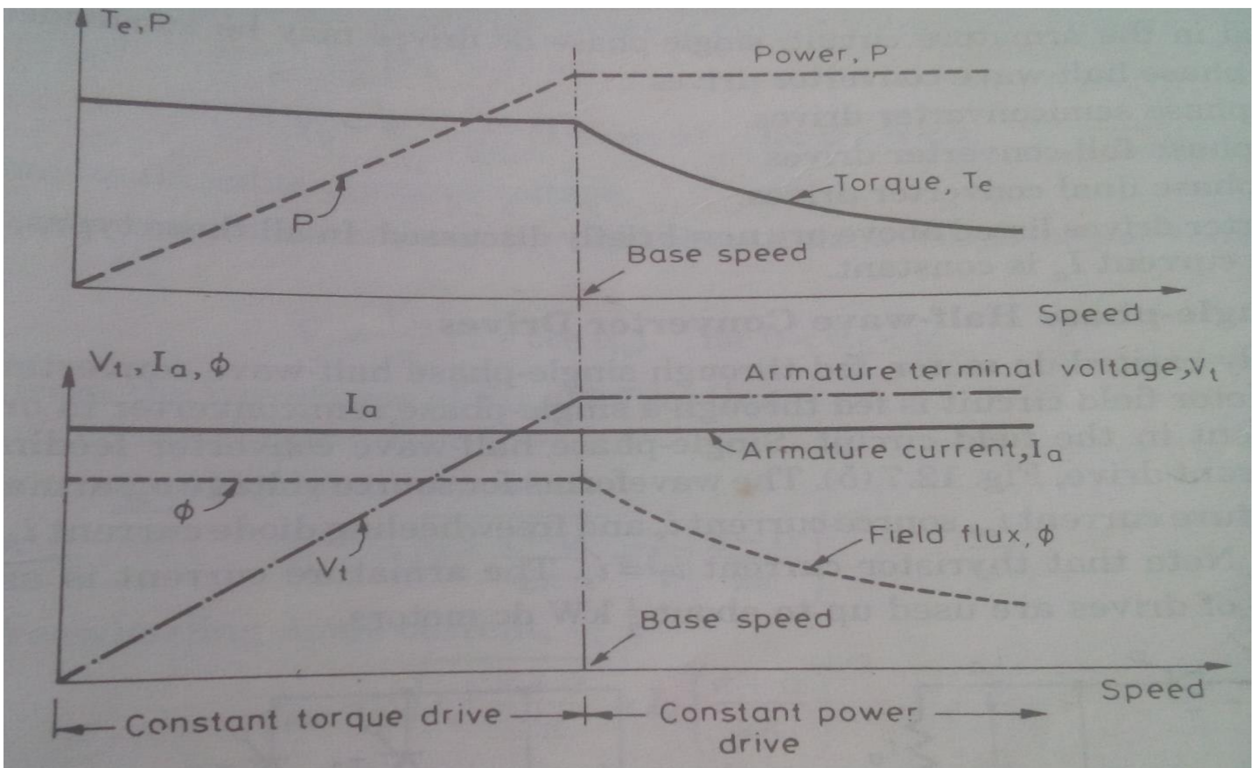



Fig. 12.5. Characteristics of a dc series motor.

**Synchronous Motor: -** synchronous motor field excitation system , the excitation e.m.f. $E_f$ is directly proportional to the supply frequency . The synchronous reactance $X_s$ is also directly proportional to frequency.

$$P_{max} = \frac{E_f V_t}{X_s}$$

$$T_{em} = \frac{1}{w_s} \frac{E_f V_t}{X_s}$$

In above equation $E_f$ / $X_s$ is independent of frequency variation. If supply frequency $V_t$ is varied is proportional to frequency so that V / F or $V_t$ / $w_s$ is constant then pull out torque remains constant.

Pull out power $P_{max} = T_{em} w_s$ is constant.

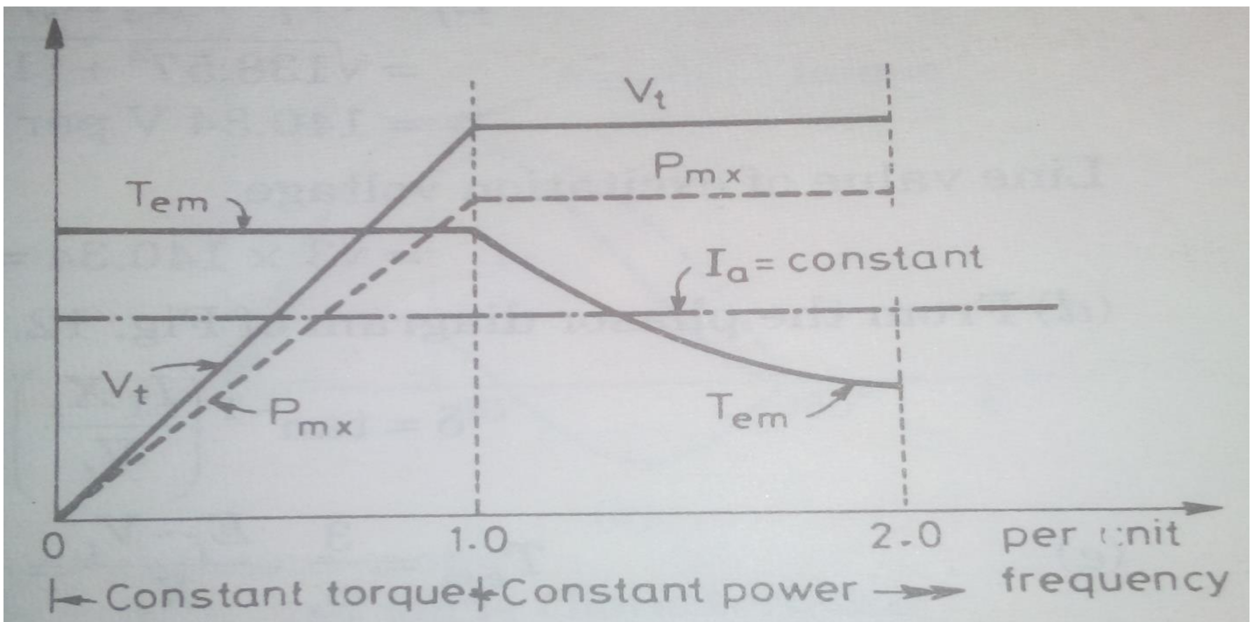



**Fig. 12.47. Variation of pull-out torque, pull-out power, terminal voltage and armature current with frequency for a synchronous motor.**

**Induction Motor**:- The torque & power variation for a given stator current and for frequencies below and rated frequency . When the stator current maximum permissible value , these will represent the maximum torque and power capabilities of the motor in variable frequency control.

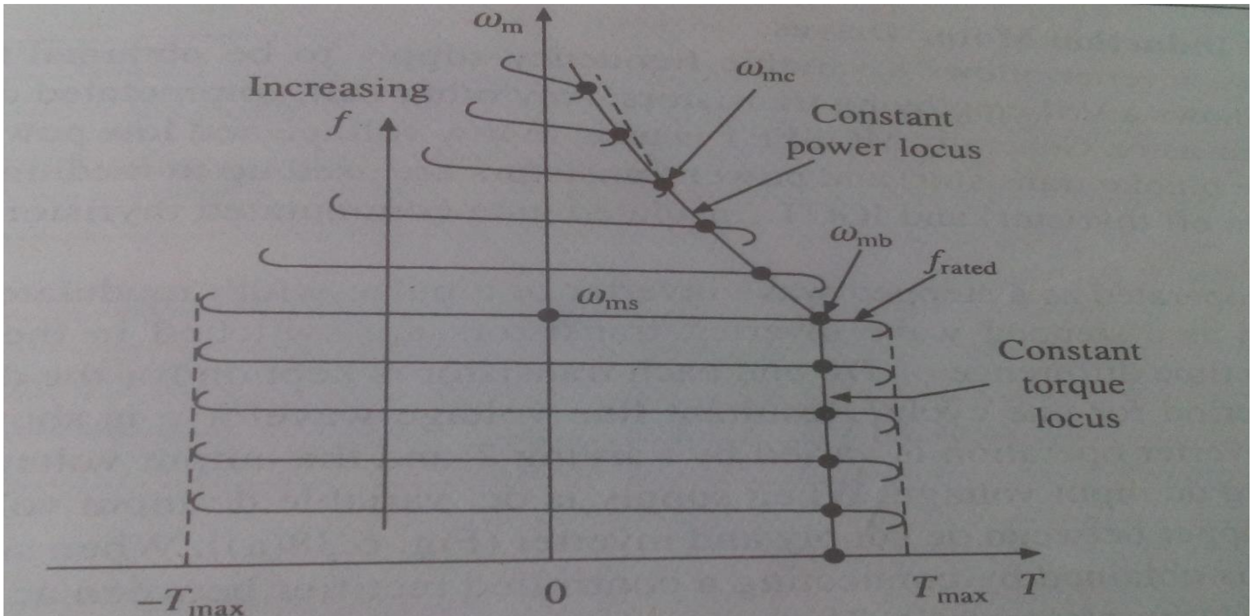
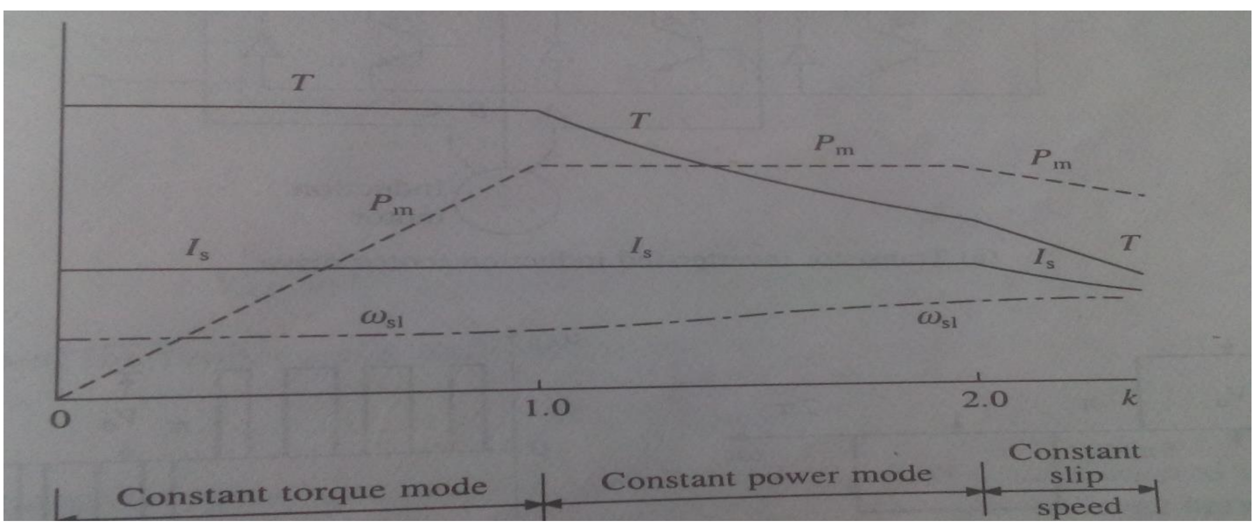



**Fig. 6.35** Modes of operation and torque and power limits

The motor has a constant torque maximum torque from zero to base speed $\omega_m$, hence drive operates in constant torque mode.



**Components of load torques: -** load torque $T_l$ can be further divided in to following components-

**(i) Friction torque ($T_F$):-** Friction will be present at the motor shaft also in various part of the load . Friction torque is equivalent value of various frictions torques referred to the motor shaft.

**(ii) Windage Torque ($T_w$):-** When a motor runs , wind generates a torque opposing the motions . This is known as windage torque.

Windage torque $T_w$, which is proportional to speed squared is given by-

$$T_w = C\,\omega_m^2$$

**(iii) Torque required doing the useful mechanical work ($T_L$):-** Nature of this torque depends on particular application. It may be constant and independent of speed and load. It will time variant or invariant.

Viscous friction is given by – $T_V = B\,\omega_m$

Then the finite speeds-

$$T_l = T_L + B\,\omega_m + T_c + C\,\omega_m^2$$

($T_c + C\,\omega_m^2$) is very small compared to $B\,\omega_m$ then

$$T_l = T_L + B\,\omega_m + J\,\frac{dw}{dt}$$

If transnational shaft coupling the load to the motor, an additional component of load torque, known as coupling torque will be present. Coupling torque ($T_c$) is given by

$$T_C = K_e\,\Theta_e \qquad \text{Where } \Theta_e = \text{Torsion angle}$$

## Nature and classification of load torque:-

The nature of load torque depends on particular application. A low speed hoist is an example of a load where the torque is constant and independent of the speed. At low speed, windage torque is negligible. Therefore, net torque is mainly due to gravity which is constant and independent of speed.

Fan , compressors, areoplane, centrifugal pumps, ship-propellers, high speed traction hoists are example of the case of load torque is function of speed. In fans, compression and aero plane the windage dominates, consequently, load torque is proportional to speed squared. Shown in fig.

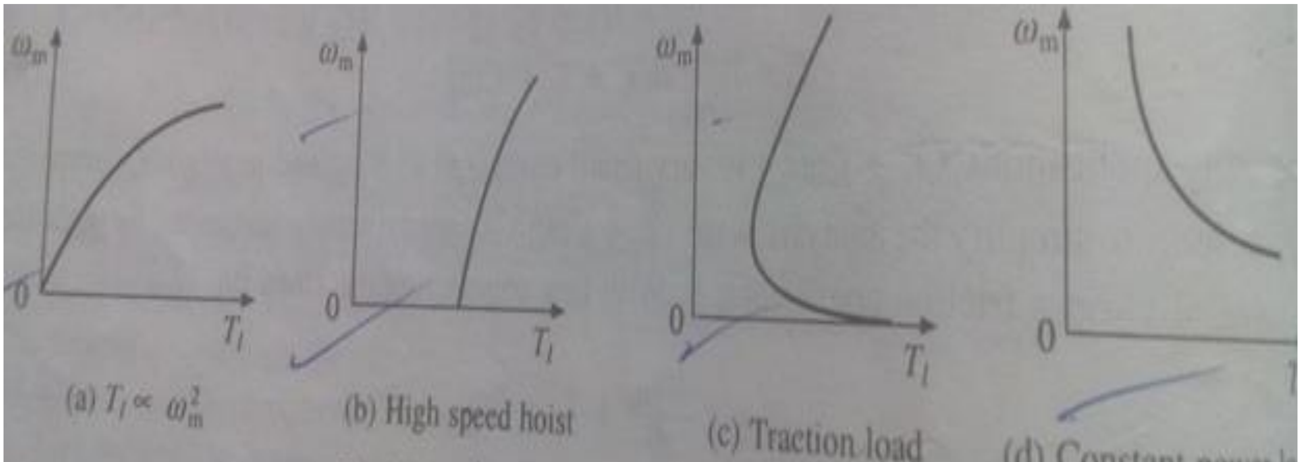



Fig. 2.7 Steady state load torque speed curves

In high speed hoist, viscous friction and windage also have appreciable magnitude, in addition to gravity shown fig b. Nature of speed torque characteristics of a traction load when moving an a leveled ground in fig c. Because of its heavy mass, the striation is large , near to zero speed net torque due to striation.

Torque in a coiler drive is also a function of speed. If is approximately hyperbolic in nature shown in fig d.