EE8601 Solid state drives

UNIT-1 DRIVE CHARACTERISTICS

Page No.:

1. Equivalent moment of Inertia & Torque Rotational Motion & Translational Motion.

Rotational Motion :.

Load with rotational Motion, It Consist of motor, two load and gears, the motor driving two loads. one load is directly Connected to shaft and other one through Gear with n and n_1.

$$\text{Gear teeth Ratio } a_1 = \frac{n}{n_1} = \frac{W_{m1}}{W_m}$$

Kinetic Energy is equal to Kinetic Energy Various parts

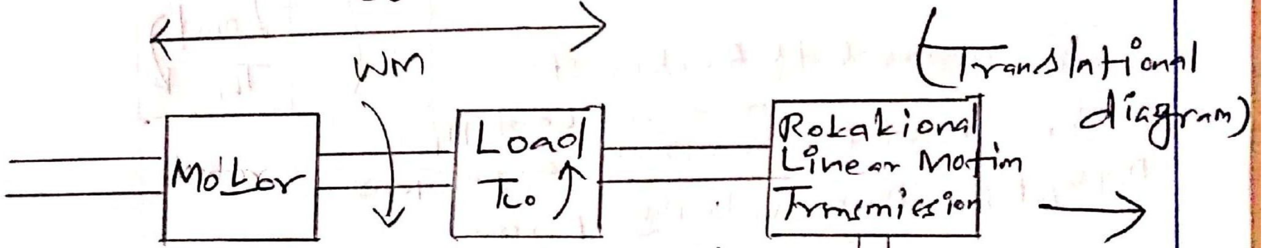
$$\frac{1}{2} J W_m^2 = \frac{1}{2} J_0 W_m^2 + \frac{1}{2} J_1 W_{m1}^2$$

$$J W_m^2 = J_0 W_m^2 + J_1 W_{m1}^2$$

$\div W_m^2$

$$\frac{J \cancel{W_m^2}}{\cancel{W_m^2}} = \frac{J_0 \cancel{W_m^2}}{\cancel{W_m^2}} + \frac{J_1 W_{m1}^2}{W_m^2}$$

J_0

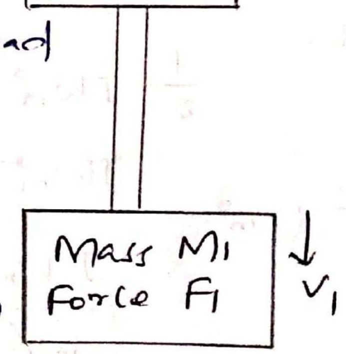


J_0 - moment of Inertia of motor and load

W_m - Motor Speed

T_{L0} - Load torque

J_1 - Moment of Inertia of the load Connected to gear



W_{m1} - Speed of the load Coupled through Gear

T_{L1} - Load torque (directly Connected to Gear)

$$J = J_0 + J_1 \frac{W_{m1}^2}{W_m^2} \qquad a_1 = \frac{W_{m1}}{W_m}$$

$$J = J_0 + a_1^2 J_1$$

power at the Motor $= T_L \times W_m$

power at th load $= T_{L0} \times W_m$

Power at Load $T_1 = \frac{T_{L1} \times \omega_{m1}}{\eta_1}$

power at load & motor must be equal

$$T_L \omega_m = T_{Lo} \times \omega_m + \frac{T_{L1}\omega_{m1}}{\eta_1}$$

$\div$ equation ω_m

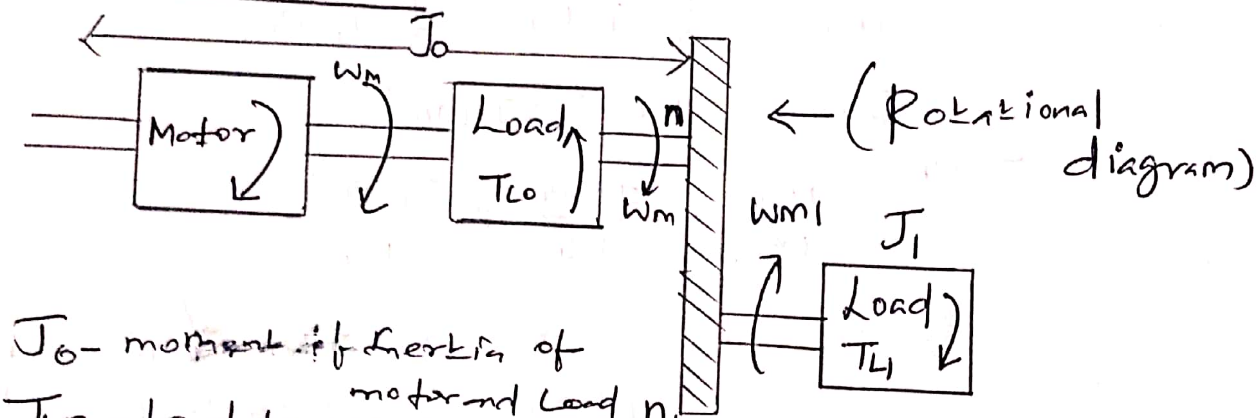
$$\frac{T_L \cancel{\omega_m}}{\cancel{\omega_m}} = T_{Lo}\frac{\times \cancel{\omega_m}}{\cancel{\omega_m}} + \frac{T_{L1}\omega_{m1}}{\eta_1 \omega_m}$$

$$T_L = T_{Lo} + \frac{T_{L1}}{\eta_1} a_1$$

$$J = J_o + a_1^2 J_1 + a_2^2 J_2 + \dots + a_n^2 J_n$$

$$T_L = T_{Lo} + \frac{a_1 T_{L1}}{\eta_1} + \frac{a_2 T_{L2}}{\eta_2} + \dots + \frac{a_n T_{Ln}}{\eta_n}$$

Translational Motion:-



J_o - moment of inertia of motor and load

T_{Lo} - load torque directly coupled

M_1, V_1, F_1 - mass, velocity force

Thus

$$\frac{1}{2} J \omega_m^2 = \frac{1}{2} J_o \omega_m^2 + \frac{1}{2} M_1 V_1^2$$

$$J\omega_m^2 = J_o \omega_m^2 + M_1 V_1^2$$

$\div \omega_m^2$

$$\frac{J \cancel{\omega_m^2}}{\cancel{\omega_m^2}} = J_o \frac{\cancel{\omega_m^2}}{\cancel{\omega_m^2}} + M_1 \frac{V_1^2}{\omega_m^2}$$

$$J = J_o + M_1 \left(\frac{V_1}{\omega_m}\right)^2$$

Power at the Motor $= T_L \omega_m$

power at the Load $= T_{Lo} \omega_m$

Power at the transmission $= \frac{F_1 V_1}{\eta_1}$

$$T_L \omega_m = T_{Lo}\omega_m + \frac{F_1 V_1}{\eta_1}$$

$\div \omega_m$

$$\frac{T_L \cancel{\omega_m}}{\cancel{\omega_m}} = \frac{T_{L0} \cancel{\omega_m}}{\omega_m} + \frac{F_1 V_1}{\eta_1 \omega_m}$$

$$T_L = T_{L0} + \frac{F_1}{\eta_1}\left(\frac{V_1}{\omega_m}\right)$$

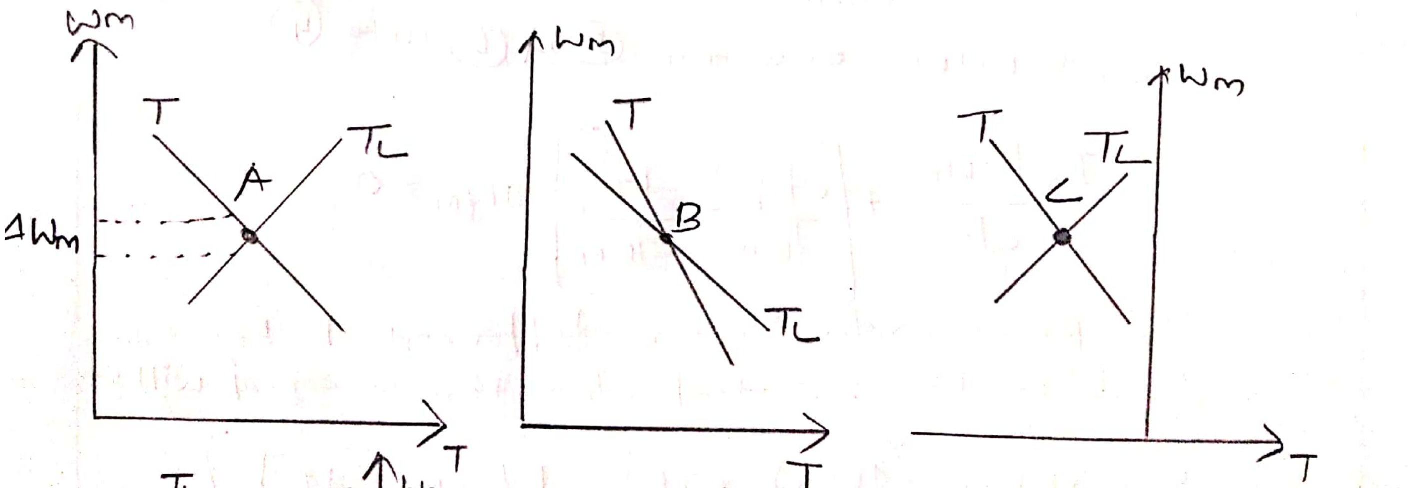
$$\therefore J = J_0 + M_1\left(\frac{V_1}{\omega_m}\right)^2 + M_2\left(\frac{V_2}{\omega_m}\right)^2 + \dots + M_n\left(\frac{V_n}{\omega_m}\right)^2$$

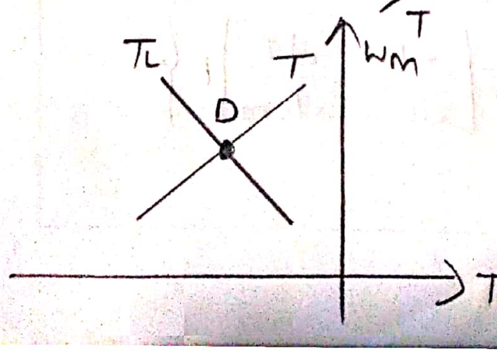
$$T_L = T_{L0} + \frac{F_1}{\eta_1}\left(\frac{V_1}{\omega_m}\right) + \frac{F_2}{\eta_2}\left(\frac{V_2}{\omega_m}\right) + \dots + \frac{F_n}{\eta_n}\left(\frac{V_n}{\omega_m}\right)$$

2. Steady State Stability:

When Motor torque Equals to load torque, equilibrium speed of a motor Load can be achieved At this speed, electric drive system operates in steady state

Also during Transient Conditions, electrical Motor is assumed to be in electrical equilibrium state Steady state speed torque Curves holds good for transient Condition. The electrical time Constant of Motor is negligible in Comparison with mechanical time Constant for many electrical drives.





point 'A' is Stable state, The Motor operation restored after a Small departure during motor & Load disturbances.

When small disturbance $(T > T_L)$ & $(T_L > T)$ the point A operates equilibrium point A.

Condition for stability :. $\frac{dT_L}{d\omega_m} > \frac{dT}{d\omega_m}$

$\Delta\omega_m$ - small perturbation in speed

ΔT - small pertubation in motor torque

ΔT_L - small perturbation in load torque

$$T = T_L + J\frac{d\omega_m}{dt} \quad \text{--- (1)}$$

$$(T + \Delta T) = (T_L + \Delta T_L) + J\frac{d}{dt}(\omega_m + \Delta\omega_m) \quad \text{--- (2)}$$

$$T + \Delta T = T_L + \Delta T_L + J\frac{d\omega_m}{dt} + J\frac{d\Delta\omega_m}{dt} \quad \text{--- (3)}$$

Subtract (2) & (3)

$$\frac{J\,d\Delta\omega_m}{dt} = \Delta T - \Delta T_L \quad \text{--- (4)}$$

$$\therefore \Delta T = \frac{dT}{d\omega_m}(\Delta\omega_m) \quad \text{--- (5)}$$

$$\Delta T_L = \frac{dT_L}{d\omega_m}(\Delta\omega_m) \quad \text{--- (6)}$$

Substitute equation (5) & (6) into (4)

$$J\frac{d\Delta\omega_m}{dt} + \left[\frac{dT_L}{d\omega_m} - \frac{dT}{d\omega_m}\right]\Delta\omega_m = 0$$

Is first order linear differential equation

At time $t=0$, Intial deviation in speed will be

$$\Delta\omega_m = (\Delta\omega_m)_0 \exp\left\{-\frac{1}{J}\left[\frac{dT_L}{d\omega_m} - \frac{dT}{d\omega_m}\right]t\right\}$$

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3. Typical Load torque Characteristics:

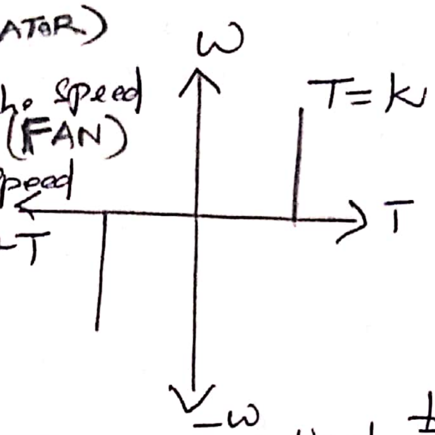
(i) Constant torque type

(ii) Torque proportional to speed (GENERATOR)

(iii) Torque proportional to square of the speed (FAN)

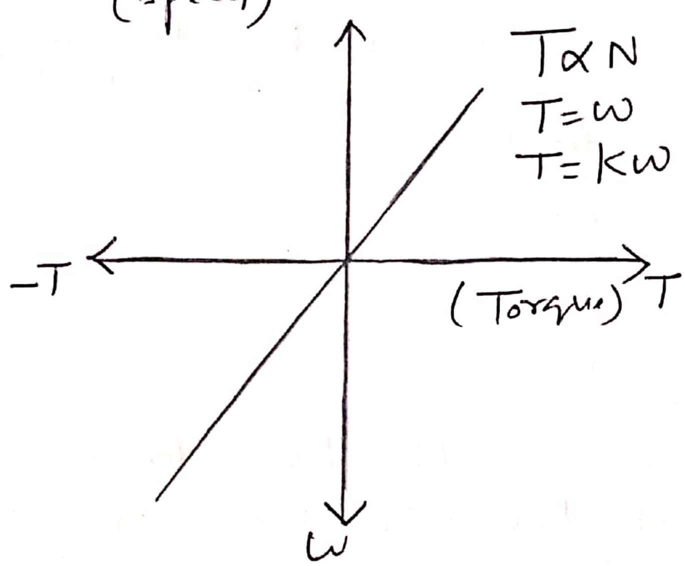
(iv) Torque Inversely proportional to speed (Constant POWER TYPE)

(i) Constant torque type $(T = k)$



(ii) Torque proportional to speed:

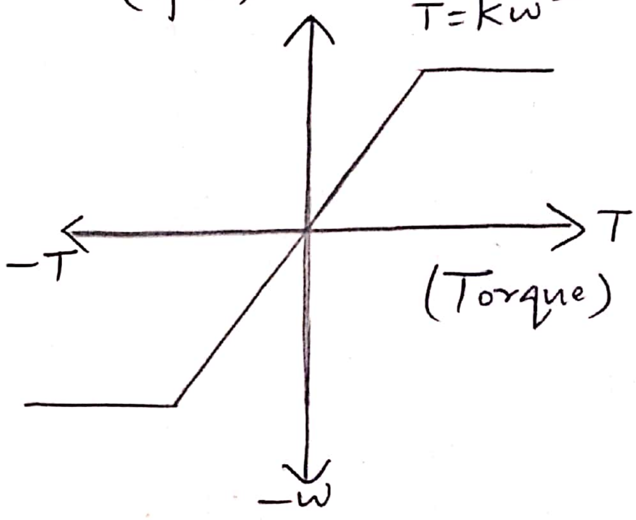
$(T \propto \omega)$



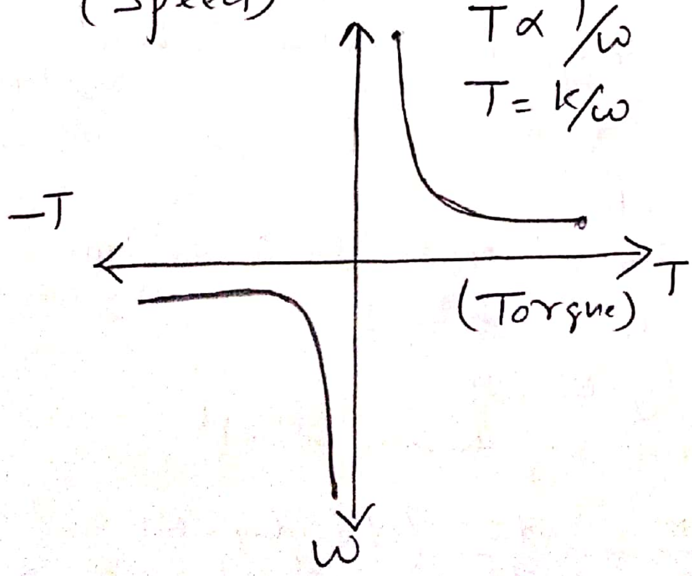
(iii) Torque proportional to square of speed

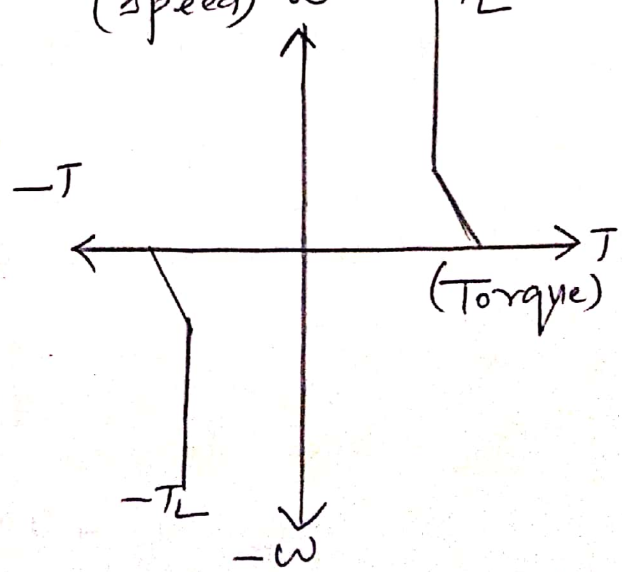
$(T \propto \omega^2)$

$T = k\omega^2$



(iv) Torque Inversely proportional to speed: $(T \propto 1/\omega)$





4. Selection of Electric drive:

(i) Duty cycle, Speed Range, Speed Regulation, Efficiency, Nature of S-T charracteristics, Speed fluctuations, Quadrants of operation are the requirements for Steady State operation

(ii) Performance during Starting, Braking, reversing Conditions and Acceleration & DeAcceleration values are the requirements for transient operation.

(iii) Source requirements

AC/DC Source, voltage Magnitude, voltage fluctuations, line Hermonics, I/p PF.

(iv) Capital Cost, Running Cost, durability, Maintenance Needs.

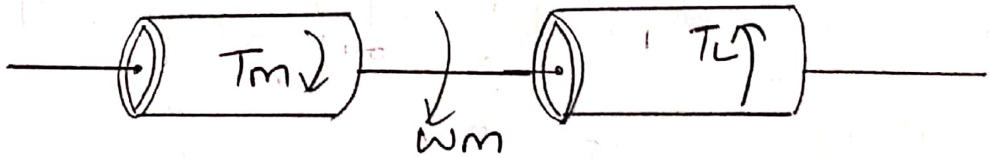
(v) Location and Envirnomental factors

(vi) Weight and Space Restrictions

(vii) Reliability

Fundamental Torque Equation:

The motor always rotates, but the load donot undergo rotational Motion all the time. The load may Undergo a transltional motion (or) either Undergo a rotational Motion.



Fundamental Torque Equation Motor - Load System

$$T_m = T_L + \frac{d(J\omega_m)}{dt}$$

J - Polar moment of Inertia of Motor load system kg-m²

Wm - Angular velocity of motor shaft

Tm - Torque developed by Motor

TL - Load torque developed by Motor shaft

$$T_m = T_L + J\frac{d\omega_m}{dt} + \omega_m\frac{dJ}{dt} \quad \left(\text{For Constant Inertia } \frac{dJ}{dt} = 0\right)$$

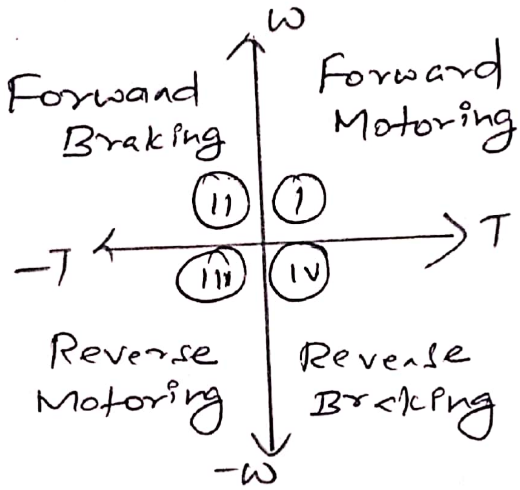
$$T_m = T_L + J\frac{d\omega_m}{dt}$$

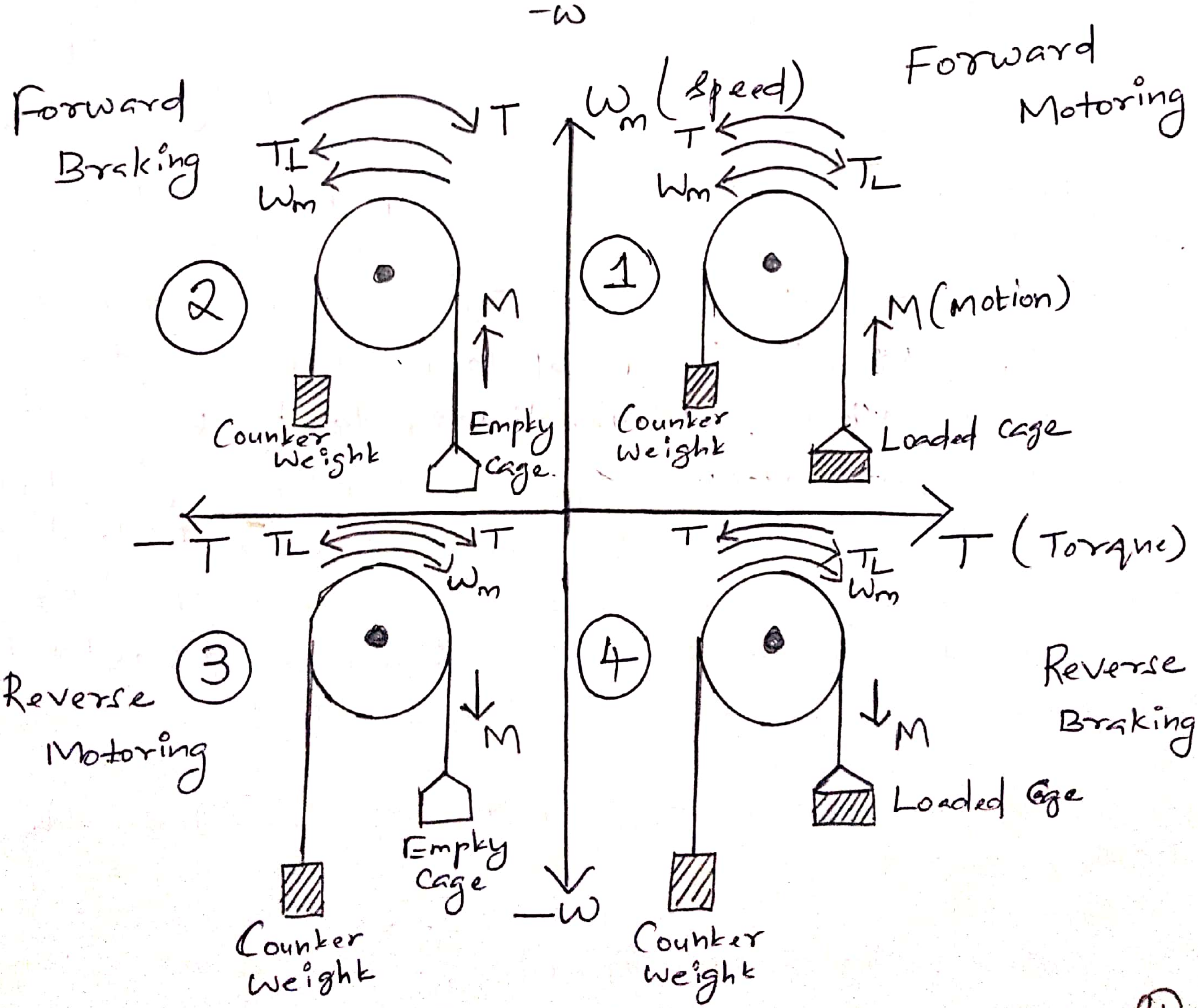
5. Multi Quadrant operation of drive System:-

Speed and torque characteristics of electrical drive System.

In Motoring Mode – Electrical Energy Converted to Mechanical Energy

In Braking Mode – Mechanical Energy Converted to Electrical Energy





Power developed by Motor = Speed X Torque

I^{st} Quadrant – Forward Motoring – power developed positive, speed positive

II^{nd} Quadrant – Forward Braking – Power Negative, Speed positive

III^{rd} Quadrant – Reverse Motoring – power positive, Speed Negative

IV^{th} Quadrant – Reverse Braking – power and speed Negative

Let us Consider the operation of a Hoist. A Hoist Comprises of rope wound on a drum which is Coupled to the shaft of the Motor.

Note:

Weight of the Counter weight > Weight of Empty Cage

Weight of the Counter weight < Weight of a Fully Loaded cage

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6. A Motor drives two Loads. One has rotational Motion. It's Coupled to motor through a reduction gear with a=0.1 and Efficiency 90%. The load has moment of Inertia of 10 kg-m² & torque of 10 Nm. other load has translational Motion and Consist of 1000 kg weight to be lifted upto a Uniform Speed of 1.5 m/s. Coupling b/w the load and motor has an Efficiency of 85%. Motor has an Inertia of 0.2 kg-m² and runs at a Constant speed of 1420 rpm. Determine equivalent Inertia referred to the motor shaft and power developed by the Motor.

Total Moment of Inertia referred to the Motor shaft.

$$J = J_0 + a_1^2 J_1 + M_1\left(\frac{V_1}{W_m}\right)^2$$

$J_0 = 0.2\,kg\text{-}m^2$, $a_1 = 0.1$, $J_1 = 10\,kg\text{-}m^2$

$n = 1.5\,m/s$

$$W_m = \frac{1420 \times \pi}{30} = 148.7\ rad/s$$

$$J = 0.2 + (0.1)^2 \times 10 + 1000\left(\frac{1.5}{148.7}\right)^2$$

$$J = 0.4\ kg\text{-}m^2$$

$$T_L = \frac{a_1 T_{L1}}{n_1} + \frac{F_1}{\eta_1}\left(\frac{V_1}{W_m}\right)$$

$\eta_1 = 0.9$, $\eta_1' = 0.1$

$T_{L1} = 10\,Nm$, $\eta_1' = 0.85$

$F_1 = 1000 \times 9.81$, $n_1 = 1.5\,m/s$

$W_m = 148.7\ rad/s$

$$T_L = \frac{0.1 \times 10}{0.9} \times \frac{1000 \times 9.81}{0.85}\left(\frac{1.5}{148.7}\right)$$

$$T_L = 117.53\,Nm$$

power developed $= T_L W_m = 117.53 \times 148.7$

$$P = 17.48\,kW$$

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7. A drive has following parameters

$T = 150 - 0.1N$, Nm

$T_L = 100\,Nm$

Initially the drive is operating in steady state, The characteristics of the load torque are changed $T_L = -100\,Nm$, Calculate Initial and Final Equilibrium Speeds.

5

(i) Initial Equilibrium Speed :

For steady state

$$T - T_L = 0$$

$$150 - 0.1N - 100 = 0$$

$$0.1N = 50$$

$$N = \frac{50}{0.1} = 500 \text{ rpm} \quad \therefore N = 500 \text{ rpm.}$$

(ii) final Equilibrium Speed :

Characteristics of Load torque changed

$$150 - 0.1N - (-100) = 0$$

$$150 - 0.1N + 100 = 0$$

$$250 - 0.1N = 0$$

$$N = \frac{250}{0.1} = 2500 \text{ rpm}$$

$$\therefore N = 2500 \text{ rpm}$$