EN 206: Power Electronics and Machines

Electric Drives

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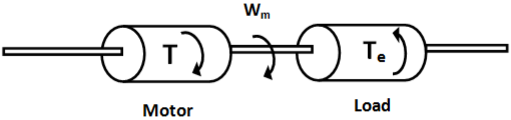
Equation governing drives

- Motor always rotate, the load may rotate or may undergo a translational motion
- Load speed need not be same as motor speed
    - Gear train
    - Translatory motion
- 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 torque developed by motor, N-m.
- Te - Instantaneous load torque referred to motor shaft, N-m

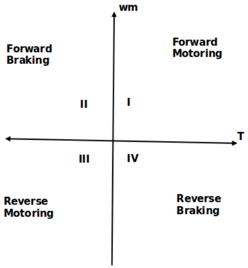


Equation governing drives

- Condition for drive operating point
  - If $T_m > T_L$ - Motor Accelerates
  - If $T_m < T_L$ - Motor Decelerates
- In case of drives In case of drives with large inertia the motor torque must exceed the load torque by a large amount in order to overcome drive inertia. Ex - Electric trains
- In case of drives with fast transient response, motor load system shall be designed for low values of inertia.
- Energy related to this dynamic torque is stored in terms of kinetic energy given by $E = \frac{1}{2}J\omega^2$

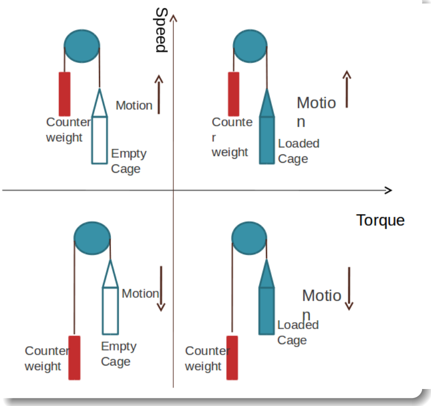
Multi Quadrant operation of Drives

- If the drives operates in one direction, forward speed will be their normal speed
- In drives involving up-down motion, upward direction is considered as forward motion
- If motor torque is negative, it produces deceleration
- Power is proportional to product of speed and torque $P = \omega \times T$



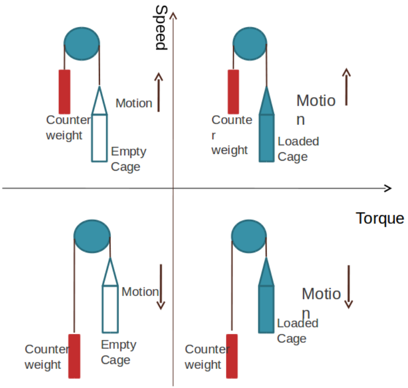
Multi Quadrant operation of Hoist

- Weight : Empty cage < Counter weight < fully loaded cage
- In case of low speed hoist/lift the torque is more or less constant
- Gravitational torque dominates friction and windage torque.
- Gravitational torque doesnt change its direction even if motor direction is reversed.



Multi Quadrant operation of Hoist

- T_{L1} in quadrants I and IV represent speed torque characteristic for the loaded hoist.
- T_{L2} in quadrants II and III represent speed torque characteristic for the empty hoist.
- ω_s s in anticlockwise is considered as forward motion

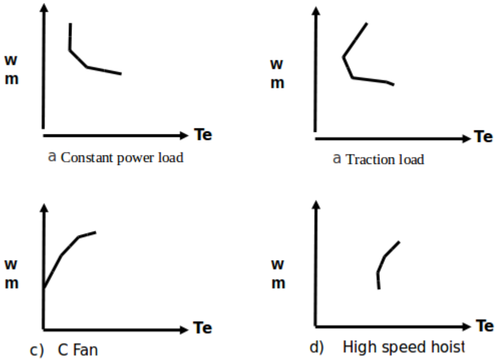


Components of Load Torque

- Components: Friction, Windage, Torque required to do useful work
- Friction at zero speed is called stiction or static friction
  - Coulumb (T_c)+Friction at stand still (T_s)+Viscous Friction ($B\omega_m$)
- Windage torque is proportional to square of speed $T_\omega = C(\omega_m^2)$

$$T_L = T_L + B\omega_m + T_c + C(\omega_m^2)$$

Types of Load Torque



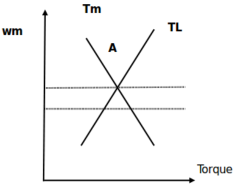
- Paper Mill Drive Torque is independent of speed
- Fans, compressors, centrifugal pump- Torque is functino of speed
- In fans, aeroplane and compressors, windage dominates and hence load torque is proportional to square of speed

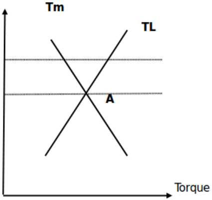
Types of Load Torque

- Load torque which have potential to drive the motor under equillibrium are called active load torque
- Active loads, torque retain their sign even when the direction of rotation changes.
- Load torque which always oppose the motion and change their sign on reversal of motion are called passive load torque.

Stability of Electric Drive

- Equilibrium speed is obtained when load torque is equal to motor torque.
- If due to some disturbance, speed drops by $\Delta\omega_m$, and at this new level, $T_m > T_L$ hence motor acceleration and bring back the system to "A".
- Due to some disturbance speed is increased by $\Delta\omega_m$ and at this new level, $T_L > T_m$ motor decelerates and hence operating port (speed) is shifted to "A"
- The motor is said to be at equilibrium/stable is it retains its portion due to small disturbance in motor or loads.





Condition for stable equilibrium

- A small perturbation in speed, $\Delta\omega_m$ results in ΔT_m and ΔT_L perturbation in T_m and T_L.

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

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

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

For very small perturbation, speed torque can be assumed straight line

Condition for stable equilibrium

$$J\frac{d}{dt}(\Delta\omega_m) = \frac{dT_m}{d\omega_m}\Delta\omega_m - \frac{dT_L}{d\omega_m}\Delta\omega_m$$

Solving first order differential equation:

$$\Delta\omega_m = (\Delta\omega_m)_0 exp[-\frac{1}{J}(\frac{dT_L}{d\omega_m} - \frac{dT_M}{d\omega_m})]$$

As t tends to reach steady state, we expect $\Delta\omega_m$ to be zero i.e., as steady state approaches we expect $\Delta\omega_m = 0$, in order this to happen,

$$\frac{dT_L}{d\omega_m} - \frac{dT_M}{d\omega_m} > 0$$