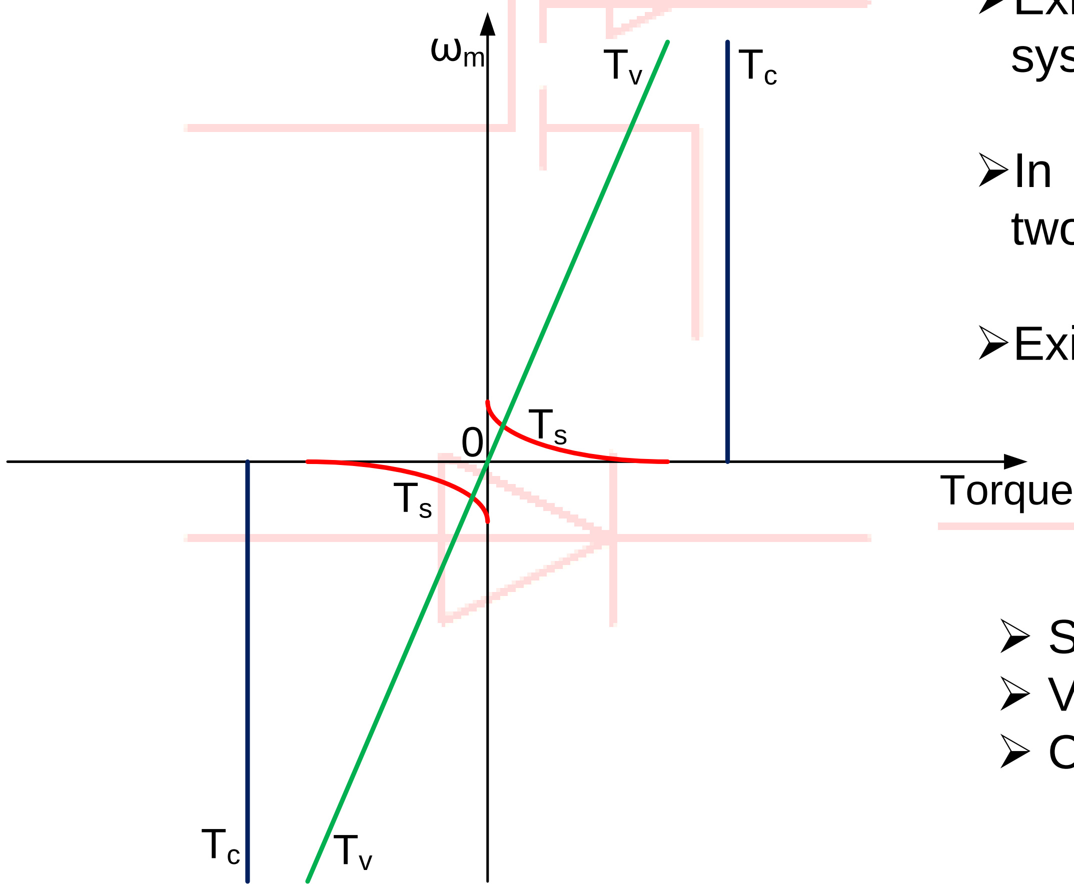
# Electrical Drives

Lecture 3 (08-01-2024)

# Components of Load Torques

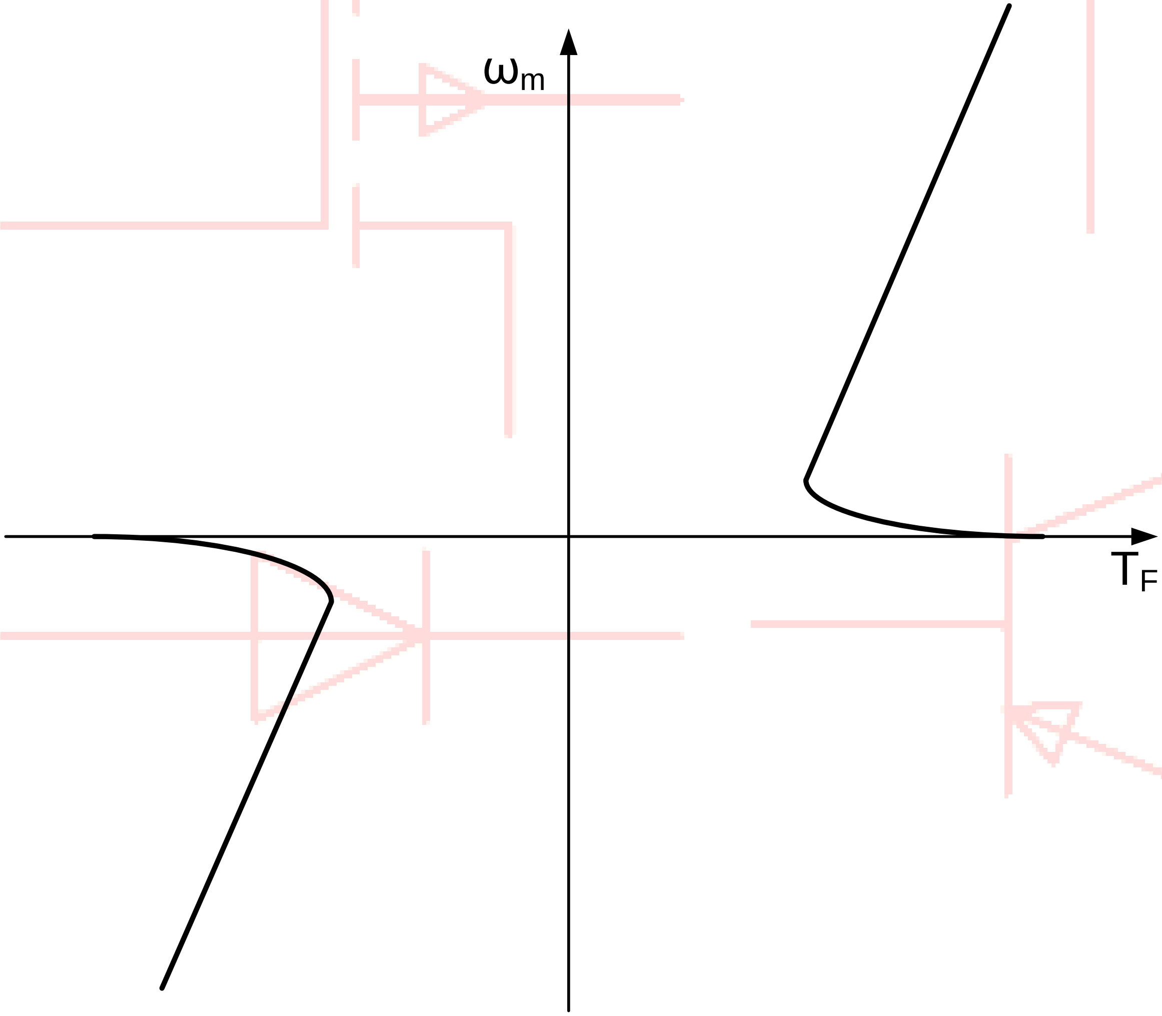
## Frictional torque (passive load) ($T_F$)




- Exist in all motor-load drive system simultaneously
- In most cases, only one or two are dominating
- Exists when there is motion

- Static Friction (Stiction)
- Viscous Friction
- Coulomb Friction

# Components of Load Torques



# Components of Load Torques

- Static Friction (Stiction): Static friction is friction between two or more solid objects that are not moving relative to each other. Ts is present only at stand still. So it is neglected in dynamic analysis.

- Viscous Friction: Component of frictional torque which varies linearly with speed is called viscous friction.

$$\mathbf{T_v = B\omega_m}$$

where B is Viscous Friction Coefficient

- Coulomb Friction: The component of frictional torque which is independent of speed is called Coulomb Friction.

## Components of Load Torques

### Windage Torque ($T_w$)

- When a motor runs, wind generates a torque opposing the motion. So it reflects as a torque opposing the electro magnetic torque developed by the motor.
- Windage torque is proportional to the square of the speed and it can be represented by

$$T_w = C\omega_m^2$$

where C is a constant

### Torque required to do the useful mechanical work($T_L$):

- It depends on the application
- It may be constant and independent of speed
- It may be some function of speed
- It may vary periodically etc.........

# Components of Load Torques

➢ From the above discussion, for finite speeds

$$\mathbf{T_l = T_L + B\omega_m + T_c + C\omega_m^2}$$

In many applications, ( $\mathbf{T_c + C\omega_m^2}$) is very small compared to $\mathbf{B\omega_m}$ and negligible compared to $\mathbf{T_L}$. In other cases, the term ( $\mathbf{T_c + C\omega_m^2}$) is approximately accounted by updating the value of Viscous Friction Coefficient (B).

# Components of Load Torques

If there is torsional elasticity in shaft coupling the load to the motor, an additional component of load torque, known as coupling torque will be present. Coupling torque ($T_{cp}$) is given by

$$\mathbf{T_{cp} = K_e \theta_e}$$

Where $\theta_e$ is the torsion angle of coupling (radians) and $K_e$ the rotational stiffness of the shaft (N-m/rad)

In most applications, shaft can be assumed to be perfectly stiff and Coupling torque ($T_{cp}$) can be neglected. Its presence in appreciable magnitude has adverse effects on the motor.

- There is potential energy associated with coupling torque and kinetic energy with dynamic torque.
- Exchange of energy produce oscillations which are damped by Viscous Friction
- When B is small, oscillations occur producing noise and shaft may break when the drive is started.

# Components of Load Torques

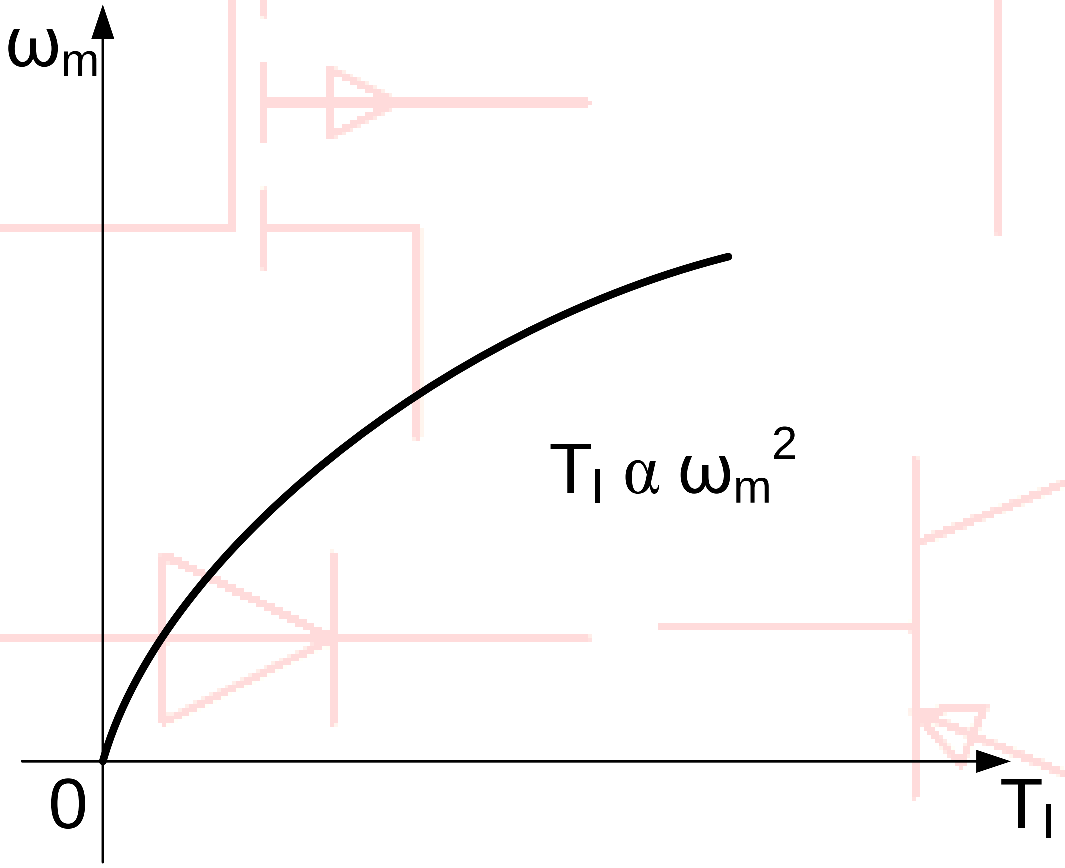
With this approximation , we can write the dynamic torque equation as

$$\mathbf{T_e = J\frac{d\omega_m}{dt} + T_L + B\omega_m}$$

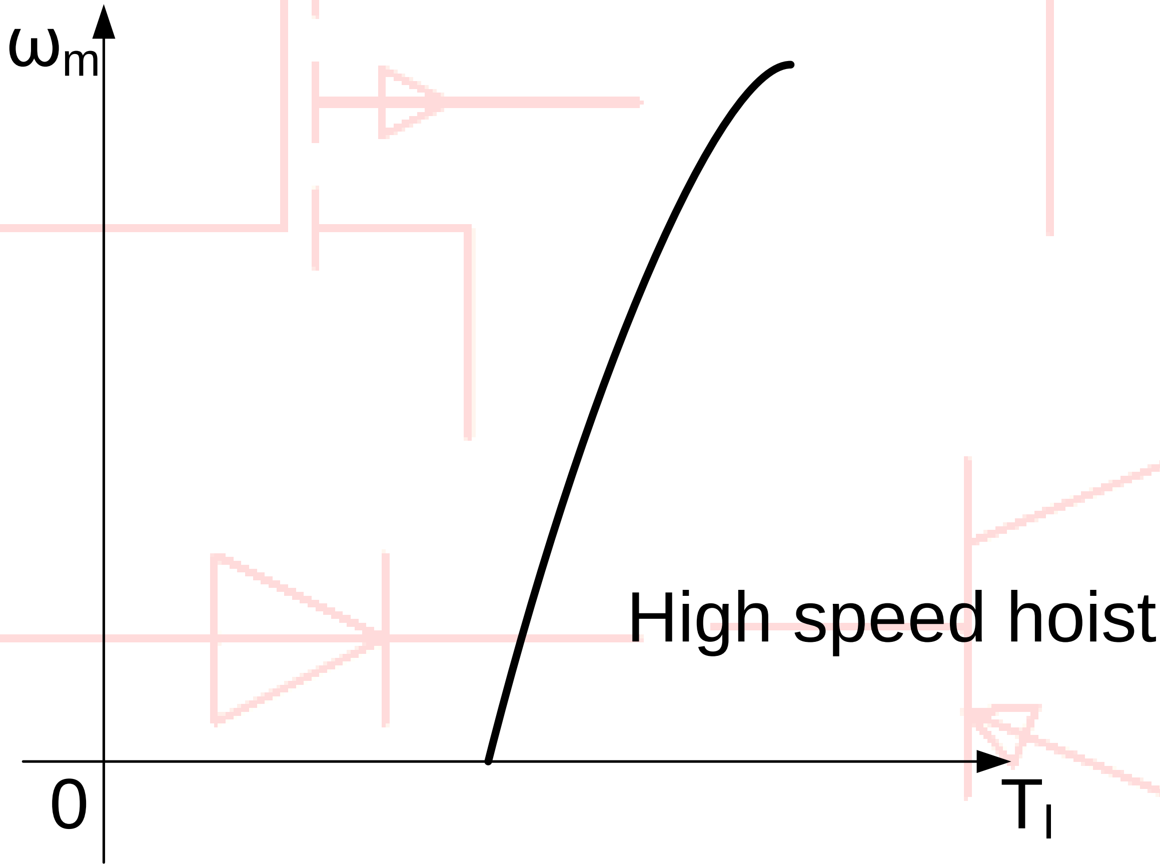
## Nature and Classification of load torques

- Depends on application
- A low speed hoist and paper mills – constant torque independent of speed
- Torque function of speed – fans, compressors, centrifugal pumps, ship-propellors, coilers, high speed hoists, traction etc.
- In fans, compressors and aeroplanes windage torque dominates. So torque is proportional to the square of the speed. Centrifugal pumps and ship-propellors are also examples of this type of load

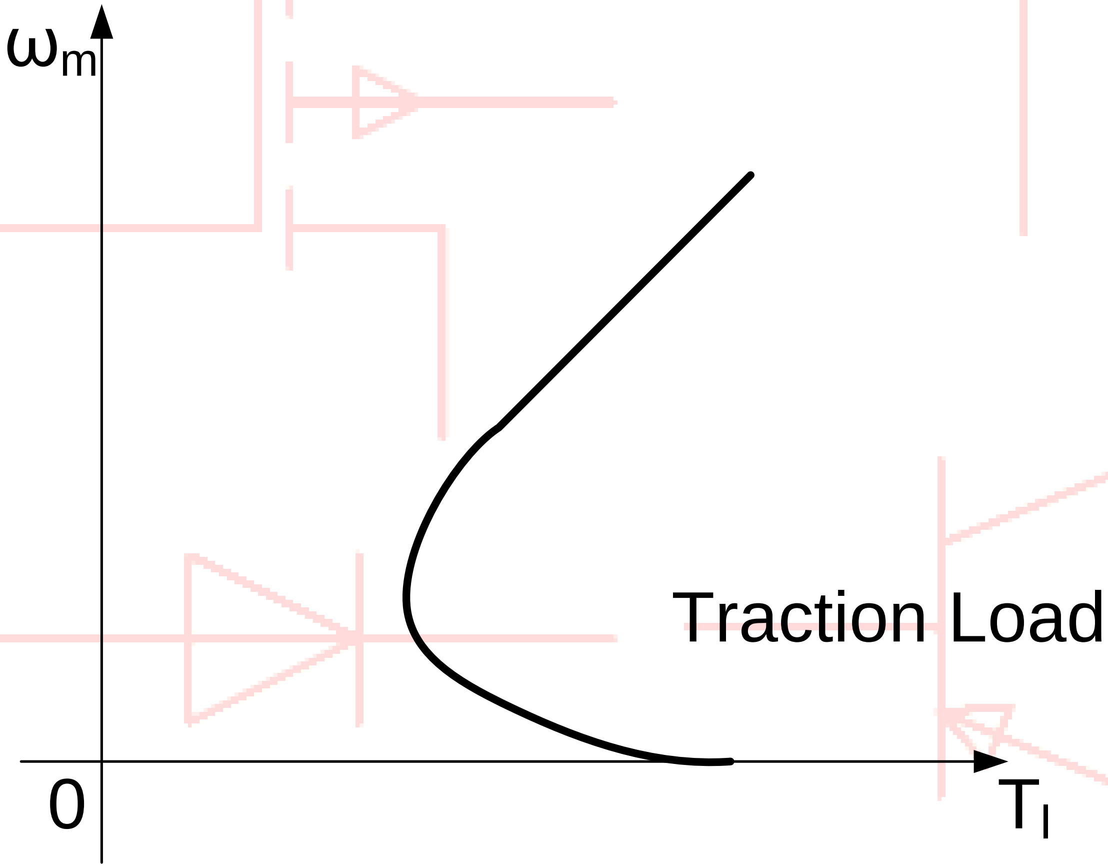
Nature and Classification of load torques



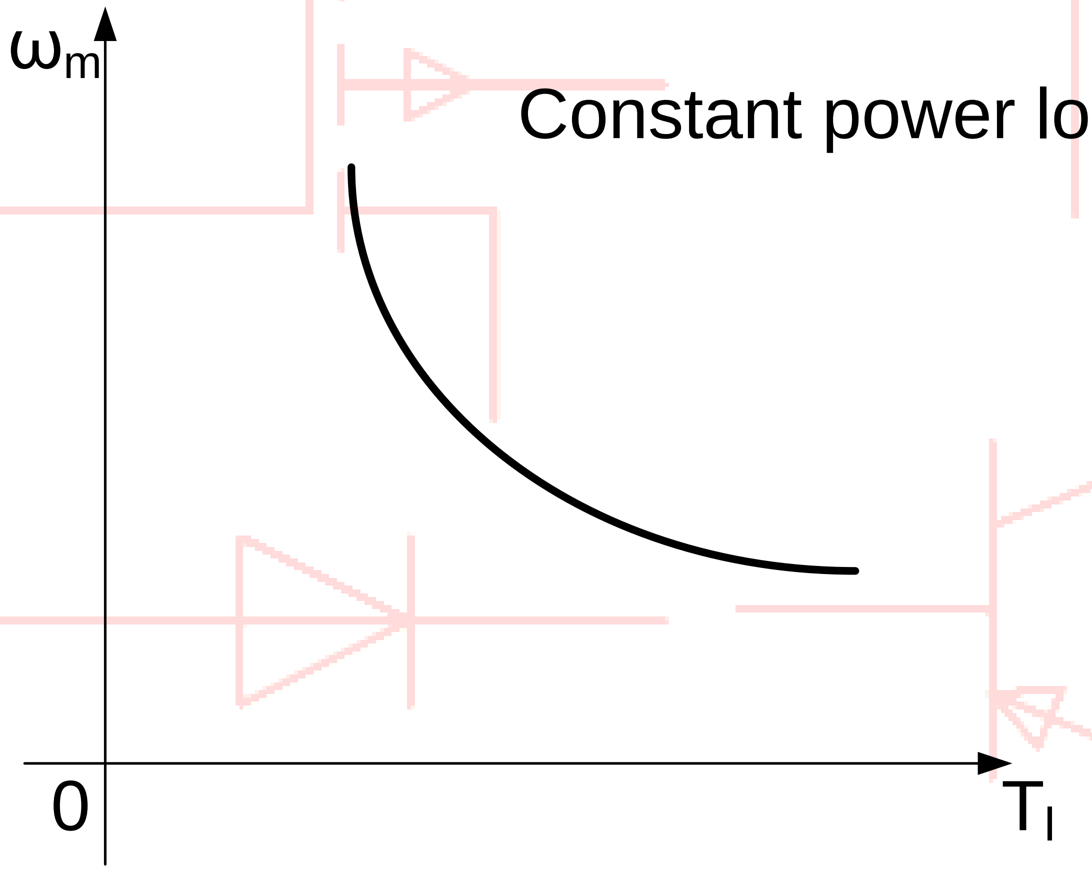
# Nature and Classification of load torques



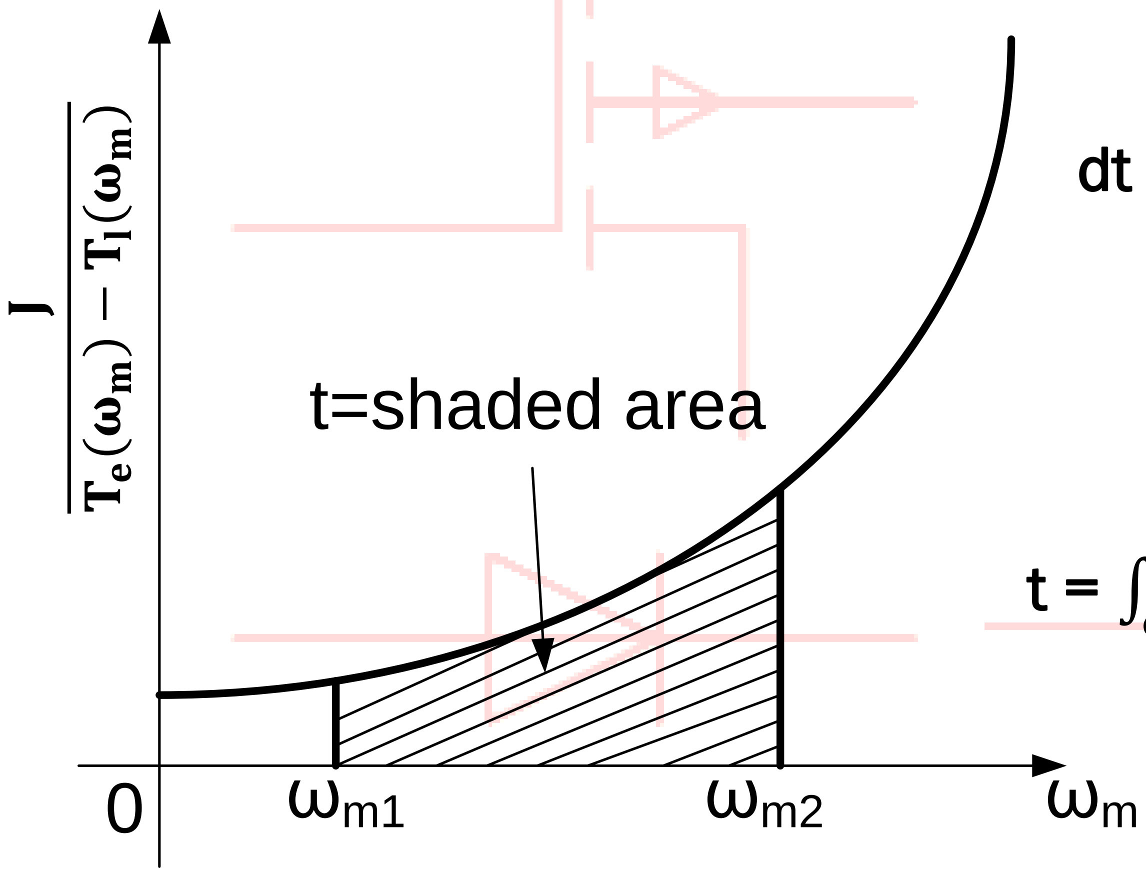
Nature and Classification of load torques



# Nature and Classification of load torques



## Calculation of time and energy loss in transient operations

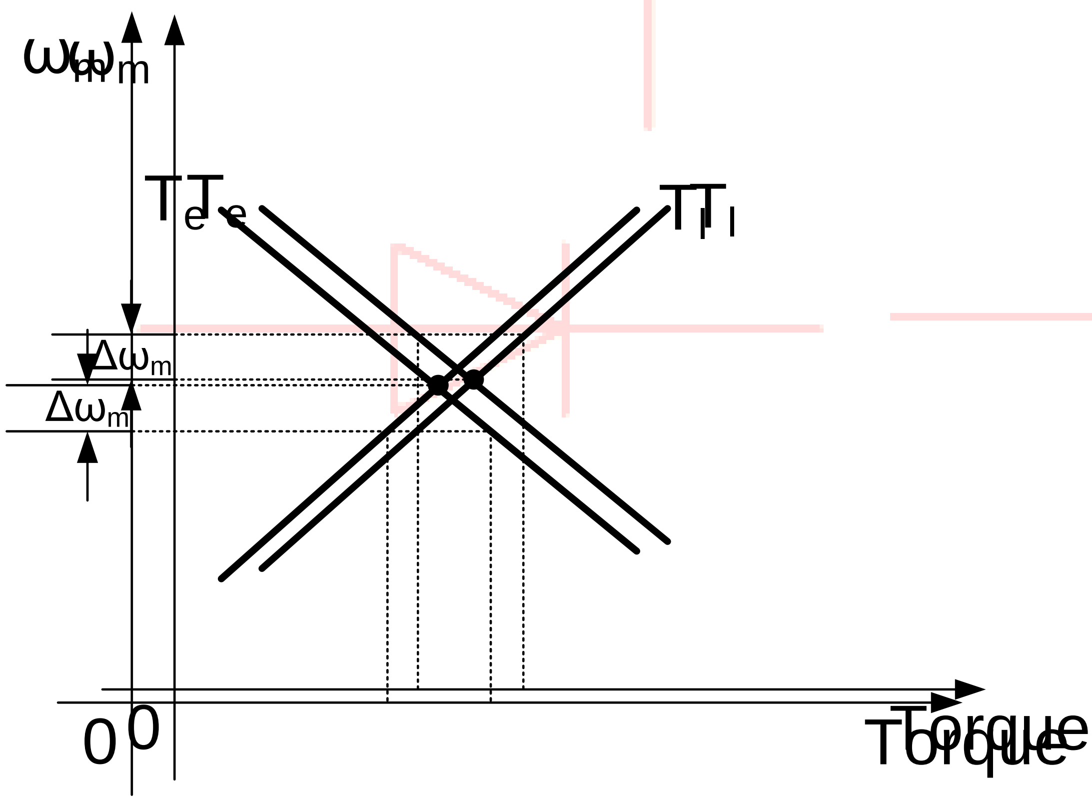



$$dt = \frac{J d\omega_m}{T_e(\omega_m) - T_l(\omega_m)}$$

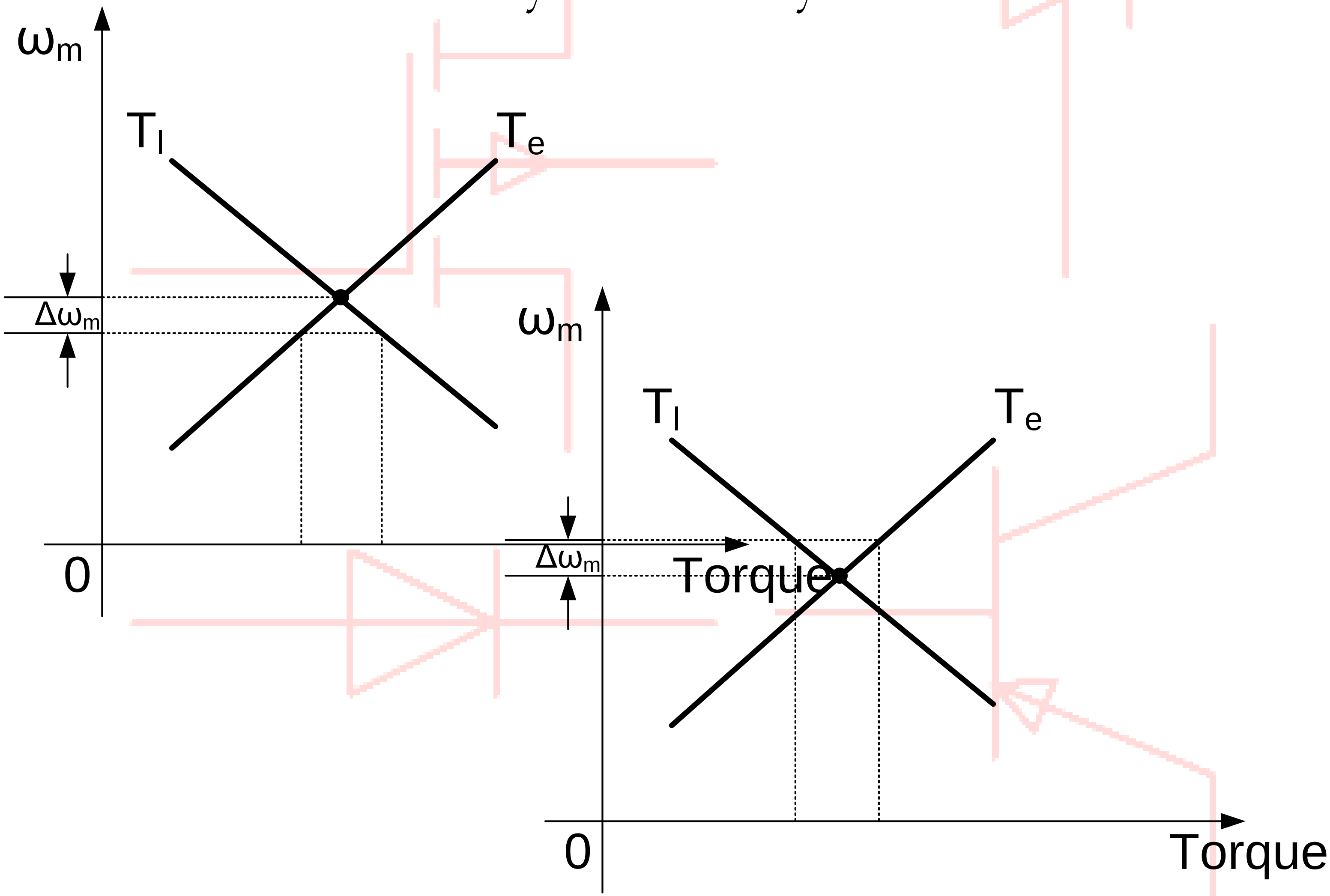
$$t = \int_{\omega_{m1}}^{\omega_{m2}} \frac{J d\omega_m}{T_e(\omega_m) - T_l(\omega_m)}$$

# Steady state stability

- Equilibrium Speed – motor torque equals load torque
- Drive will operate at this equilibrium speed provided it is stable.
- How to find whether the equilibrium point is stable or not?



# Steady state stability



# Steady state stability

**Mathematical derivation – condition for stability**

Let a small perturbation in speed $\Delta\omega_m$ results in $\Delta T_e$ and $\Delta T_l$ change in $T_e$ and $T_l$ respectively

$$(T_e + \Delta T_e) = (T_l + \Delta T_l) + J\frac{d(\omega_m + \Delta\omega_m)}{dt}$$

$$(T_e + \Delta T_e) = (T_l + \Delta T_l) + J\frac{d\omega_m}{dt} + J\frac{d\Delta\omega_m}{dt}$$

$$\Delta T_e - \Delta T_l = J\frac{d\Delta\omega_m}{dt}$$

$$J\frac{d\Delta\omega_m}{dt} + \left(\frac{dT_l}{d\omega_m} - \frac{dT_e}{d\omega_m}\right)\Delta\omega_m = 0$$

Steady state stability

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

$\frac{dT_l}{d\omega_m} - \frac{dT_e}{d\omega_m}$ needs to be positive

$$\frac{dT_l}{d\omega_m} > \frac{dT_e}{d\omega_m}$$

is the condition for steady state stability

For a Motor-Load system with motor and load torques $1+2\omega_m$ and $3\omega_m^{0.5}$ respectively, obtain the equilibrium points analytically and graphically. Determine the steady stability of these equilibrium points.