Electrical Drives

Lecture 4 (09-01-2024)

Course Outcomes

- **CO1:** To develop capability to choose a suitable Motor and Power Electronic Converter package from a description of drive requirement – involving load estimation, load cycle considerations, thermal aspects and motor-converter matching
- **CO2:** To learn about various DC and AC machines used in drives.
- **CO3:** To Acquire detailed knowledge of Electrical Motor operation using generalized machine theory.
- **CO4:** To select converters required for Electrical Drives and design controllers for them.

Assessment Plan

- **Midterm Test** : Portions covered before Midterm **Test**. {35 Marks}
- **Project/Simulations** : n*** {10 Marks}
- **Assignments** : 4 {05 Marks}
- **End Semester Exam** : All portions covered in the course. {50 Marks}
- **Grading** : Relative

- ***** It is based on your interest…………….**

Steady State Stability

- We have to consider two types of disturbance

  - Changes from the state of equilibrium take place slowly and the effect of either the inertia of the rotating mass or that of inductance is insignificant.

  - Sudden and fast changes from the equilibrium state, as a result of which the effect of neither the inertia of the rotating mass nor the inductance can be ignored

Transient Stability

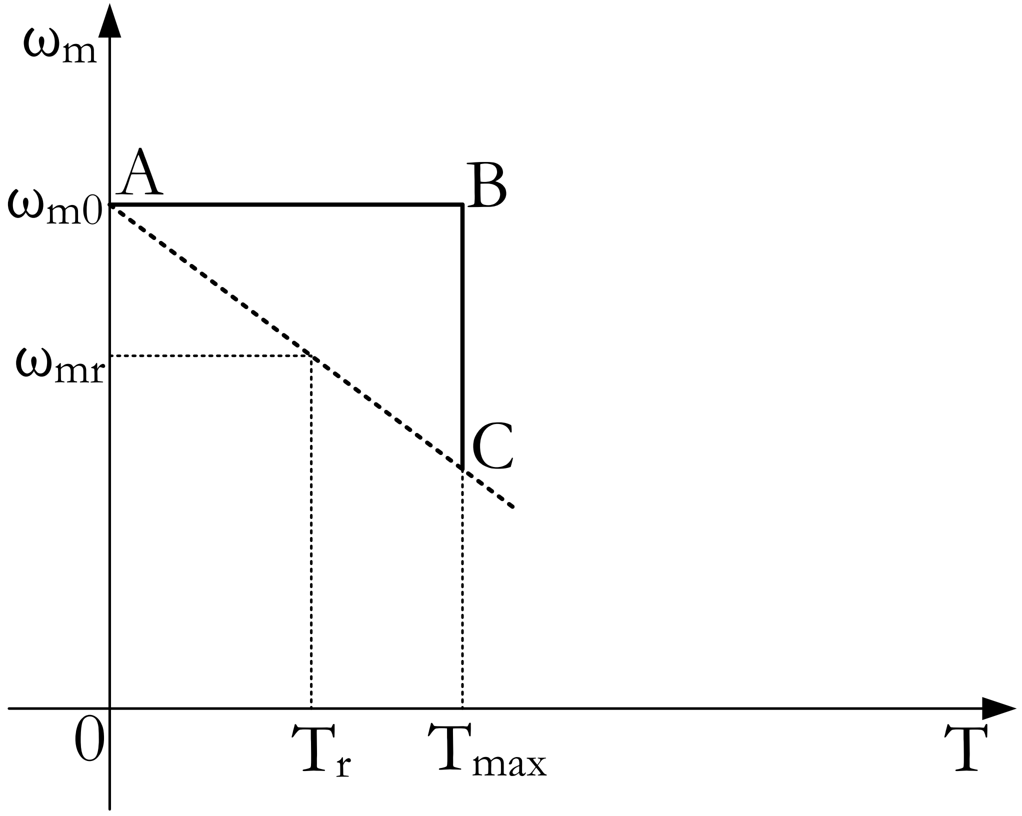
- In steady state stability, only initial and final conditions are examined on the basis of speed-torque characteristics of the motor and the load.
- It does not consider the inertia torques and time taken for changing from initial condition to final condition.
- The nature of motion of the motor during this period is also not considered
- The essence of transient satiability analysis is to consider all the influence of above mentioned factors on stability
- Such a study enable us to estimate drive performance more accurately with respect to its stability of motion.

Transient Stability

- Main thing to remember in transient stability is that, the equality between motor torque and load torque which forms the basis of steady state stability is no longer valid in transient operations.
- It also involves inertia torque which aids motor torque during deceleration and opposes motor torque during acceleration.

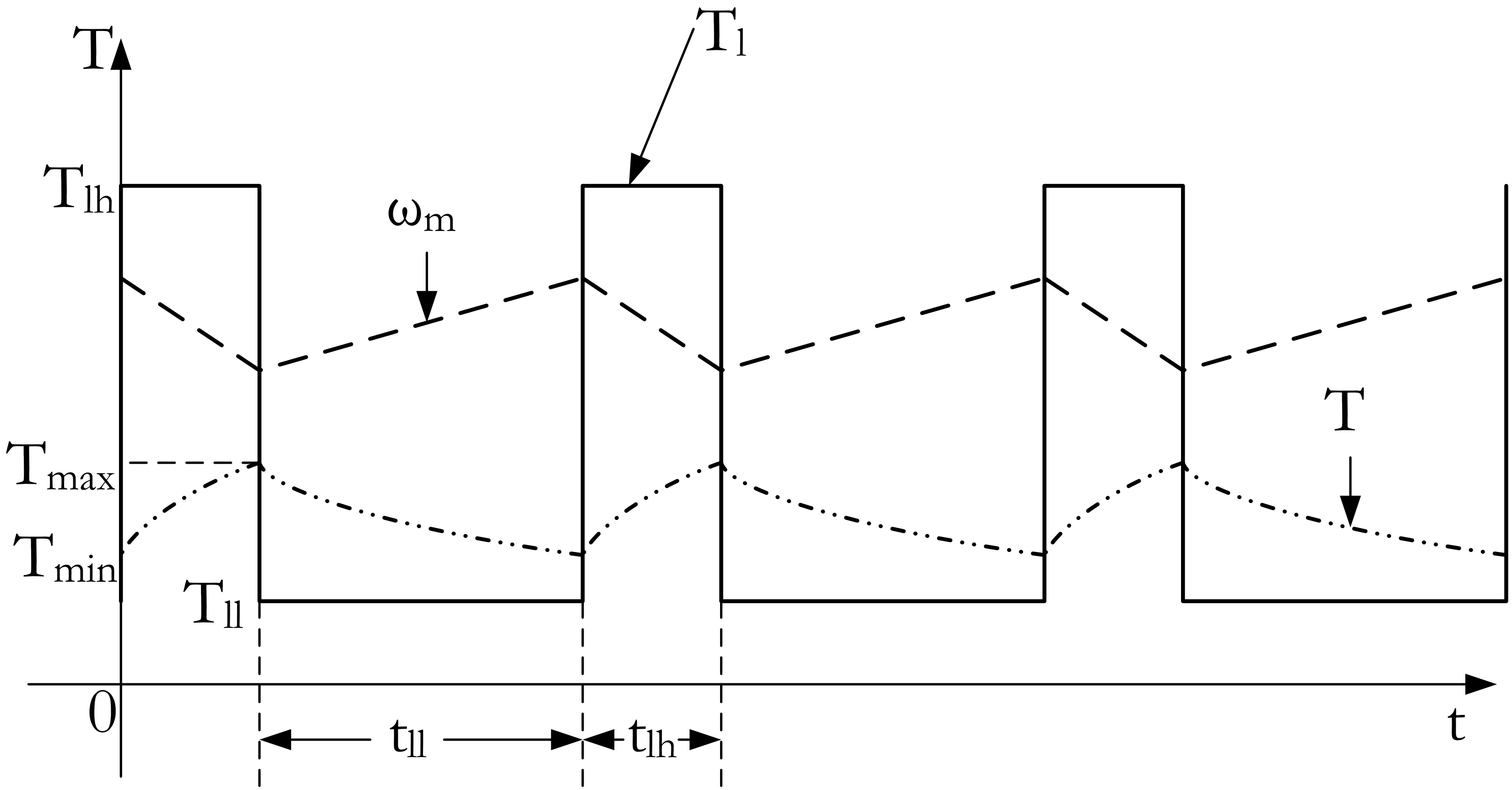
LOAD EQUALISATION

- Some applications load torque fluctuates widely – eg. Pressing machines, electric hammer etc.
- Mounting of fly-wheel on the shaft of non-reversible drives.
- Motor torque-speed characteristics is made drooping (Characteristics AC in the figure)
- During high load period load torque will be much larger than motor torque, deceleration of the motor helps to supply load torque.
- During light load periods motor torque will be larger than load torque and it accelerates the drive.



ω_m
A
B
ω_{m0}
ω_{mr}
C
0
T_r
T_{max}
T

Variation of motor and load torques, speed for a periodic load and for a drooping torque-speed characteristics are shown in figure below



This is called load equalization

Calculation of MOI of the flywheel required for load equalization

Assuming linear motor speed-torque curve (drooping) in the region of interest

$$\omega_m = \omega_{m0} - \left(\frac{\omega_{m0} - \omega_{mr}}{T_r}\right) \times T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Because of the slow response due to large inertia, motor can be assumed to be in electrical equilibrium intransient operation of the motor-load system. So eqn. 1 can be applied to transient operation also. Differentiating eqn. 1 and multiplying both side with J, we get

$$J\frac{d\omega_m}{dt} = -J\left(\frac{\omega_{m0} - \omega_{mr}}{T_r}\right)\frac{dT}{dt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$J\frac{d\omega_m}{dt} = -\tau_m\frac{dT}{dt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where $\tau_m = J\left(\frac{\omega_{m0} - \omega_{mr}}{T_r}\right)$, is defined as mechanical time constant of the motor. It is the time required for the motor speed to change by $\omega_{m0} - \omega_{mr}$ when motor torque is maintained constant at rated value T_r.

But , $J\frac{d\omega_m}{dt} = T - T_l$. We can rewrite eqn. 3 as

$$T - T_l = -\tau_m \frac{dT}{dt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$T_l = T + \tau_m \frac{dT}{dt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Consider now a periodic load torque, a cycle of which consists of one high load period with torque T_{lh} and duration th, and light load period with torque T_{ll} and duration tl.

For the high load period, 0<t<t_h, the solution of eqn. 5 is given by

$$T = T_{lh}\left(1 - e^{-\frac{t}{\tau_m}}\right) + T_{min} e^{-\frac{t}{\tau_m}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where T_{min} is the motor torque at t=0 and which is also the instant at heavy load T_{lh} is applied. If the motor torque at the end of heavy load period $(t = t_h)$ is T_{max} , then from eqn. 6

$$T_{max} = T_{lh}\left(1 - e^{-\frac{t_h}{\tau_m}}\right) + T_{min} e^{-\frac{t_h}{\tau_m}} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

For the light load period, $t_h < t < t_{h} + t_l$, the solution of eqn. 5 with initial motor torque equal to T_{max} is given by

$$T = T_{ll}\left(1 - e^{-\frac{t'}{\tau_m}}\right) + T_{max}e^{-\frac{t'}{\tau_m}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$$0 < t' < t_l, t' = t - t_h$$

At $t' = t_l$, $T = T_{min}$, So we can write

$$T_{min} = T_{ll}\left(1 - e^{-\frac{t_l}{\tau_m}}\right) + T_{max}e^{-\frac{t_l}{\tau_m}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

From eqn. 7, we can get

$$\tau_m = \frac{t_h}{\ln\left(\frac{T_{lh} - T_{min}}{T_{lh} - T_{max}}\right)} \ldots\ldots\ldots\ldots\ldots (10)$$

From eqn. 9, we can get

$$\tau_m = \frac{t_l}{\ln\left(\frac{T_{max}-T_{ll}}{T_{min}-T_{ll}}\right)} \quad \ldots\ldots\ldots\ldots\ldots(11)$$

From eqn. 10, we can get

$$J = \left(\frac{T_r}{\omega_{m0}-\omega_{mr}}\right)\left[\frac{t_h}{\ln\left(\frac{T_{lh}-T_{min}}{T_{lh}-T_{max}}\right)}\right] \quad \ldots\ldots\ldots\ldots\ldots(12)$$

From eqn. 11, we can get

$$J = \left(\frac{T_r}{\omega_{m0}-\omega_{mr}}\right)\left[\frac{t_l}{\ln\left(\frac{T_{max}-T_{ll}}{T_{min}-T_{ll}}\right)}\right] \quad \ldots\ldots\ldots\ldots\ldots(13)$$

$$J = WR^2,$$

where W is the weight of fly wheel and
R is the radius of the fly wheel

Problem

A motor equipped with a flywheel is to supply a load torque of 1000Nm for 10sec. Followed by a light load period of 200Nm long enough for the flywheel to regain its steady state speed. It is desired to limit the motor torque to 700Nm. What should be the moment of inertia of the flywheel? Moment of Inertia of motor is 10kg-m^2. Its noload speed is 500rpm and the slip at a torque of 500Nm is 5%. Assume speed-torque characteristic of motor to be a straight line in the region of interest.

Ans: **1942.7 kg-m^2.**