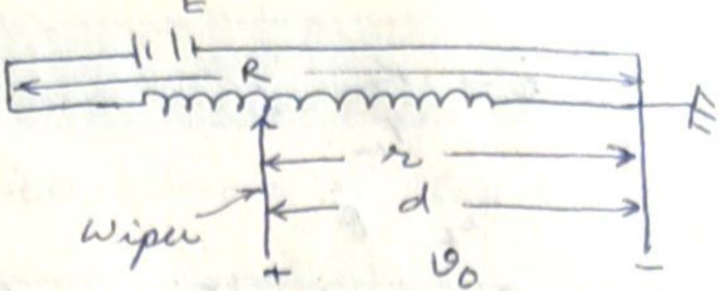
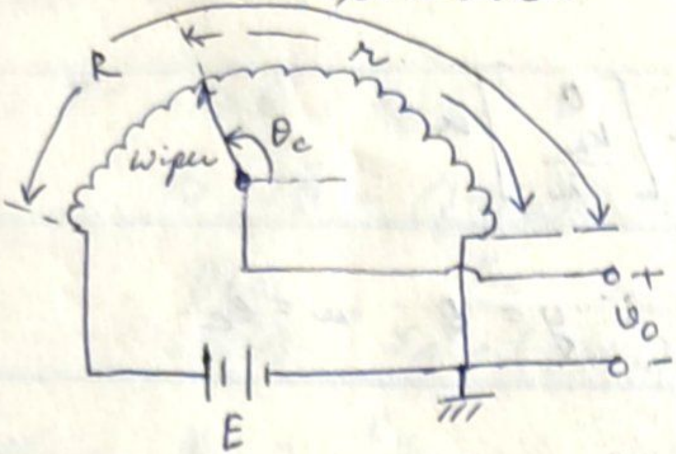
Sensors.

1. Potentiometers { linear / rotational

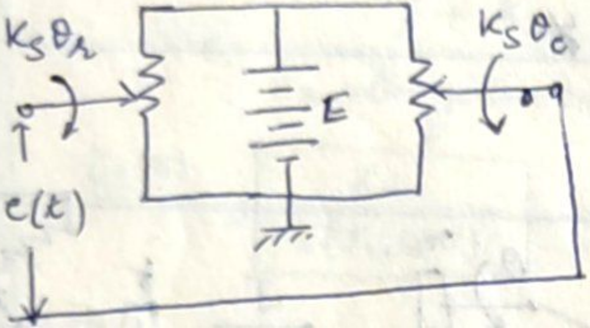




$v_0 = K_S \theta_c (t)$ or $= k \theta_C E$

where $K_S = \dfrac{E}{2\pi N}$ V/rad ; $k = \dfrac{1}{2\pi N}$ rad^{-1}

when it is a N turn rotary pot.

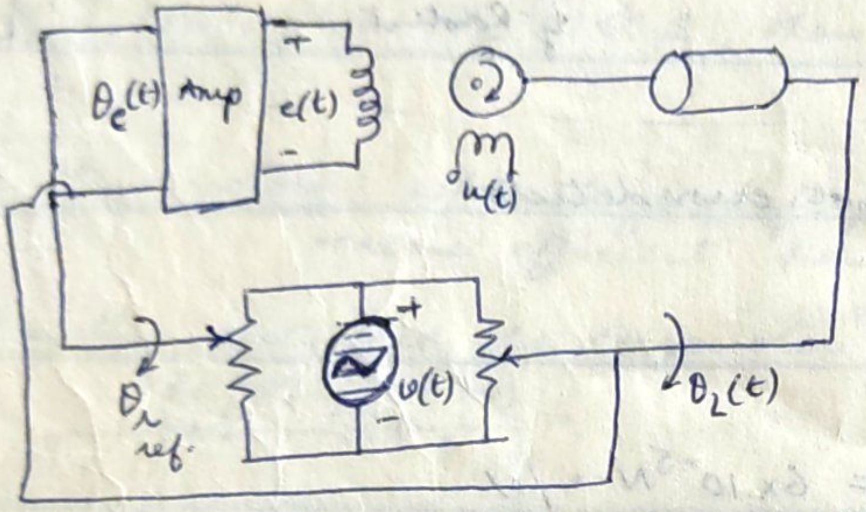


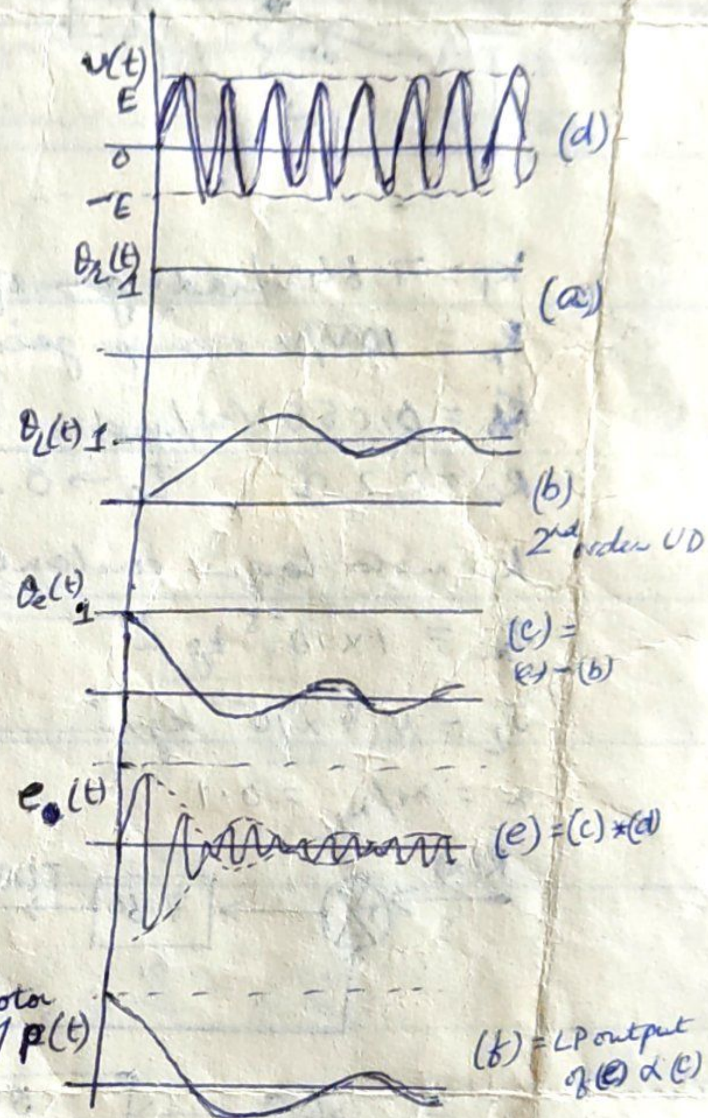
$e(t) = K_S [\theta_r - \theta_c]$ for error detector

$= k[\theta_r - \theta_c] E$

IV

AC position servo:





CARRIER $v = E \sin \omega_c t$ AMP. MODULATION

$e = K_s \theta_e v$ Let $\theta_e = \sin \omega_s t$ $\omega_s \ll \omega_c$

$= \frac{1}{2} K_s E[\cos(\omega_c - \omega_s)t$ $= \theta_r - \theta_L$

$- \cos(\omega_c + \omega_s)t]$ (where $K = \frac{1}{2\pi N}$)

$= \frac{1}{2} K_s [\cos(\omega_c - \omega_s)t - \cos(\omega_c + \omega_s)t]$

Motor acts as integrator

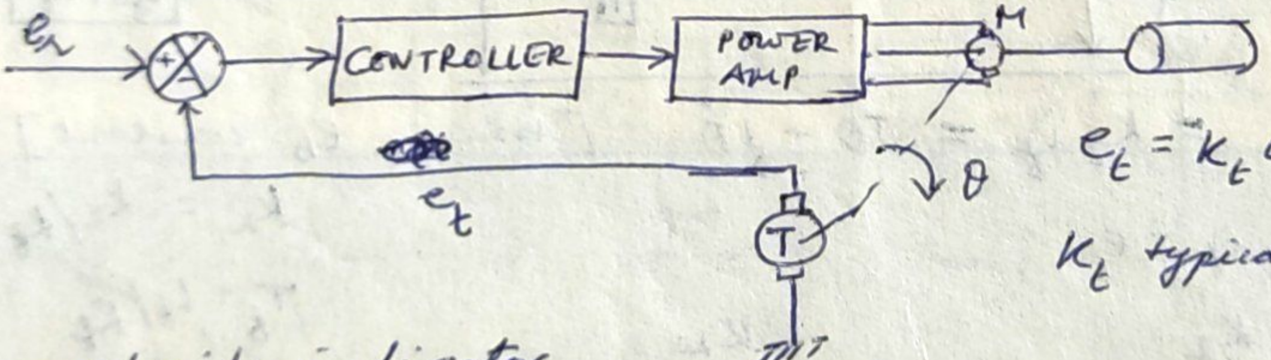
ac — used in aerospace applications for noise suppression (signal drifts - LF!)

f < 50Hz Normal
400Hz Military
1000Hz Aerospace

2. Tachometers : Tachogenerators — Mech energy to electrical energy

DC tachometer : a) Iron core rotor , field from PM, no external supply voltage b) moving coil tacho : ironless rotor + armature cantilevered bet. PM poles

AC tacho : Quad-arrangement, rotor shaft rotation ∝ o/p voltage : speed
(phase) $\phi = f$ (direction of rotation)

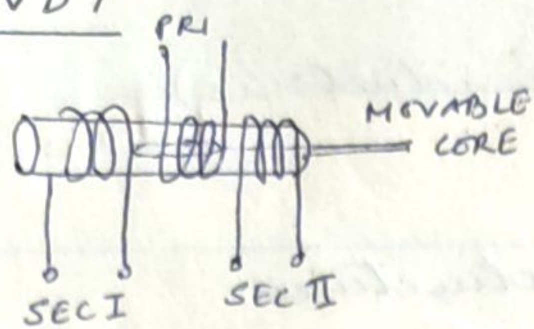


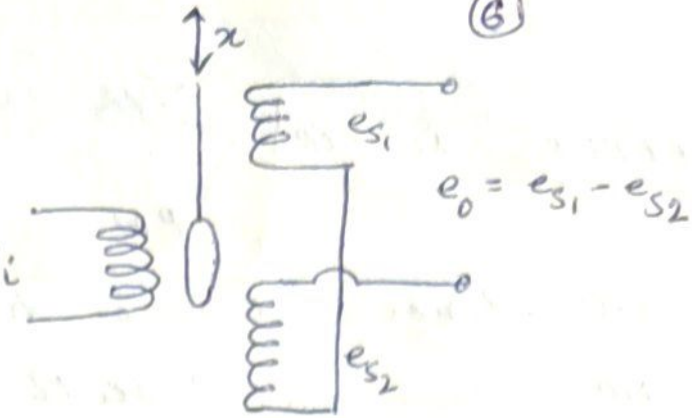
$e_t = K_t \omega$

K_t typically 6V/krpm

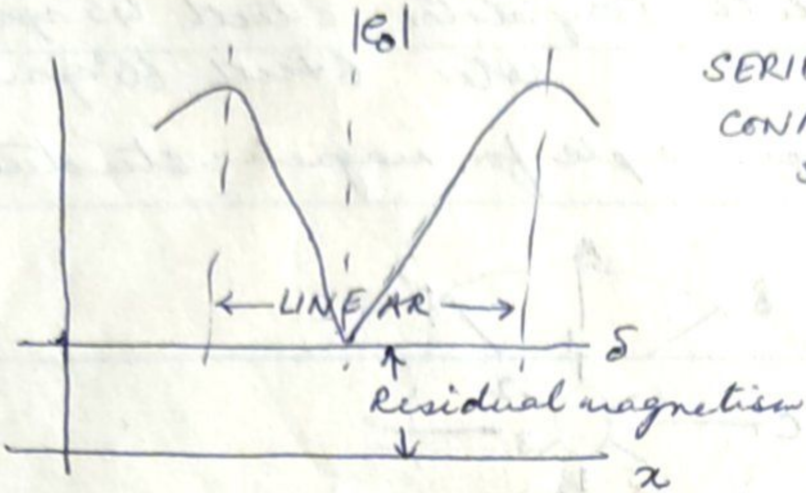
— velocity indicator
— velocity fb. for speed control [need accuracy as in fb loop]
— velocity fb for improving stability or damping — inner fb loop
∴ NON CRITICAL.

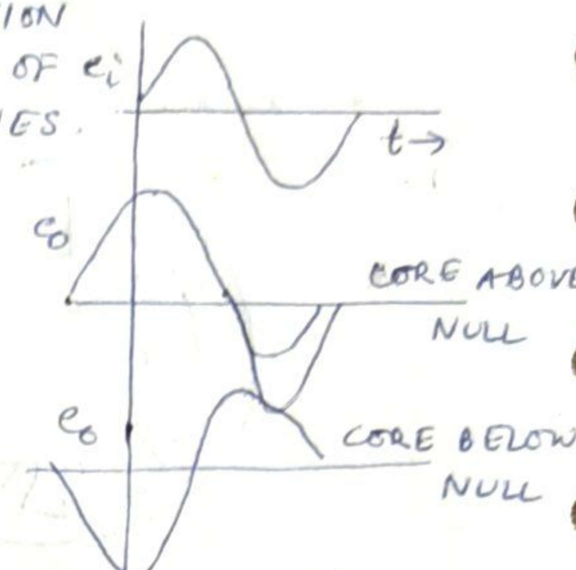
3. LVDT





SERIES OPPOSITION CONNECTION OF SECONDARIES.





UNLOADED

$$i_p R_p + L_p \frac{di_p}{dt} = e_i$$ for primary when secondaries open ckt.

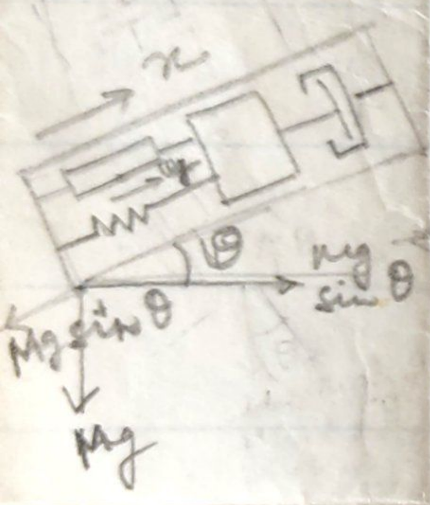
$$I_p(s) = \frac{E_i(s)}{R_p} \cdot \frac{1}{\tau_p s + 1} \qquad \tau_p = L_p/R_p$$

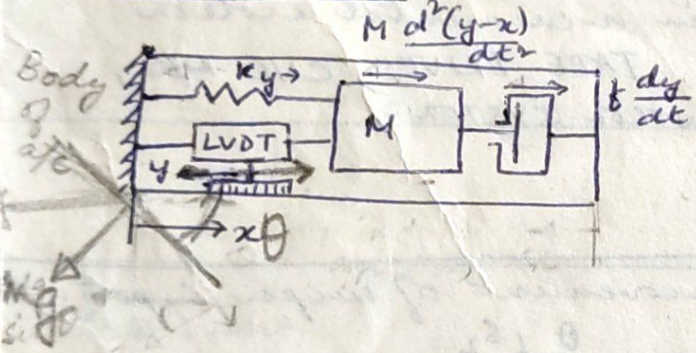
$$E_o(s) = E_{S_1}(s) - E_{S_2}(s) = (M_1 - M_2)\, s\, I_p(s)$$

$$\therefore \frac{E_o(s)}{E_i(s)} = \frac{s(M_1 - M_2)/R_p}{s\tau_p + 1} \Rightarrow |e_o(t)| = A_o = K(M_1 - M_2)|e_i(t)|$$

$$K = \frac{\omega \cancel{(M_1 - M_2)}}{R_p\sqrt{(\omega\tau_p)^2 + 1}} \;;\; \phi = \frac{\pi}{2} - \tan^{-1}\omega\tau_p$$

4. Accelerometers OGATA / KUO





Due to the jerk ($\frac{d}{dt}a$), frame of accelerometer accelerated (effective x)

∴ Spring deflects till enough force is produced to accelerate M at same rate as the frame.

∴ Deflection of spring ∝ a.

Mg sin θ = component ALONG accelerometer

Mg cos(90−θ) = Mg sin θ

$$M\frac{d^2(y-x)}{dt^2} + f\frac{dy}{dt} + Ky = 0$$ of elements in accelerometer

For constant acceleration, $\frac{dy}{dt} = \frac{d^2y}{dt^2} = 0$ assuming S.S. (locally – for duration of measurement applied forces do not change)

$$\therefore Ma = Ky \Rightarrow y = \frac{M}{K}a.$$

– Require sufficient 'damping' so spring-mass combination does not 'ring' (OSCILLATE) significantly.

$$M\frac{d^2(y-x)}{dt^2} + f\frac{dy}{dt} + Ky = Mg\sin\theta + M\frac{d^2x}{dt^2}$$ (reactionary free body force) OR.. a = g sin θ ∴ but if θ = π/2. For measuring g

$$\Rightarrow M\frac{d^2y}{dt^2} + f\frac{dy}{dt} + K\left(y - \frac{M}{K}g\sin\theta\right) = M\frac{d^2x}{dt^2} = Ma$$

* Let $z = y - \frac{M}{K}g\sin\theta$ ∴ $\dot{z} = \dot{y}$, $\ddot{z} = \ddot{y}$ for $\theta(t) = \theta$, $g(t) = g$

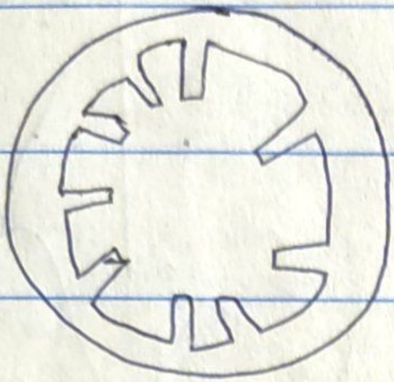
$$\therefore M\ddot{z} + f\dot{z} + kz = Ma$$

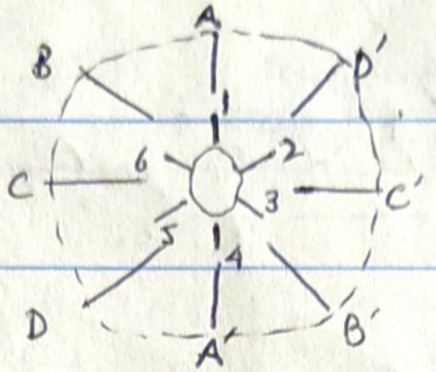
Note: for θ = 0, Mg sin θ is 0 ∴ g cannot be measured ∴ Input axis ⊥ (– accel. vertical) as axis desirable for accelerometers to measure g accurat…

eg. baloon moves horizontally – x axis motion

STEPPER MOTOR
- VR (Variable reluctance)
- PM

- both stator and rotor toothed structures
- NOT same no. of teeth (say stator 8 teeth 45° apart
  rotor 6 teeth 60° apart)
- min. reluctance principle for magnetic structure





phase A energised

Then B ⇒ 3 & 6 move 15° to align with B B'
then C ⇒ 5 & 2 another 15°
then D ⇒ 4 & 1 (∴ 4 steps to move 6 to A)

∴ CW rotation A B C D A
CCW rotation A D C B A

∴ For 360° rotation of rotor, need 24 steps.

Step angle $= 360° \dfrac{|N_S - N_r|}{N_S N_r}$

N_S, N_r: no. of stator & rotor teeth.

No. of steps / rev. $= \dfrac{N_S N_r}{|N_S - N_r|}$

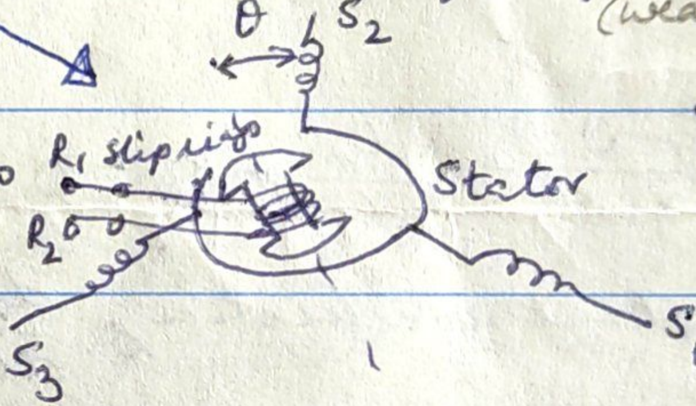
- Used as digital actuator in incremental motion control systems — PRINTERS, TAPE DRIVES, CNC M/C, PROCESS CONTROL SYSTEMS.
- decision of phase seq. imp.

SYNCHRO: to avoid physical movement of wiper in pot. (wear & tear)

— control transmitter (CX)

— control transformer (CT)

Supply to rotor via slip rings



DUMBBELL Shaped ROTOR

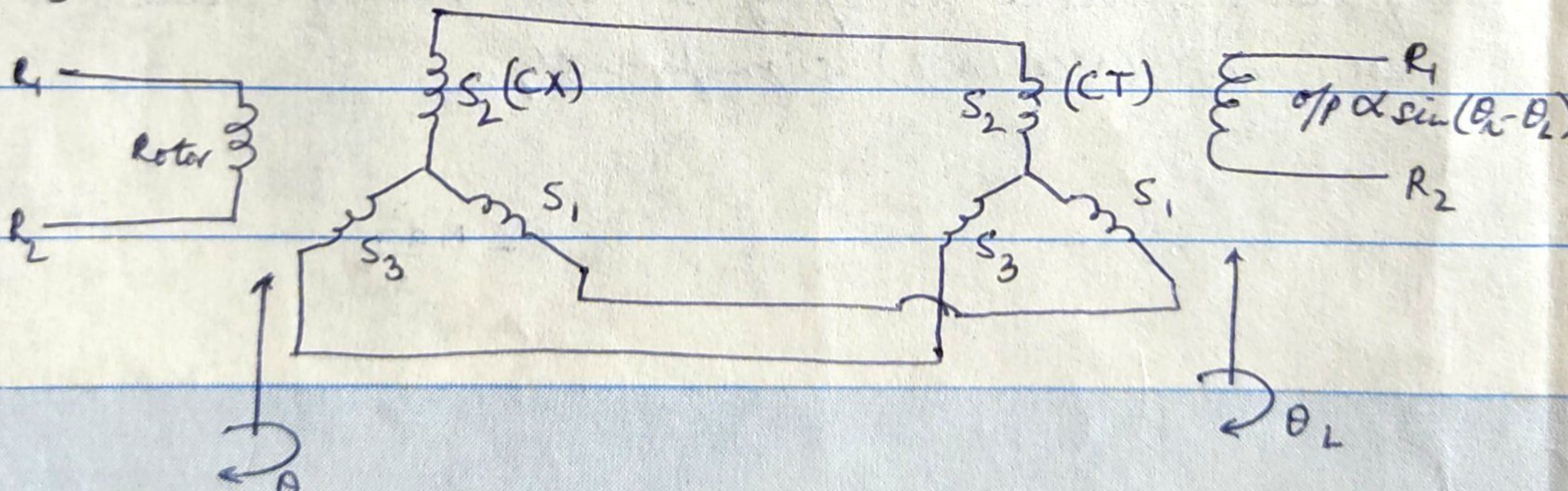
* CT rotor round – high i/p Z

$E_{OS_2} = A\cos\theta$

$E_{OS_1} = A\cos(\theta - 120°)$

$E_{OS_3} = A\cos(\theta - 240°)$

$E_{S_1S_2} = E_{OS_1} - E_{OS_2} = \sqrt{3}A\cos(\theta + 30°)$



Supply voltage to rotor

Voltage induced in stator phase depends on angle of rotor.

CT rotor is round ∴ high i/p Z ∴ not load supply voltage