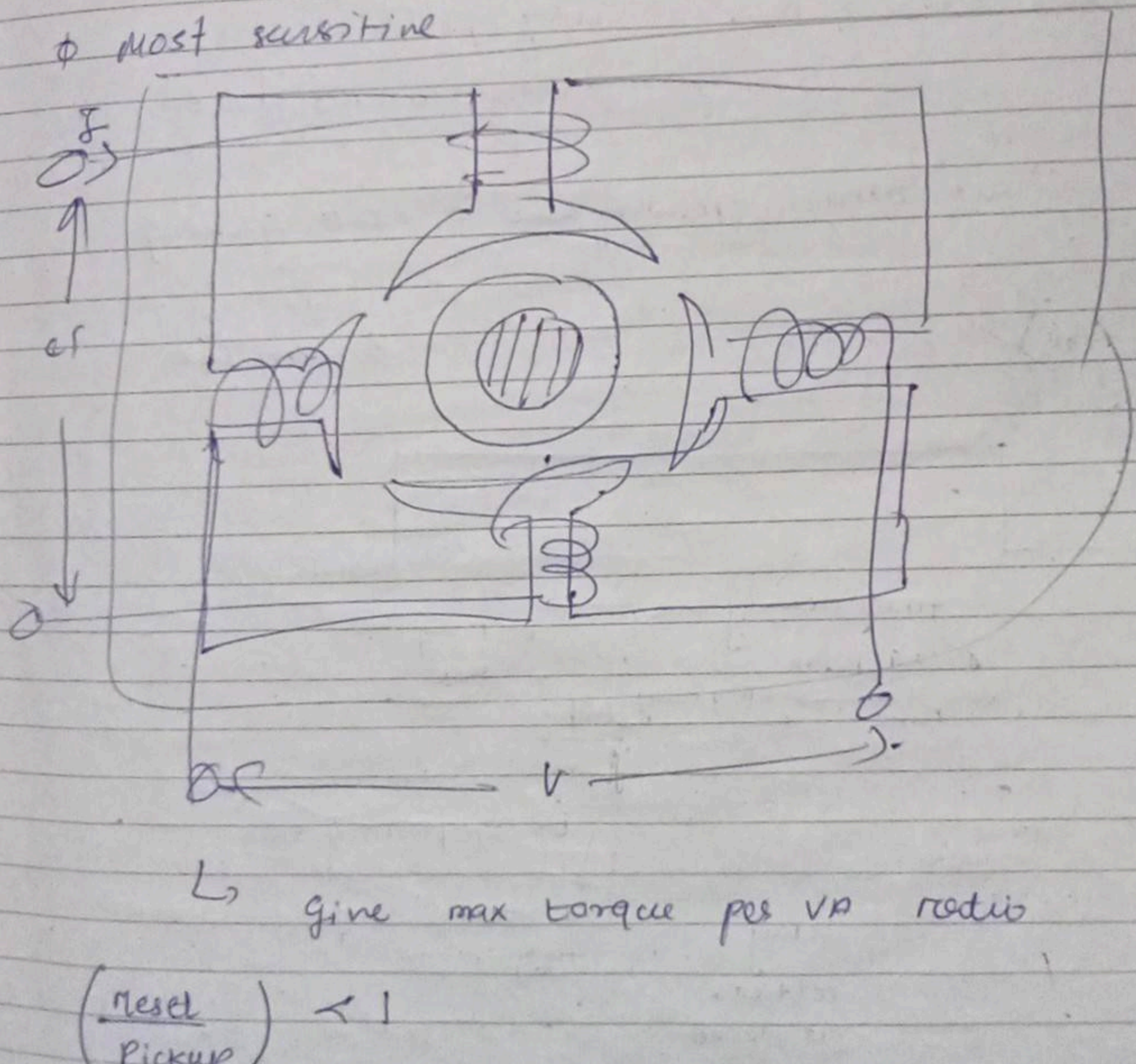
PSPS

10 Jan

Indⁿ cup type construction:

* most sensitive



↳ give max torque per VA ratio

$\left(\frac{\text{reset}}{\text{pickup}}\right) < 1$

↳ 0.95 − 1 for induction principle

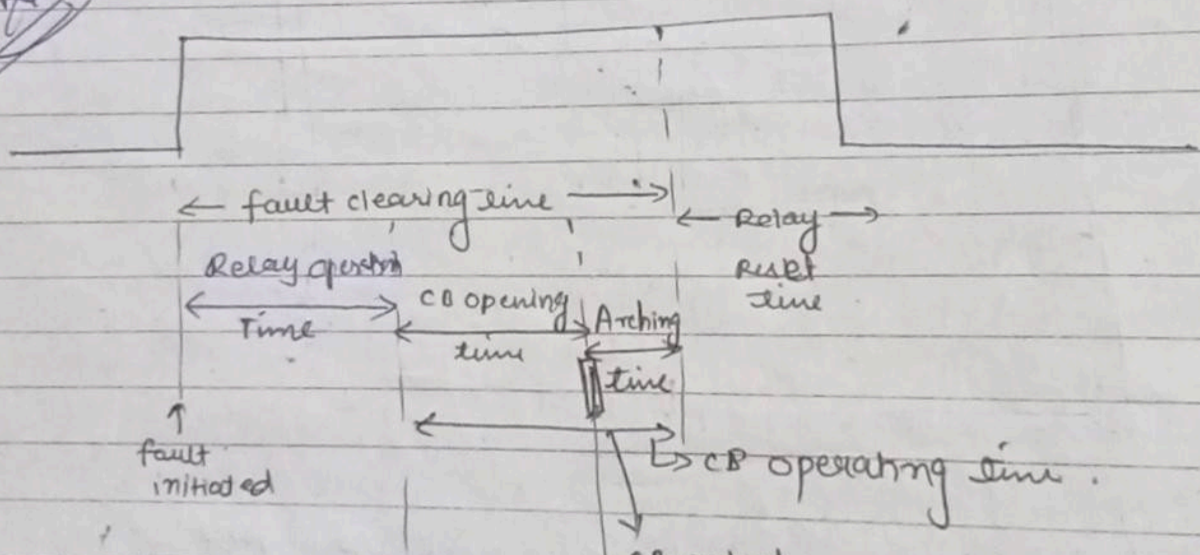
0.1 − 0.9 electromagnetic attraction type relay

operating times :

Fault clearing time = Relay operating time + Circuit breaker operating time

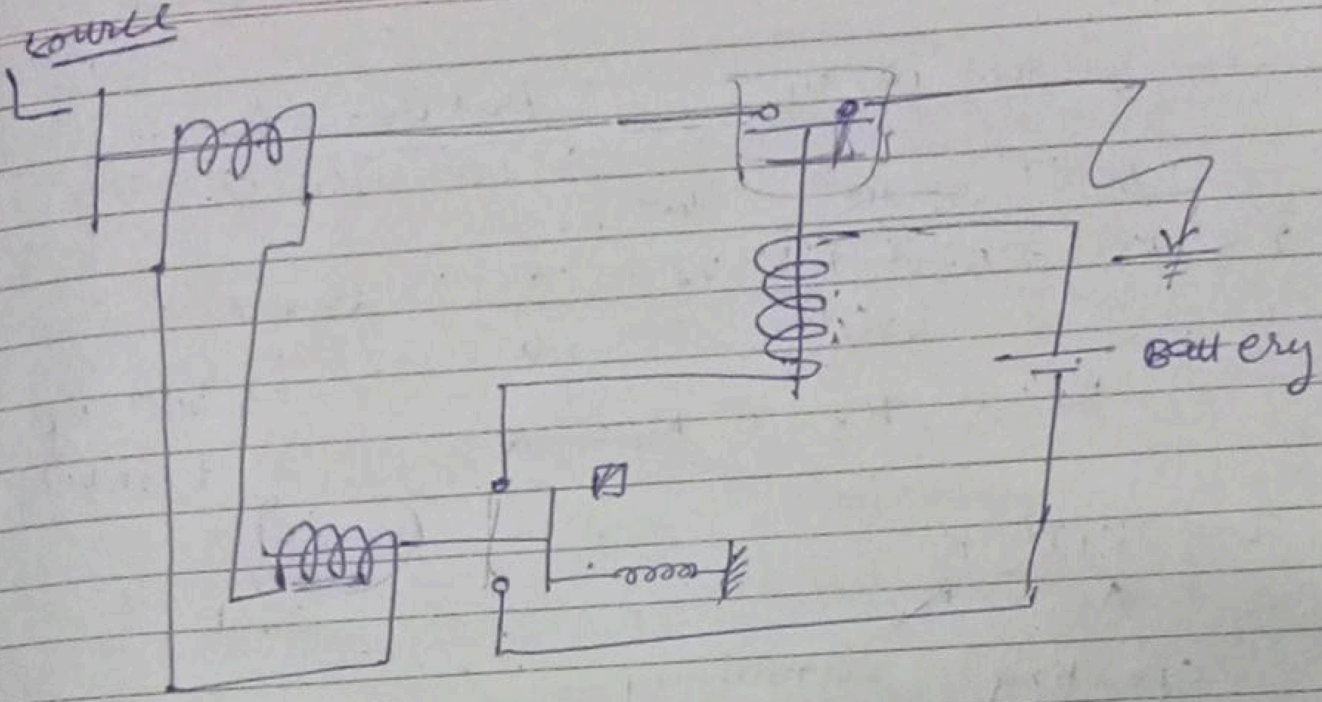
Circuit breaker operating time = C-B. opening time + Arching time

imp



Relay contacts get closed initiated Trip signal to circuit breaker

CB contact fully opened



CB open hone ke time arch form hoti hai
thermo ionic emission ki vajah se

Imp
Universal torque equation:

$$\boxed{T = K_1 I^2 + K_2 V^2 + K_3 V I \cos(\theta - \tau) + K_4}$$

$K_1 I^2$ → current unit

$K_2 V^2$ → voltage unit

$K_3 V I \cos(\theta - \tau)$ → Direction unit or Power unit

K_4 → spring

↳ Derive any kind of relay from this equation

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↳ Not a directional relay

Over current relay:

∴ don't know dirⁿ.
∴ $K_3VI\cos(\theta-\tau)=0$.

No dirⁿ   No dirⁿ   dirⁿ.

$$T = K_1I^2 + \underbrace{K_2V^2}_{\hookrightarrow 0} + \underbrace{K_3VI\cos(\theta-\tau)}_{\hookrightarrow 0} + K_4$$

↳ spring torque.

$K_2=0,\ K_3=0,\ K_4=-K$

$$T = K_1I^2 - K$$

operating torque   Restraining torque

$\underline{T_{op} = T_{Rest}}$ ⟶ over current relay operate.

$I_{pick\text{-}up} = \sqrt{Re(I)^2 + Im(I)^2} = C$

$K_1I^2 - K = 0$

$I_{pick\text{-}up}$ = constant

$I = \sqrt{\frac{K}{K_1}} = I_{pick\text{-}up} \Rightarrow \boxed{\therefore I_{pick\text{-}up} = C}$

pickup current usi threshold current ko kahte hai

↳ threshold current above which our relay ~~current~~ will operate

generally called I_{pickup}.

$K_1I^2 > K$

$I > \sqrt{\frac{K}{K_1}}$

$\boxed{I > I_{pick\text{-}up}}$ → relay operate transient fault: this fault includes the momentary loss of network connectivity to components & services, the temporary unavailability of a service (or timeouts) that are when a service is busy.

This faults often self correcting.

Restoration: process of returning to its earlier good cond^n

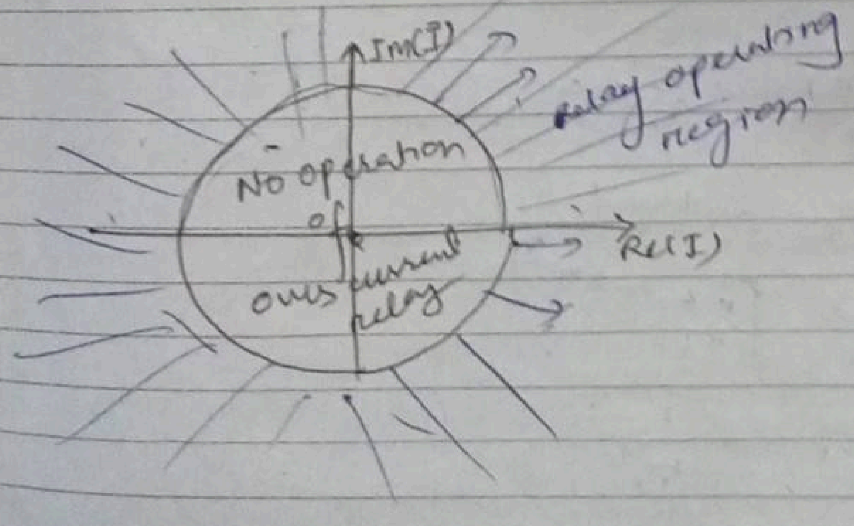
Thermal stress:

→ spice vs

$\Rightarrow Re(I)^2 + Im(I)^2 = c^2$

$(I)^2$ ↳ this is circle centres at (0,0).

C



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$\frac{7}{5} = 1.4$

Current setting (CS%) / ~~flug~~ plug setting / threshold value

$$\text{current setting (in \%)} = \frac{I_{pick\text{-}up}}{I_{relay}} \times 100$$

ex: (1) $I_{relay} = 5A$

$I_{pick\text{-}up} = 7A$

$$CS(\%) = \frac{I_{pick\text{-}up}}{I_{relay}} \times 100$$

$$= \frac{7}{5} \times 100 = 140\%$$

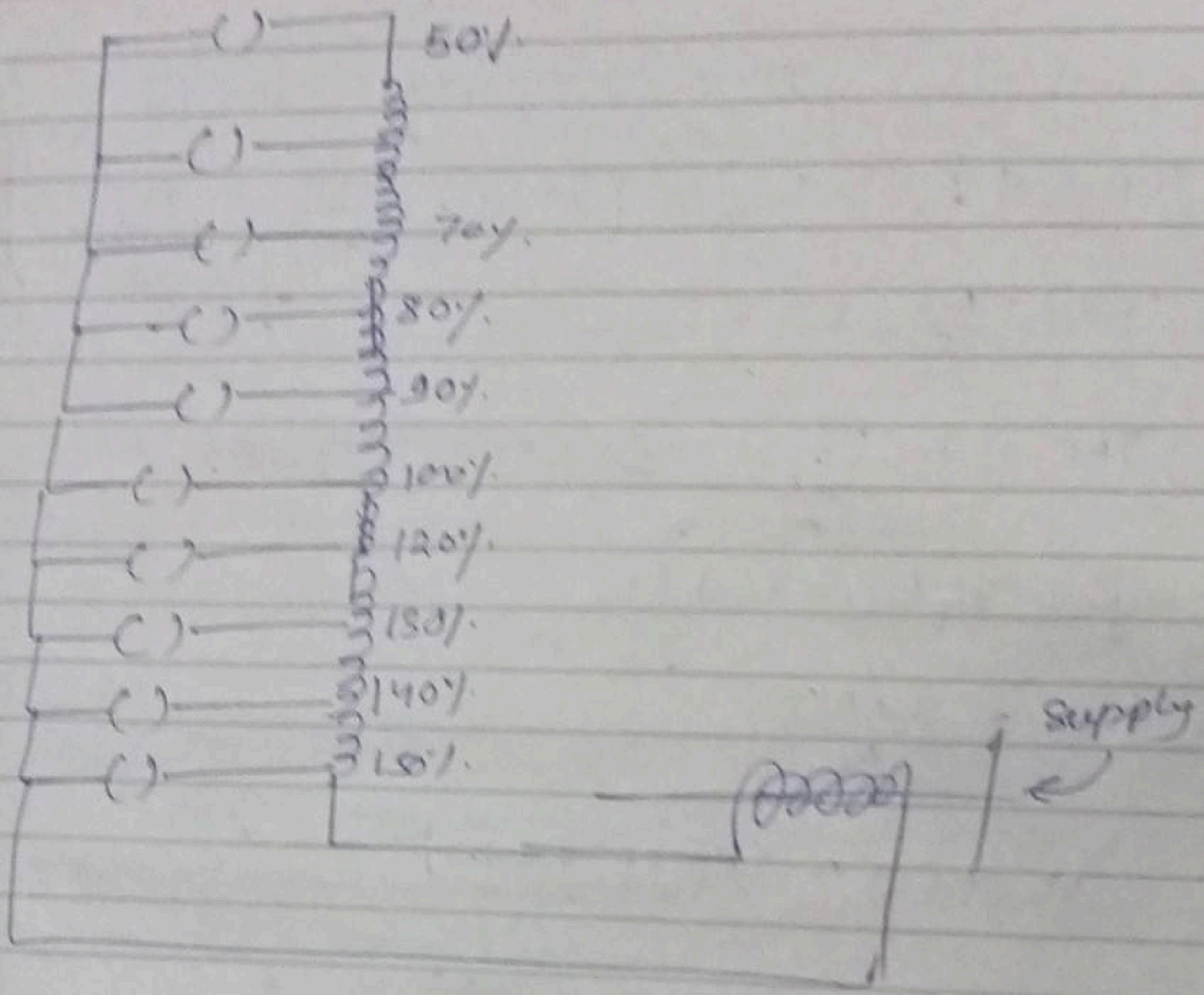
(2) if $I_{pick\text{-}up} = 5A$

$$\text{then } CS(\%) = \frac{5}{5} \times 100$$

$$= 100\%$$

$$I_{pick.up} = \sqrt{\frac{K}{K_1}} \leftarrow \text{constants}$$

$$I_{pick\text{-}up} \propto \frac{1}{\sqrt{K_1}}$$



current setting $\propto$ $I_{pick\text{-}up}$

* by the help of current setting we decide the pick-up current.

$T_{op} \propto K_1 I^2$ —— ①

$T_{op} \propto \phi I$ $\left[\because \phi = \frac{NI}{Re} \leftarrow \text{Reluctance} \right]$

$T_{op} \propto \frac{NI}{Re} \times I$

$T_{op} = K_0 \frac{NI^2}{Re}$ — ②

compare eq^n ① and ②

$K_1 = \frac{K_0 N}{Re}$

$\Rightarrow K_1 \propto N$ (No. of turns). —— ⓧ

CS (%) $\propto$ $I_{pick\text{-}up}$ —— ⓨ

$I_{pick\text{-}up} = \sqrt{\frac{K_0}{K_1}}$.

$\therefore I_{pick\text{-}up} \propto \frac{1}{\sqrt{K_1}}$ —— ②

by ⓧ ⓨ, ②

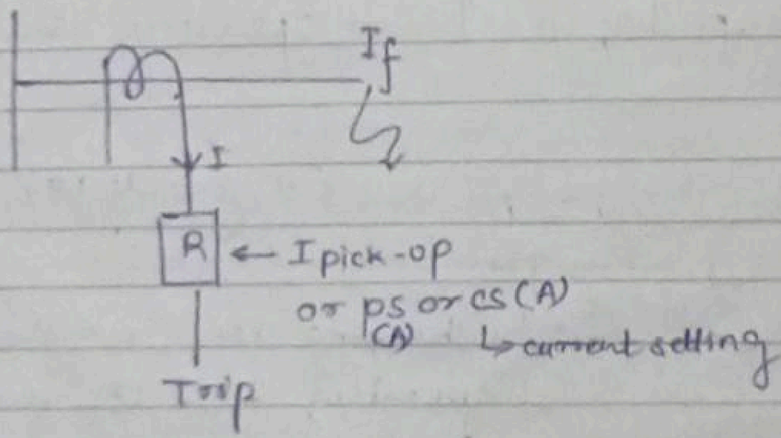
$$\boxed{CS(\%) \propto I_{pick\text{-}up} \propto \frac{1}{\sqrt{N}}}$$

PSN

Plug setting Multiplier (PSM).

$$PSM = \frac{\text{Secondary current of CT}}{\text{current setting (in ampere)}}$$

$$PSM = \frac{\text{Primary current}}{\text{CT ratio} \times \text{current setting (A)}}$$



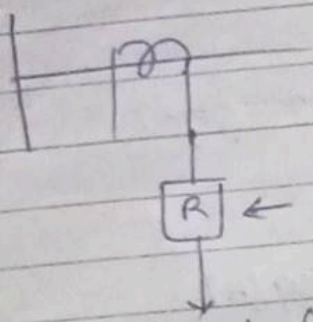
$$PSM = \frac{I_f}{\text{CT ratio} \times CS(A)}$$

if PSM > 1 → relay operates

PSM < 1 → relay Not ~~operation~~ operates. operating time of relay is infinite.

PSM = 1 → relay at verge of operation

PSM Vs Operating Time :



← CS(A) or PS(A) or $I_{pick-up}$

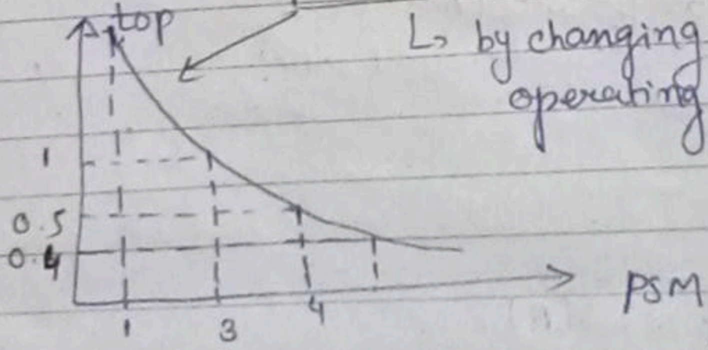
Trip (This signal goes to CB).

$I_f \uparrow \rightarrow PSM \uparrow \rightarrow$ speed of disc $\uparrow \rightarrow$ operating time $\downarrow$

$t_{op} \propto \frac{1}{PSM}$

→ Time setting multiplier

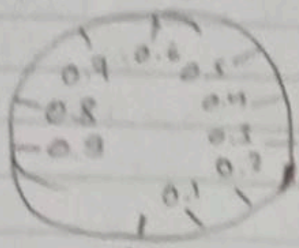
$\boxed{\text{when TMS} = 1}$



↳ by changing TMS we can change operating time of relay

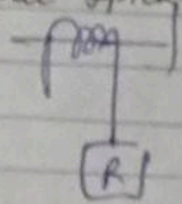
$t_{op} = TMS \times t_{rating}$

Que TMS = 1



↑
TMS

Que an over current relay is connected to the supply circuit through a 1000/1A current Xer, the relay is set at 120%. Calculate Ipick-up.



Sol^n given CT = 1000

CS = 120%

$$\boxed{CS = \frac{I_{pickup} \times 100}{I_{relay}}}$$

120

$1.2 = \frac{I_{pic}}{1}$

$I_{pic} = \cancel{1200}$

$$120 = \frac{I_{pick.up}}{I_{relay}} \times 100$$

$$I_{pick.up} = \frac{120}{100} \times 1$$

$$\boxed{I_{pick.up} = 1.2\,A}$$

* question always give relay current.

relay current

Que A 5A over current relay is set at 100%. and its relay operating coil has 144 turns. if $I_{pick-up}$ is adjusted to 6A calcul. No of amp. turns required in its relay operating coil.

$I_{relay} = 5$ or $I_{pick\,up}$

$CS = 100\%$

$$\cancel{100} \times \frac{I_{pickup}}{I_{relay}} = \cancel{100}$$

$$\boxed{I_{pick-up} = I_{relay}}$$

$N = 144$.

~~PSM =~~

Sol^n

$$I_{pickup} \propto \frac{1}{\sqrt{N}}$$

$$5 \propto \frac{1}{\sqrt{N_1}} \Rightarrow \frac{5}{6} = \frac{\sqrt{N_2}}{\sqrt{N_1}}$$

$$6 \propto \frac{1}{\sqrt{N_2}} \qquad \frac{5}{6} = \frac{\sqrt{N_2}}{\sqrt{144}}$$

$$\boxed{N_2 = 100}$$ Ans

(Methods).

Classification of protective schemes:

1. over current protection.
2. Distance protection.
3. carrier current protection.
4. Differential protection.

Types of overcurrent relays.

i> Instantaneous over current relay: doesn't depend on mag of I_f.

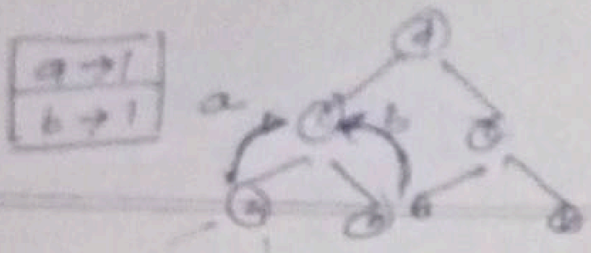
ii> definite time over current relay.
iii) Inverse definite time over current relay. (IDMT).
iv) very inverse over current relay.
v) extremely inverse over current relay

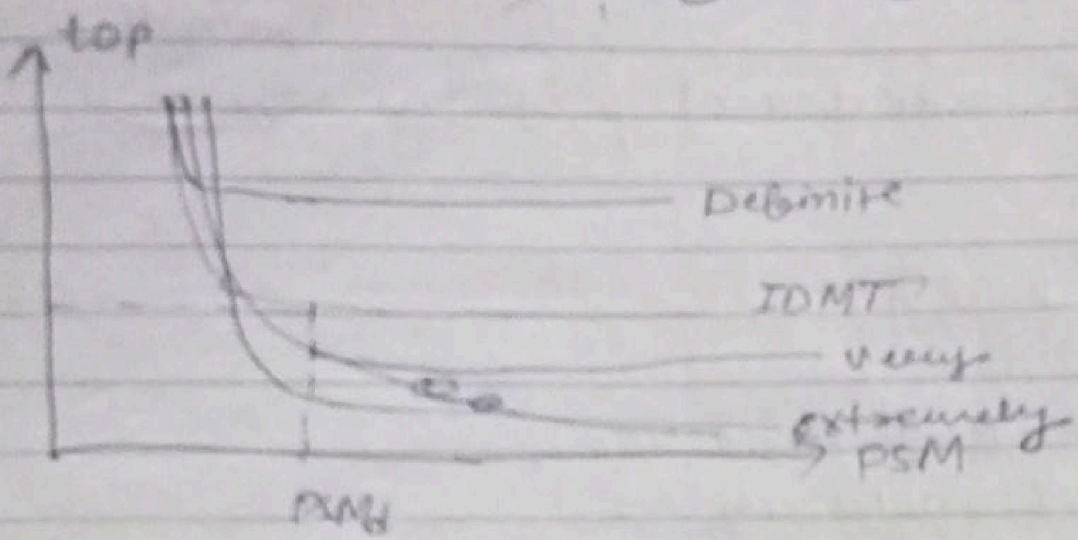
$\rightarrow PSM_t = \frac{I_{fd}}{CT_{ratio} \times CS(A)}$

$1 \leq PSM < PSM_d$.

$\hookrightarrow$ inverse definite time.

$PSM > PSM_d \rightarrow$ Definite time





volume of core

EI > VI > IDMT > Definite

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Very Imp

Distance Relays [3 types]

1. Impedence relay.
2. Reactance relay
3. Mho relay

Impedence relay / Voltage restrain over current relay :

$$T = K_1 I^2 + K_2 V^2 + K_3 VI \cos(\theta - \tau) + K_4$$

I will provid operating torque
V will provide restraing torque.

For Impedance relay

$K_1 = +ve,\ K_2 = +ve,\ K_3 = 0 = K_4$

Here we are obtaing restraing force with the help of voltage.

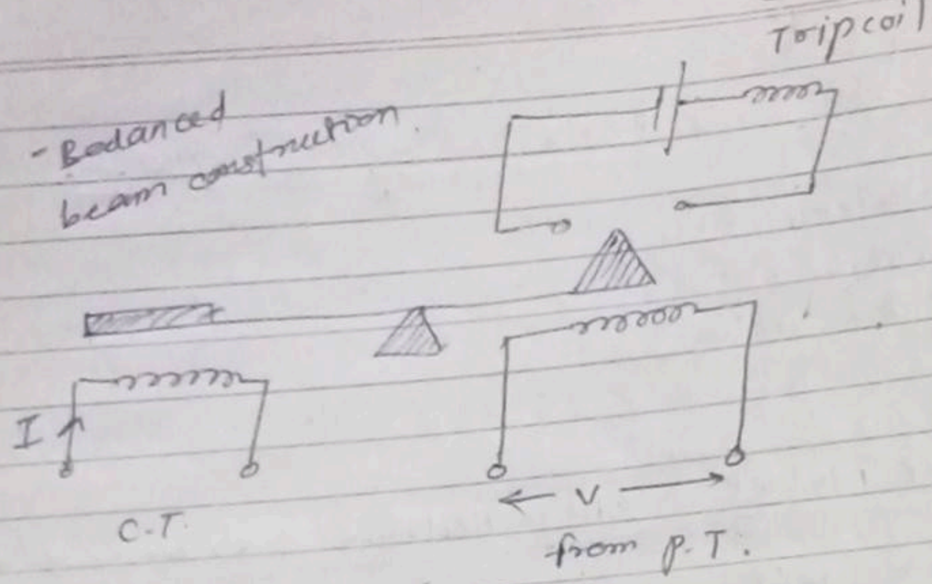
$$T = K_1 I^2 - K_2 V^2$$

$K_1 I^2$ ↳ provid T_{op}

$K_2 V^2$ ↳ provide restraining torque

$V = IR$

- Balanced beam construction



Under threshold cond^n

$T = 0 \Rightarrow T_{op}$

$T_{operating} = T_{restraining}$

$K_1 I^2 = K_2 V^2$

$\left(\frac{V}{I}\right)^2 = \frac{K_1}{K_2}$

$\underbrace{\frac{V}{I}}_{Z_{seen}} = \sqrt{\frac{K_1}{K_2}} = Z_{set}$ —— (1)

$T_{op} > T_{res}$

$K_1 I^2 > K_2 V^2$

$\left(\frac{V}{I}\right)^2 < \frac{K_1}{K_2} \Rightarrow \underbrace{\frac{V}{I}}_{Z_{seen}} < \underbrace{\sqrt{\frac{K_1}{K_2}}}_{Z_{set}}$

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~~Rset~~

$\boxed{Z_{seen} < Z_{set}}$ ⟶ (2) relay will operate.

from (1)

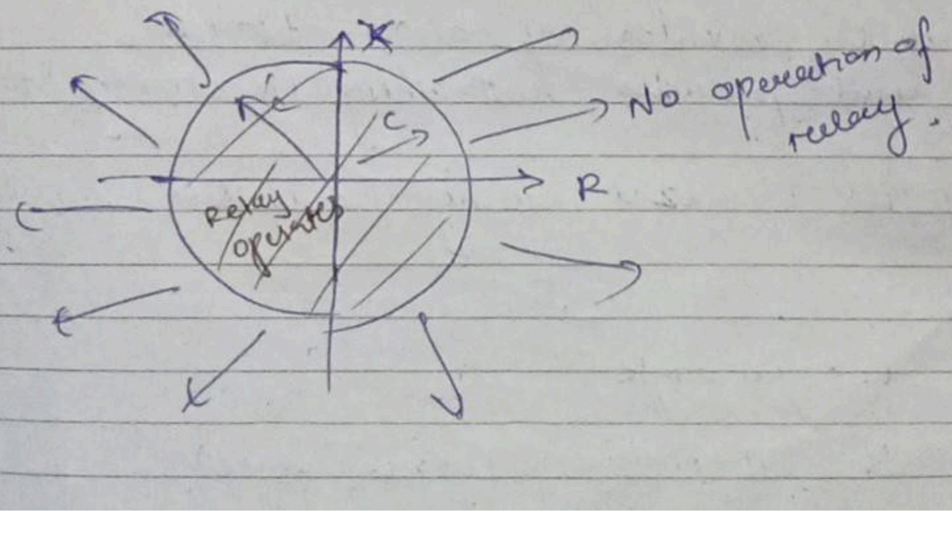
$Z_{set} = \sqrt{R_{set}^2 + X_{set}^2} = \sqrt{\frac{K_1}{K_2}}$

constant ⟶ Z_{set}

$= \sqrt{(R_{set})^2 + (X_{set})^2} = c$

$(R_{set})^2 + (X_{set})^2 = c^2$

⟶ equation of circle center as origin. and radius is c.



Reactance Relay

$$T = K_1 I^2 + K_2 V^2 + K_3 VI \cos(\theta - \tau) + K_4$$

For impedance relay ($Z = R + jX$)

$K_1 = +ve$, $K_2 = 0$, $K_4 = 0$, $K_3 = -ve$

→ torque angle

$$T = K_1 I^2 - K_3 VI \cos(\theta - \tau) \quad \text{—— (1)}$$

(ind^n disk)

current unit ↑ Power unit ↑

(or directional restrained)

- Reactance relay is power restrained over current relay

→ current unit provides operating torque
→ power unit provides restraining (restoring) torque

this relay is realized using induction cup type of relay.

τ → torque angle

$\tau = 90°$ (maximum torque angle).

By eqⁿ ①

$$T = K_1 I^2 - K_3 V I \cos(\theta - 90')$$

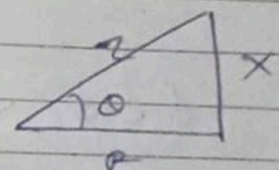
$$T = K_1 I^2 - K_3 V I \sin\theta$$ $V = IK$

under threeshold condⁿ

$$K_1 I^{\cancel{2}} = K_3 V \cancel{I} \sin\theta$$

$$I = V \sin\theta \times \frac{K_3}{K_1}$$

$$\frac{V}{I} = \frac{K_1}{K_3 \sin\theta}$$



$$Z = \frac{K_1}{K_3 \sin\theta}$$

$$Z \sin\theta = \frac{K_1}{K_3}$$

$$\sin\theta = \frac{X}{Z}$$

$$\Rightarrow \boxed{X = \frac{K_1}{K_3}}$$ ← This is set value of Reactance

$$\boxed{X_{set} = \frac{K_1}{K_3}} \quad \text{—— ②}$$

when $X < X_{set}$ then our relay will operate.

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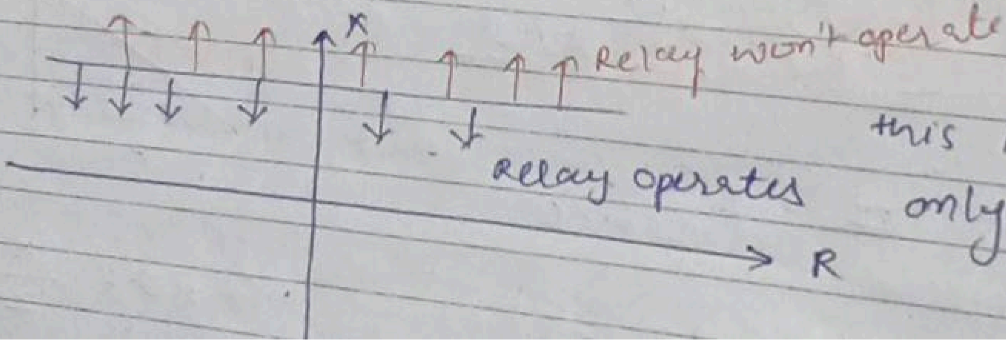
when relay operates.

$$T > 0 \qquad T_{op} > T_{res}$$

$$K_1 I^{\cancel{2}} > K_3 V \cancel{I} \sin\theta$$

$$\frac{V}{I}\sin\theta < \frac{K_1}{K_3}$$

$$\boxed{X_{seen} < X_{set}} \text{ ——— } (3)$$



this is valid only when $\tau = 90$

When $\tau = 0$

$$T = K_1 I^2 - K_3 V I \cos(\theta - \tau)$$

$$T = K_1 I^2 - K_3 V I \cos\theta$$

<u>under</u> threshold condn

$$T = 0 = K_1 I^{\cancel{2}} - K_3 V \cancel{I} \cos\theta$$

$$K_1 I = K_3 V \cos\theta$$

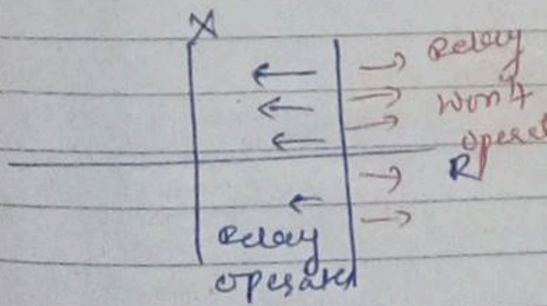
$$\frac{V}{I}\cos\theta = \frac{K_1}{K_3}$$

$$Z\cos\theta = \frac{K_1}{K_3}$$

$$\boxed{R_{set} = \frac{K_1}{K_3}}$$ set value of resistance.

when Relay operates

$$T > 0 \Rightarrow T_{op} > T_{res}$$



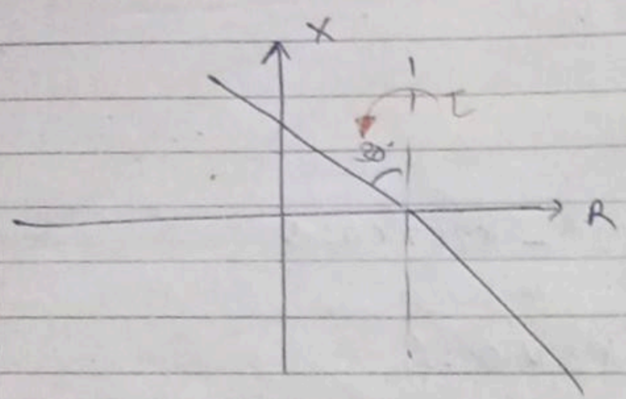
$$K_1 I^2 > K_3 V I \cos\theta$$

$$\frac{V}{I}\cos\theta < \frac{K_1}{K_3}$$

$$\boxed{R_{seen} < R_{set}}$$

when $\tau = 30$

$$T = K_1 I^2 - K_2 V I \cos(\theta - 30^\circ)$$



$0 < \tau < 90^\circ$

- This Relay don't have dir^nal feature

(distance relay)

Mho relay / voltage restrain directional relay

- This relay has directional feature.
- used for protection of long transmission line.

$$T = K_1 I^2 + K_2 V^2 + K_3 VI \cos(\theta - \tau) + K_4$$

→ Restoring force provide.

for mho relay

$K_1 = 0$, $K_2 = -ve$, $K_3 = +ve$, $K_4 = 0$

$$T = K_3 VI \cos(\theta - \tau) - K_2 V^2$$

restraining torque provided by voltage unit

Directional unit (operating torque)

under threshold condⁿ

$T = 0 \Rightarrow$

$$K_3 \cancel{V} I \cos(\theta - \tau) = K_2 V^{\cancel{2}}$$

$$\frac{V}{I} = \frac{K_3 \cos(\theta - \tau)}{K_2}$$

$$\boxed{Z_{set} = \frac{V}{I} = \frac{K_3}{K_2} \cos(\theta - \tau)} \quad \text{--- (1)}$$

Relay will operate when

$T > 0 \Rightarrow K_3 \cancel{V} I \cos(\theta - \tau) > K_2 V^{\cancel{2}}$

operating torque ↳ restraining torque

$$\frac{V}{I} < \frac{K_3}{K_2}\cos(\theta-\tau)$$

$$\boxed{Z_{seen} < Z_{set}}$$

In this condⁿ our relay will operate. — (2)

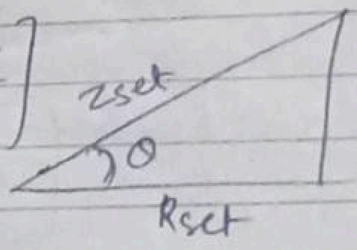
'plotting curve'

$$Z_{set} = \frac{K_3}{K_2}\cos(\theta-\tau) \qquad K_0 = \frac{K_3}{K_2}$$

$$\frac{Z_{set}}{\sqrt{R_{set}^2 + X_{set}^2}} = K_0\cos(\theta-\tau)$$

$$= K_0\left[\cos\theta.\cos\tau + \sin\theta.\sin\tau\right]$$

$$Z_{set} = K_0\left[\frac{R_{set}}{Z_{set}}.\cos\tau + \frac{X_{set}}{Z_{set}}.\sin\tau\right]$$



$$Z_{set}^2 = K_0\left[R_{set}.\cos\tau + X_{set}\sin\tau.\right]$$

$Z_{set}\cos\theta = R_{set}$

$\cos\theta = \frac{R_{set}}{Z_{set}}$

$\sin\theta = \frac{X_{set}}{Z_{set}}$

$$R_{set}^2 + X_{set}^2 = K_0 R_{set} \cos\tau + K_0 X_{set} \sin\tau$$

$$\boxed{R_{set}^2 + X_{set}^2 - K_0 R_{set} \cos\tau - K_0 X_{set} \sin\tau = 0}$$

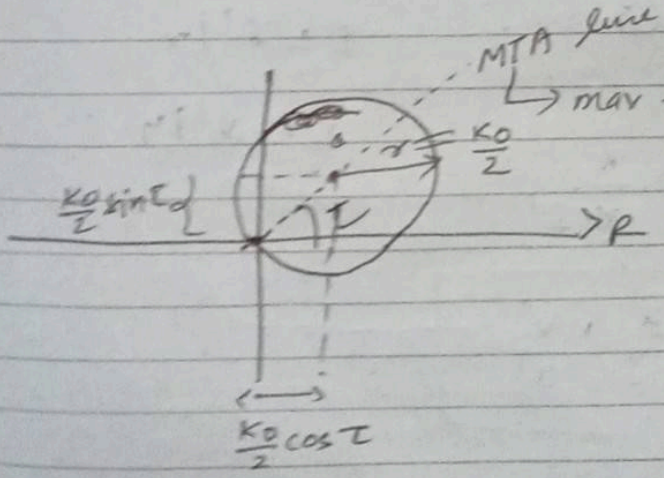
↳ This is circle passing through origin.

$$x^2 + y^2 + 2ax + 2by + c = 0$$

$$\text{Centre} = \left(\frac{K_0}{2}\cos\tau, \frac{K_0}{2}\sin\tau\right).$$

$$\text{radius} = \sqrt{a^2 + b^2 - c} = \frac{K_0}{2}$$

Diameter $= K_0$.



$$r = \frac{K_0}{2}$$

$$D = 2r = K_0$$

Max torque angle $= 65^\circ - 85^\circ$

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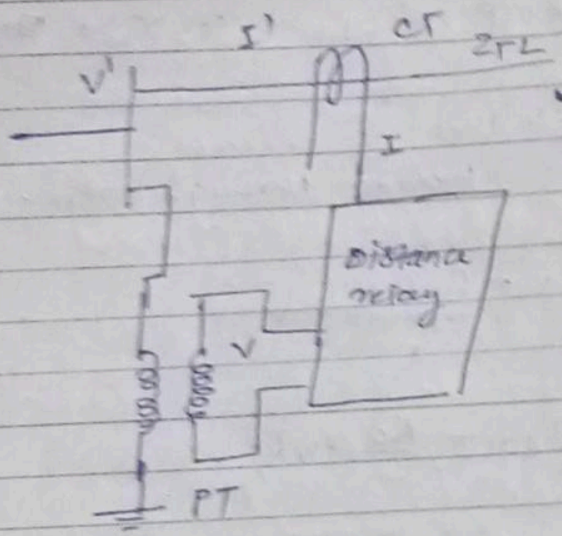
Impedence seen by Relay:



(current transformer)

$x = CT \text{ ratio} = \frac{I'}{I}$ — ①

y = Potential transformer ratio

$= \frac{V'}{V}$ — ②

$V' = I' Z_{TL}$

$Z_{seen} = \frac{V}{I}$ — ③

$x = \frac{I'}{I}$

from ①, ② and ③

$I = I'/x$

$V = V'/y$

$$Z_{seen} = \frac{V'}{y} \times \frac{x}{I'}$$

$$\boxed{Z_{seen} = \frac{x}{y} \times \frac{V'}{I'}}$$

PT

CT =

Que 132 KV TL is protected by distance relay the relay is connected to the supply circuit through 132 KV/110 V PT and 1000/5A CT impedence of TL 120 Ω, calculate

① impedence seen by the relay for a fault at middle of TL.

② calcule impedence seen by a relay for a fault at a middle of TL, with error in CT is ± 5% and error is PT is ± 5%.

132kV

PT $y = \frac{132\,kV}{110\,V} = \frac{\cancel{132}\times 10^{3}}{\cancel{110}} = 1200$

$Z_{seen} = \frac{1000}{5} \times \frac{110}{132} \times 120$

CT $= x = \frac{\cancel{1000}}{\cancel{5}}\,A = 200$

$x = 200$

$y = \cancel{12000}\ 1200$

$Z_{TL} = 120\Omega$

Middle of T.L. $(Z_{TL})_{middle} = 60\Omega = \frac{120\Omega}{2}$

$Z_{seen} = \frac{x}{y} \times (Z_{TL})_{middle} = \frac{\cancel{200}}{\cancel{1200}} \times 6\cancel{0} = 10\Omega$

② With error :

CT error = $\pm 5\%$

PT error = $\pm 5\%$

Total error = 10%

$Z_{seen} = 10 \pm 10 \times 0.1$ (?)

$$\boxed{Z_{seen} = 9 \text{ to } 11\,\Omega}$$

10

20-1-23

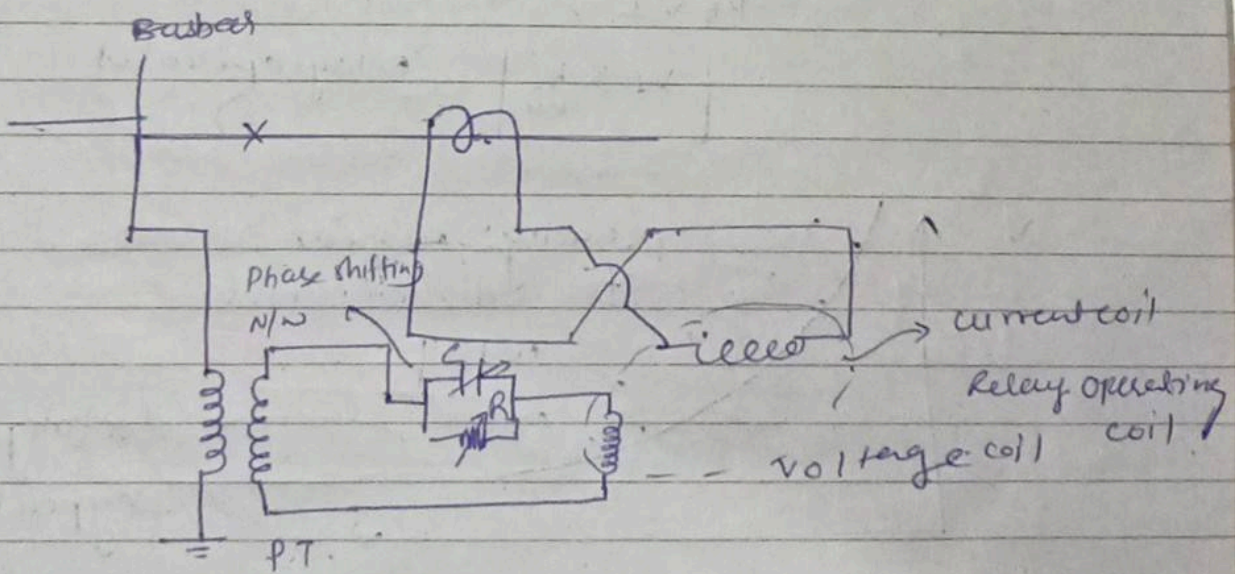
Directional relay:

- whenever dirn of current has reversed then also relay should operate. so we use directional relay

$$T = K_1 I^2 + K_2 V^2 + K_3 VI\cos(\theta - \tau) + K_4$$

$$K_1 = K_2 = 0, \quad K_3 = +ve, \quad K_4 = -K$$

$$T = K_3 VI\cos(\theta - \tau) - K$$ spring Restraining torque



Let $K_4 = K_3 \cos(\theta - \tau)$

$$T = K_4 VI - K$$

Under threshold condition.

~~Ro.~~ $T = 0 \Rightarrow T_{op} = T_{res}$

$$K_4 V I = K$$

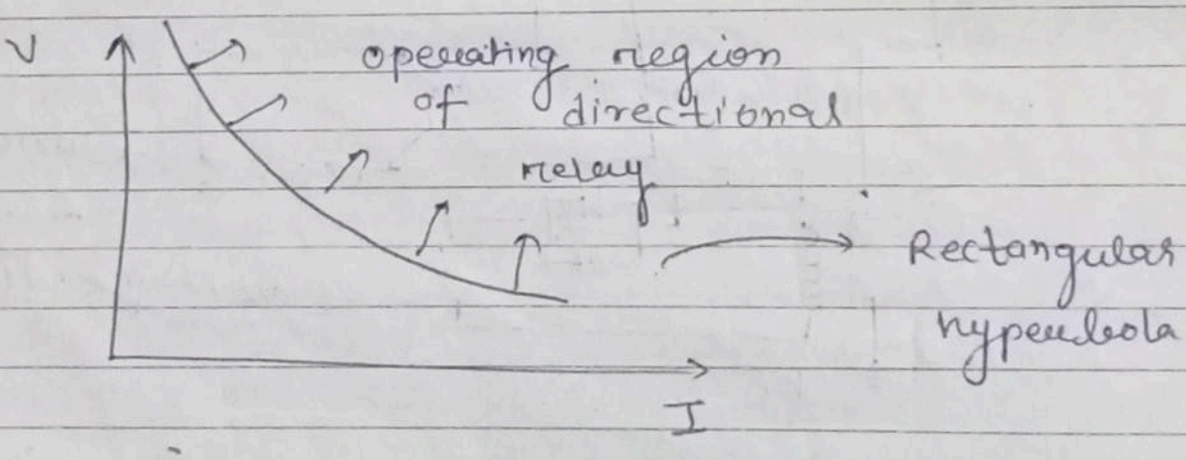
$$\boxed{VI = \frac{K}{K_4}}$$

Relay will operate when

$$T_{op} > T_{res}$$

$$K_4 V I > K$$

$\boxed{VI > \frac{K}{K_4}}$ Relay operates.



Electromechanical relay:

→ moving parts + magnet

Static relay:

→ No moving parts inside relay.

<1> Electronics relays:

<2> Transductor (magnetic amplifier).

<3> rectifier bridge type (**) imp

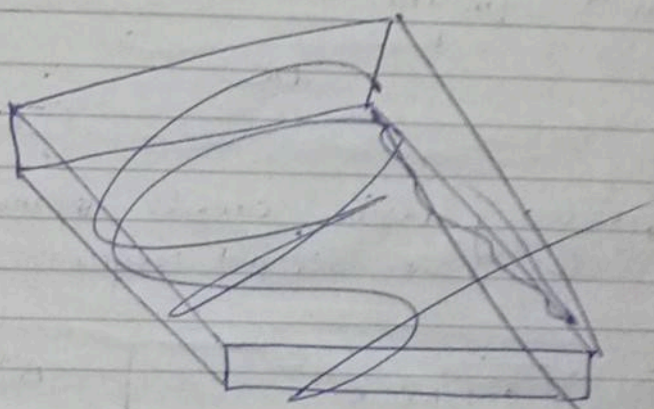
<4> Transistor. relays

<5> Hall effect relays

<6> Gauss effect relays

** (imp)

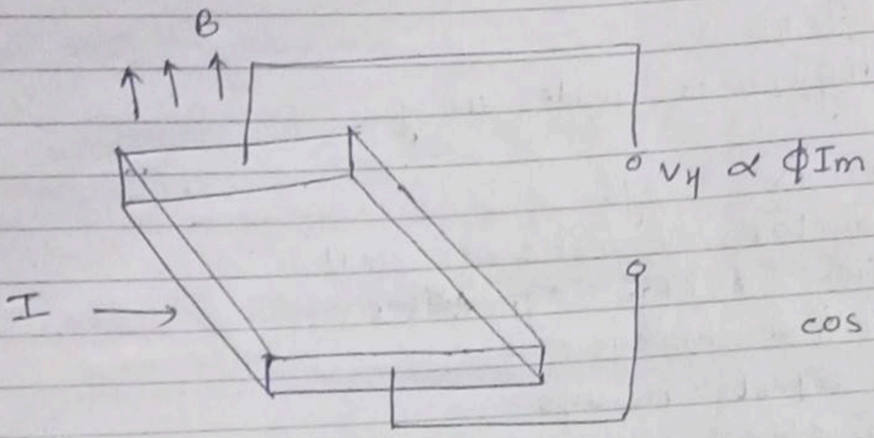
Hall effect relays



$\phi = \phi_m \sin\omega t$

$i = I_m \sin(\omega t + \alpha)$

$$\sin A . \sin B = \frac{\cos(A-B) - \cos(A+B)}{2}$$



$V_H \propto \phi I_m$

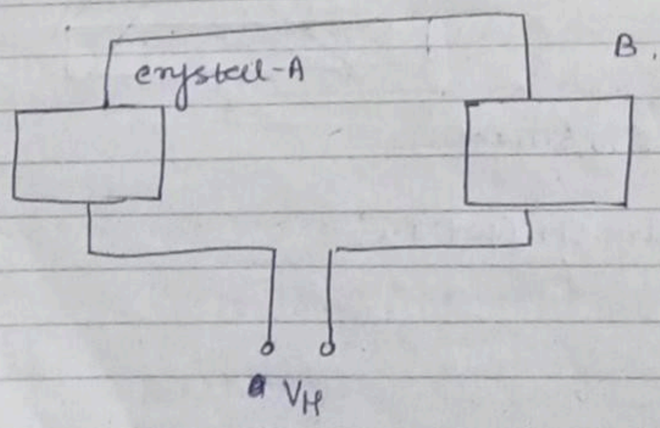
cos A

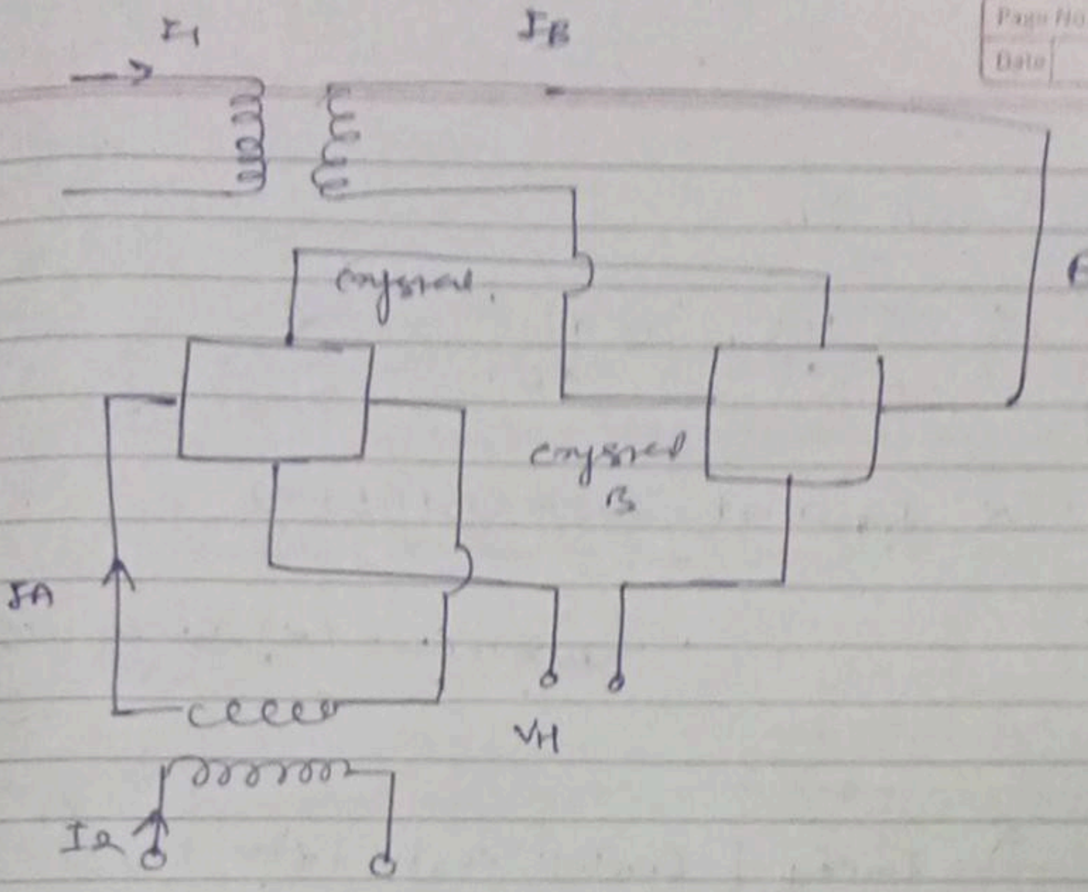
$$V_H \propto \phi_m \sin\omega t . I_m \sin(\omega t + \alpha)$$

$$V_H \propto \underbrace{\phi_m . I_m . \cancel{\cos} [\cos\alpha}_{DC} - \cos(\underbrace{2\omega t}_{AC} + \alpha)]$$

→ double frequency term create maloperation in relay. so we doesn't require this ~~relay~~ term.

#





doing cross connection to avoid double frequency term.

$I_1 = I_{m1} \sin(\omega t)$

$I_2 = I_{m2} \sin(\omega t + \alpha)$.

flux through the crystal A & B.

$\phi_A \propto I_1$

$\phi_B \propto I_2$

and current through the crystal A & B.

$$I_A \propto \frac{dI_2}{dt} \,, \quad I_B \propto \frac{dI_1}{dt}$$

$V_H \propto V_A - V_B$

$V_H \propto I_1 \frac{dI_2}{dt} - I_2 \cdot \frac{dI_1}{dt}$

$\propto I_{m_1} \sin \omega t \cdot I_{m_2} \omega \cos(\omega t + \alpha)$

$- I_{m_2} \sin(\omega t + \alpha) \cdot \omega \cdot I_{m_1} \cos(\omega t)$

$\propto I_{m_1} I_{m_2} [\sin \omega t \cdot \cos(\omega t + \alpha)$
$- \sin(\omega t + \alpha) \cdot \cos(\omega t)]$

$\propto I_{m_1} I_{m_2} [\sin(\omega t - (\omega t + \alpha))]$

$\propto - I_{m_1} I_{m_2} \sin \alpha$

$$\boxed{V_H \propto I_{m_1} I_{m_2} \sin \alpha}$$

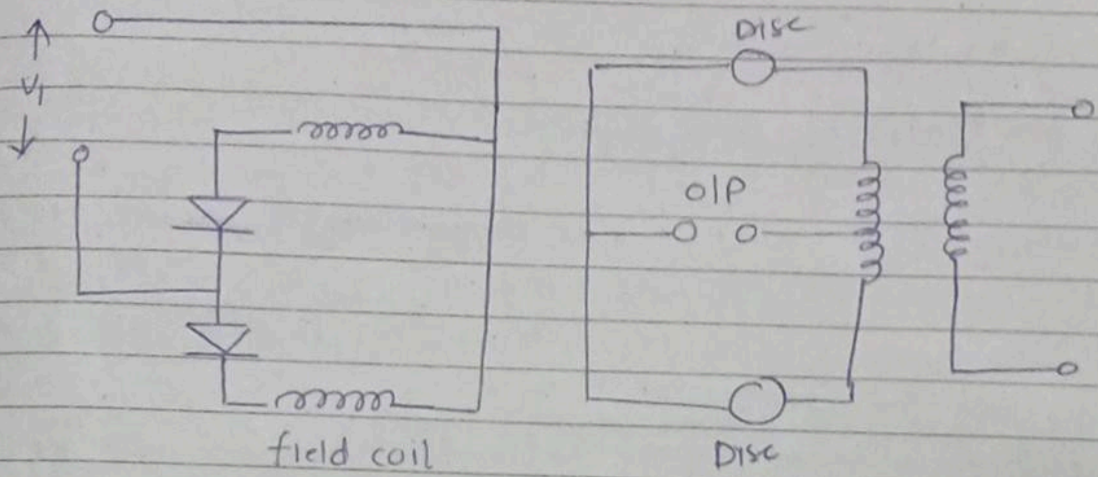
→ ussa H use karte hai.

→ element is $\underbrace{\text{Indium Antimonite}}_{\text{Indium}}$] Hall crystal

crystal used for hall generation.

31-01-23

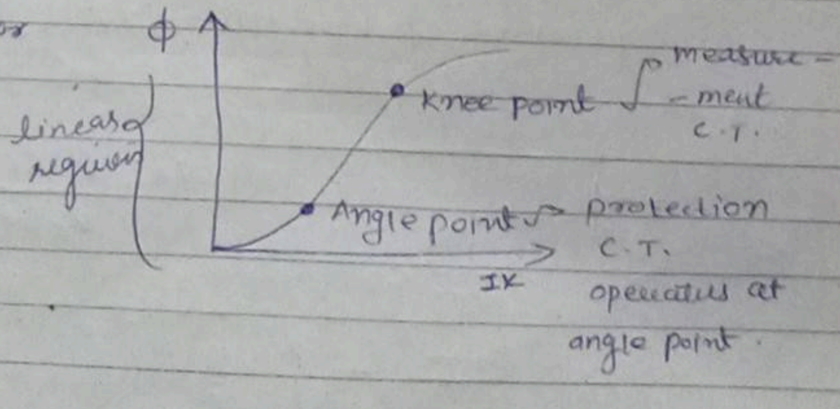
Gauss effect relay:



O/P voltage $\propto V_1 V_2 \cos\theta$

maximum voltage $(\theta = 0)$
minimum voltage $(\theta = 90°)$

C.T/P.T
↳ Phase angle error
↳ Ratio error

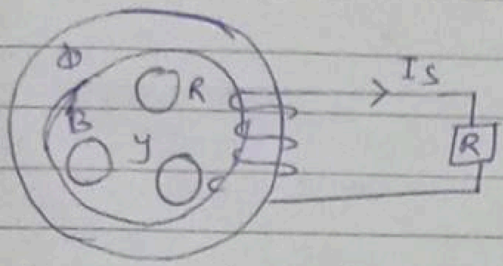


* based on the insulation we decide voltage level of any line.

(CBCT)

Core Balanced CT:

→ leakage / earth current protection.



$$I_s \propto \phi$$

$$\cancel{\phi \propto \phi_R , \ \phi \propto \phi_y , \ \phi \propto \phi_B}$$

$$\phi \propto (\phi_R + \phi_y + \phi_B)$$

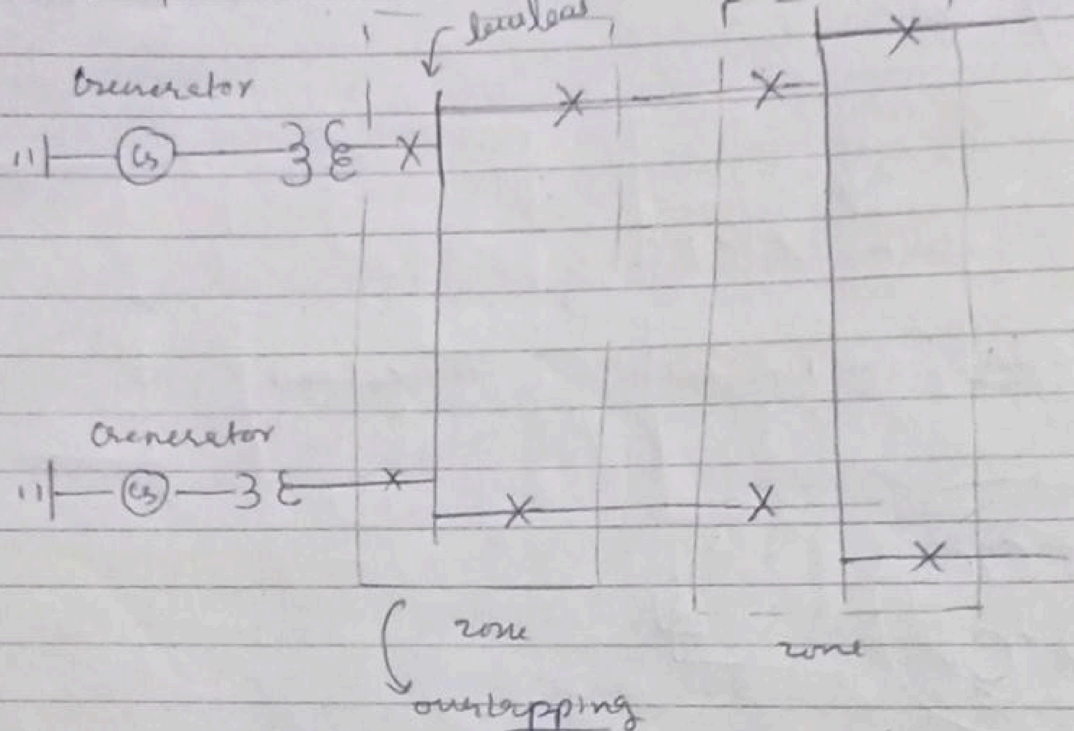
$$I_S \propto (\phi_R + \phi_Y + \phi_B)$$

$$I_n = \frac{1}{3} (I_R + I_y + I_B) \quad \text{(neutral current)}$$

$$I_s \propto (I_R + I_y + I_B)$$

$$\boxed{I_s \propto 3 I_0} \Rightarrow \text{core balance CT.}$$

zones of protection :-



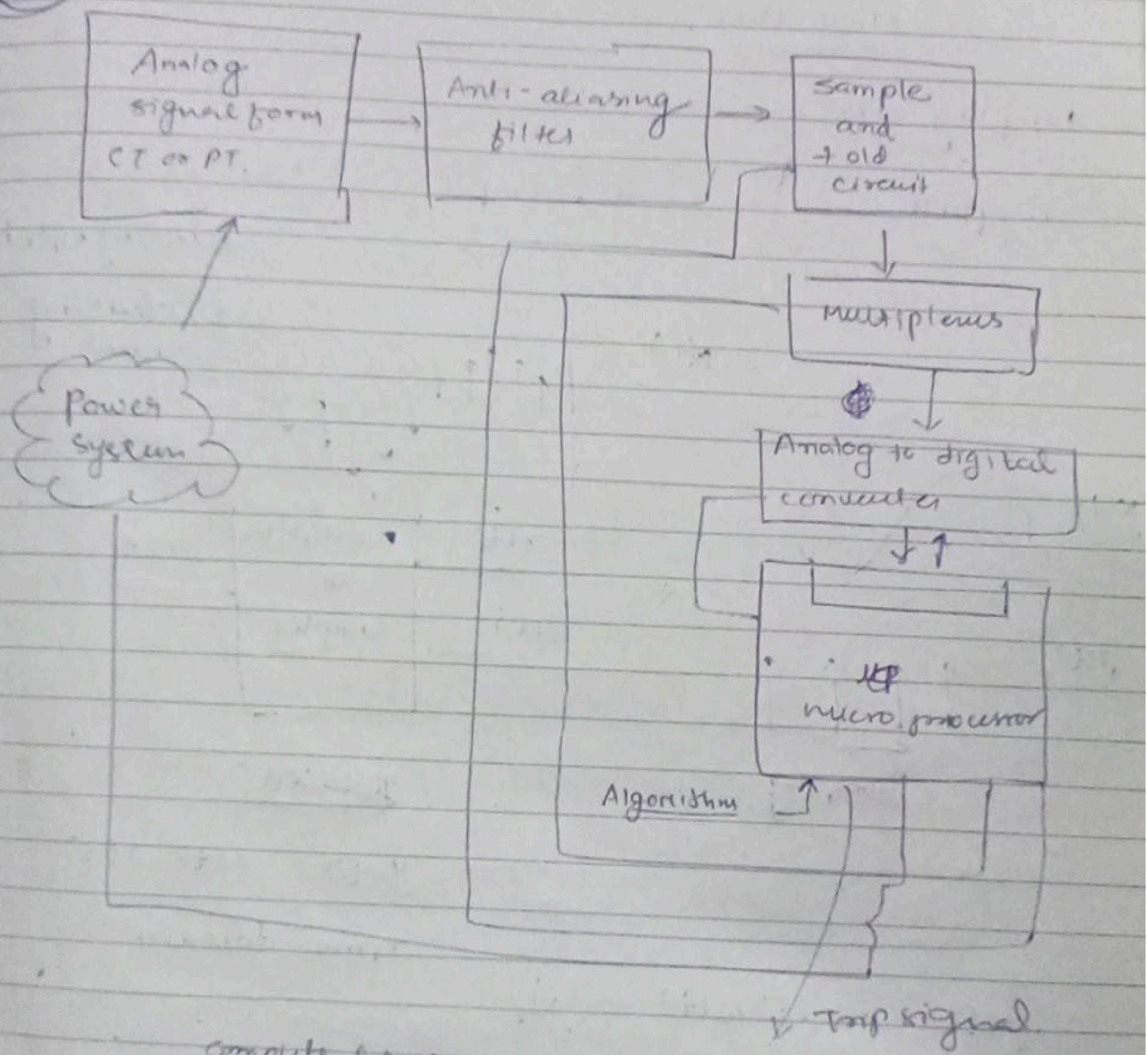
* Protection means continous monitoring of the system

* overlap the system to avoid the blind spot.

Unit 2

Imp

Numerical Relay



compute block diagram

inside microprocessor we designed everything overcurrent relay, underfreq relay

→ watchdog timer ( ) in microprocessor → Read

2-02-23

Imp

sampling theorem:

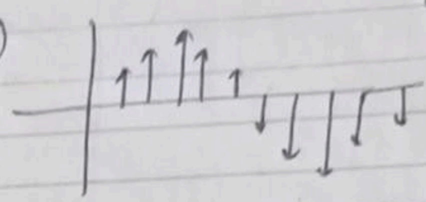
sampling theorem def:

Nyquist $\qquad$ so fsample = 2 Mess

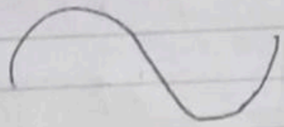
aliasing effect

anti aliasing effect

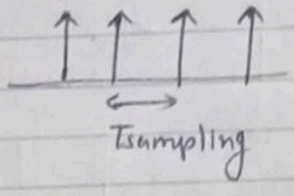
s(t)

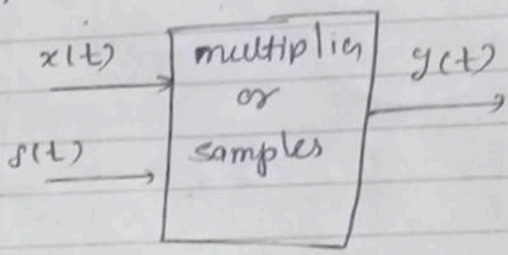


x(t)



δ(t)





~~y(t)=x.δ~~

$y(t) = x(t).\delta(t)$

Time-domain.

$$g(t) = x(t).\delta(t) \quad \text{--- (1)}$$

$$\delta_0(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos n\omega t + b_n \sin n\omega t. \quad \text{--- (2)}$$

$$a_0 = \frac{1}{T_s} \int_{-T/2}^{T/2} \delta(t).dt \to \delta($$

t=0

δ(0)=1

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$$\boxed{a_0 = \frac{1}{T_s}}$$

$$a_n = \frac{2}{T_s}\int_{-T/2}^{T/2} \delta(t).\cos n\omega t \, dt$$

$t = 0$

$$a_n = \frac{2}{T_s}\int_{-T/2}^{T/2} \delta(0).\cos n\omega(0)$$

$$\int_{-T/2}^{T/2} \delta(t)\, dt = 1$$

$$a_n = \frac{2}{T_s}$$

$$b_n = \frac{2}{T_s}\int_{-T/2}^{T/2} \delta(t).\sin n\omega t \qquad t = 0$$

$$b_n = 0$$

$$\delta(t) = \frac{1}{T_s} + \sum_{n=1}^{\infty} \frac{2}{T_s}.\cos n\omega t + 0$$

$$\delta(t) = \frac{1}{T_s}\left(1 + 2\cos n\omega t + \ldots\ldots\right) \quad \text{--- (3)}$$

substitute equation (3) in (1)

$$y(t) = x(t)\frac{1}{T_s}\left(1 + 2\cos\omega t + 2\cos 2\omega t + 2\cos 3\omega t\right)$$

$\delta \to$ sample signal.

$$y(t) = \frac{1}{T_s}\left(x(t) + 2x(t)\cos\omega t + 2x(t).\cos 2\omega t + \dots\right)$$

$$x(t) \xleftrightarrow{FT} X(\omega)$$

sampling freq

$$e^{j\omega t}\, x(t) \longleftrightarrow X(\omega - \omega_s)$$

$$x(j\omega) = \int_{-\infty}^{\infty} x(t).\, e^{-j\omega t}.dt$$

$$e^{j\omega}x(j\omega) = \int_{-\infty}^{\infty} x(t).\, e^{-j(\omega-\omega_s)t}.dt$$

$$e^{-j\omega t}.\, x(t) \longleftrightarrow X(\omega + \omega_s).$$

$$2\cos\omega t = \cancel{2}.\left(\frac{e^{j\omega t} + e^{-j\omega t}}{\cancel{2}}\right)$$

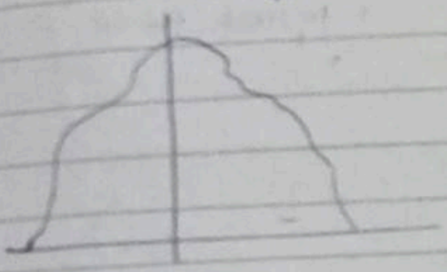
$$y(\omega) = c\left(X(\omega) + X(\omega-\omega_s) + X(\omega+\omega_s) + X(\omega-2\omega_s) + X(\omega+2\omega_s) + \dots\right)$$

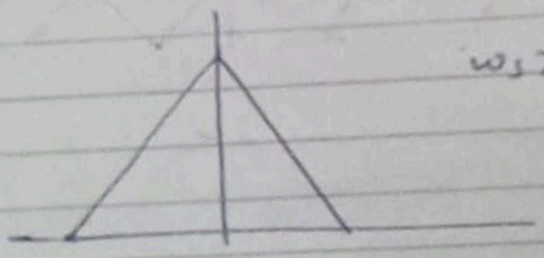
$$y(\omega) = \frac{1}{T_s}\sum_{-\infty}^{\infty} X(\omega - n\omega_s)$$

spectrum of signal

Time-domain

frequency domain

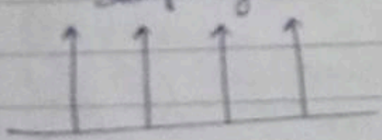


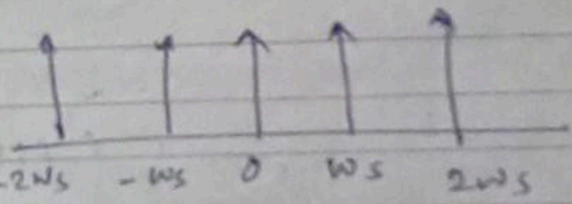


$\omega_s > 2\omega_m$

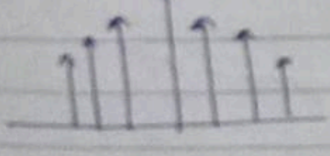
spectrum of sampled signal

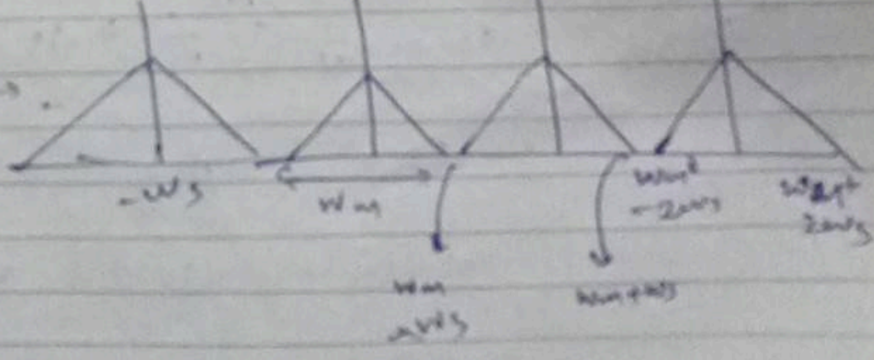
sampling

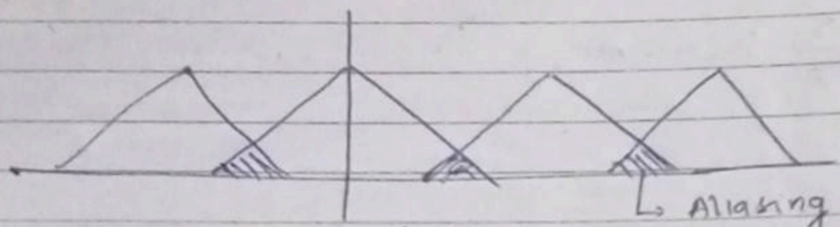




spectrum of sampled signal $\omega_s > 2\omega_m$

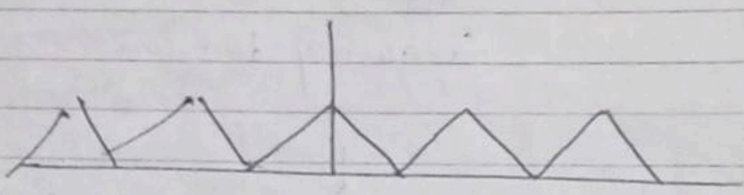






$\omega_s < 2\omega_m$

Aliasing effect



$\omega_s = 2\omega_m$

Nyquist rate

Fourier series :- Numerical relay

$$f(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos n\omega t + b_n \sin n\omega t$$

$$\downarrow$$

$$a_0 = \frac{1}{T}\int_0^{T_1} f(t)\,dt \quad \text{--- (I)}$$

$$a_0 = \frac{1}{N}\sum_{k=1}^{N} f(k.\Delta t)$$

Δt = T.sampling.

N = no of sample per cycle

Fouries Transfor

Discrete fouries transform

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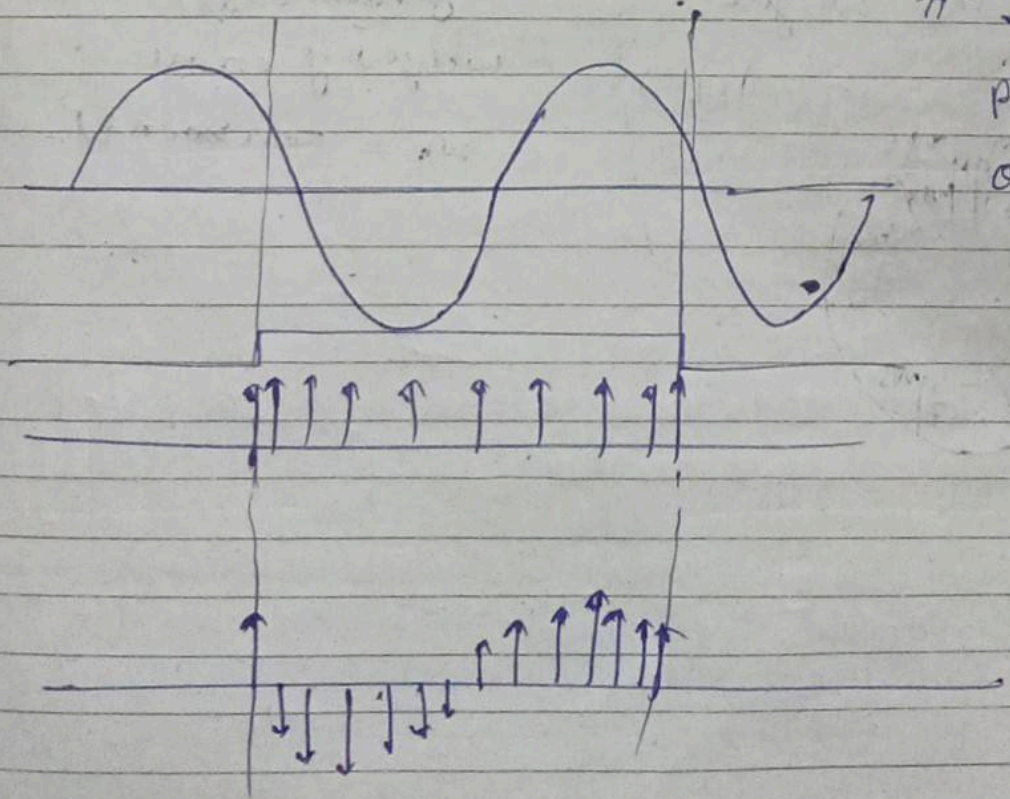
· Discrete fourier transform

$$a_0 = \frac{1}{N} \sum_{K=1}^{N} f(K.\Delta t)$$

$$a_n = \frac{2}{N} \sum_{K=1}^{N} f(K.\Delta t) . \cos(n\omega K \Delta t).$$

$$b_n = \frac{2}{T} \int_0^T f(t) . \sin n\omega t \, dt .$$

$$\Delta t = T_{sampling} = \frac{1}{f_{sampling}}$$

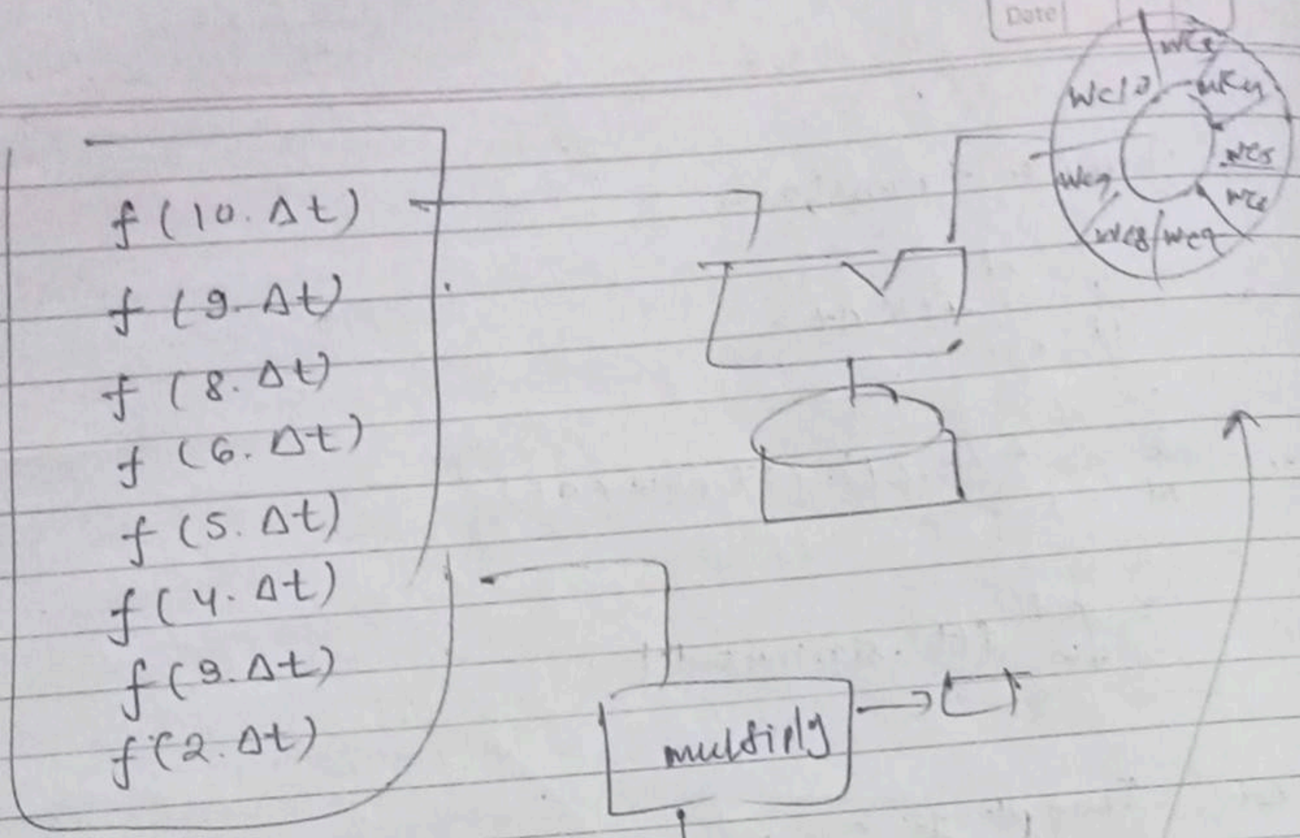


amplitude

$$f_1 = \sqrt{a^2 + b^2}$$

phase angle

$$\theta = \tan^{-1}\left(\frac{b_1}{a_1}\right)$$



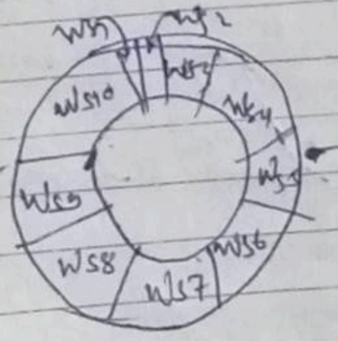
precomputed
value stored
in memory.

fundamental weight:

$w_{sn} = \sin(n\omega_s t)$

fundamental
weight of cosine

$w_n = \cos(n\omega\Delta t)$



Least error squared technique

$$i(t) = \underbrace{K_1 e^{-t/\tau}}_{\text{dc signal}} + \sum_{n=1}^{\infty} \underbrace{K_{2n} \sin(n\omega t + \theta_n)}_{\text{harmonics + fundamental}}$$

$$e^{-t/\tau} = \left(1 - \frac{t}{\tau} + \frac{t^2}{2!\tau^2} - \frac{t^3}{3!\tau^3} + \cdots \right)$$

$$K_1 e^{-t/\tau} = K_1 - \frac{K_1 t}{\tau} + \frac{K_1 t^2}{2\tau^2}$$

$$i(t) = K_1 - \frac{K_1 t}{\tau} + \frac{t^2}{2\tau^2} + K_{21} \sin(\omega t + \theta_1)$$

$$+ K_{23} \sin(3\omega t + \theta_3)$$

$$i(t) = K_1 - \frac{K_1 t}{\tau} + \frac{t^2}{2\tau^2} + K_{21} \sin\omega t . \cos\theta_1 +$$

$$K_{21} \cdot \sin\theta_1 \cdot \cos\omega t$$

$$+ K_{23} \sin(3\omega t) \cos(\theta_3)$$

$$+ K_{23} (\cos 3\omega t) \sin\theta_3 + \text{———}$$

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Let us denote unknown by x and known by a

$$f(t_1) = a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 + a_{15}x_5$$
$$+ a_{16}x_6 + a_{17}x_7$$
$$= Ax(t)$$

where unknown | known

$x_1 = k_1$ | $a_{11} = 1$

$x_2 = k_{21}\cos\theta_1$ | $a_{12} = \sin\omega t$

$x_3 = k_{23} \cancel{\cos\theta_3} \sin\theta_1$ | $a_{13} = \cos\omega t$

$x_4 = k_{23}\cos\theta_3$ | $a_{14} = \sin 3\omega t$

$x_5 = k_{23}\sin\theta_3$ | $a_{15} = \cos 5\omega t$

$x_6 = -k_1/\tau$ | $a_{16} = t$

$x_7 = \frac{k_1}{2\tau^2}$ | $a_{17} = t^2$

$$i(t_1) = a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 + a_{15}x_5 + a_{16}x_6 + a_{17}x_7$$

$$i(t_2) = a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 + a_{25}x_5 + a_{26}x_6 + a_{27}x_7$$

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$$i(t_7) = a_{71}x_1 + a_{72}x_2 + a_{73}x_3 + a_{74}x_4 + a_{75}x_5 + a_{76}x_6 + a_{77}x_7$$

$$\begin{bmatrix} i(t_1) \\ \vdots \\ i(t_7) \end{bmatrix}_{7\times1} = \begin{bmatrix} a_{11} & \cdots & a_{17} \\ \vdots & & \\ a_{71} & \cdots & a_{77} \end{bmatrix}_{7\times7} \begin{bmatrix} x_1 \\ \vdots \\ x_7 \end{bmatrix}_{7\times1}$$

$$x_{7\times1}(t) = A^{-1}_{7\times7}\, I(t)_{7\times1}$$

$$F_1 = \sqrt{x_2^2 + x_3^2}$$

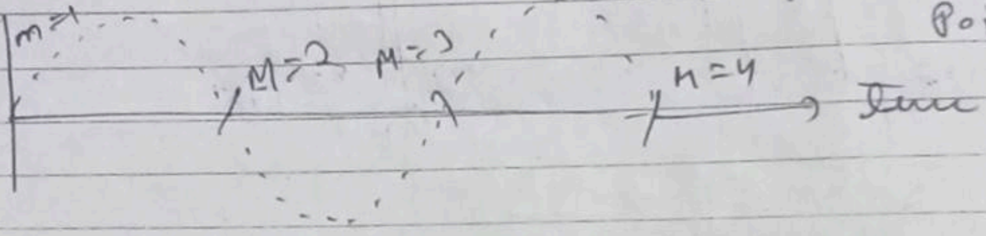
$$\theta_1 = \tan^{-1}\left(\frac{x_3}{x_2}\right)$$

3-01-23

Frequency estimation:

1> zero crossing method.
2> Phasor based method.

m = No. of zero crossing points



$$f(t_m) = \frac{m-1}{2} \cdot \frac{1}{(t_m - t_1)}$$

t_1 : time ~~period~~ of first zero crossing

t_m : time of m^{th} zero crossing

f : frequency estimated

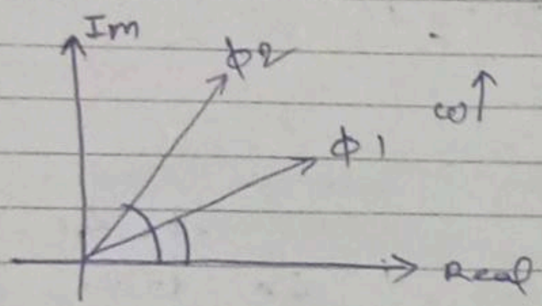
* This method require no of ~~prefilters~~ bandpass filters & low pass filters ~~postfilters~~

↳ because harmonics also creates zero crossing point.

* because of harmonics thermal capacity of motor decreases.

zero crossing method:

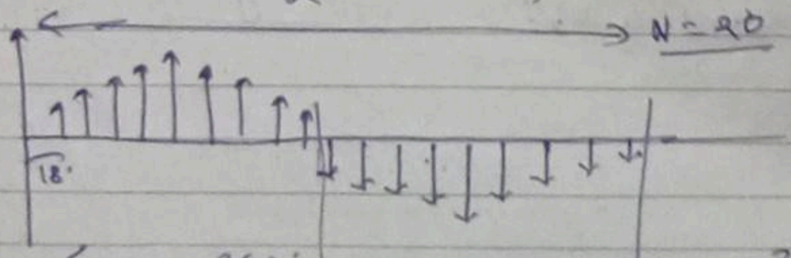
→ To integrate pv system with grid we use this method.



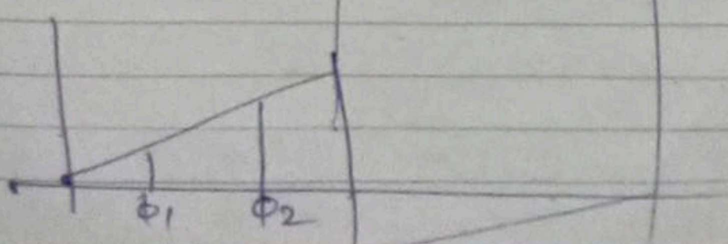
$$2\pi f = \omega = \frac{d\phi}{dt}, \quad f = \frac{1}{2\pi}\frac{d\phi}{dt}$$

↳ f is rate of change of phasor value

$10 = \frac{N}{2}$



$\frac{360}{20} = 18°$



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$\underline{\phi} =$

angle angle

$\phi_2 - \phi_1 = 18^\circ$

K : integer no of samples

T_s : sampling freq.

$2\pi f K_2 T_s - 2\pi f K_1 T_s = 18^\circ$

18°

$f = \frac{1}{2\pi} \frac{d\phi_2 - d\phi_1}{dt_2 - dt_1}$

$$f = \frac{18}{2\pi (K_2 - K_1) T_s}$$

$$f = \frac{1}{2\pi} \frac{\phi_2 - \phi_1}{t_2 - t_1}$$

Asg: phsor estimation by exponential form of fourier series (Before exam) thant this be in dierect form

1) half cycle DFT
2) cosine transform (8 pages)
3) Recursive DFT