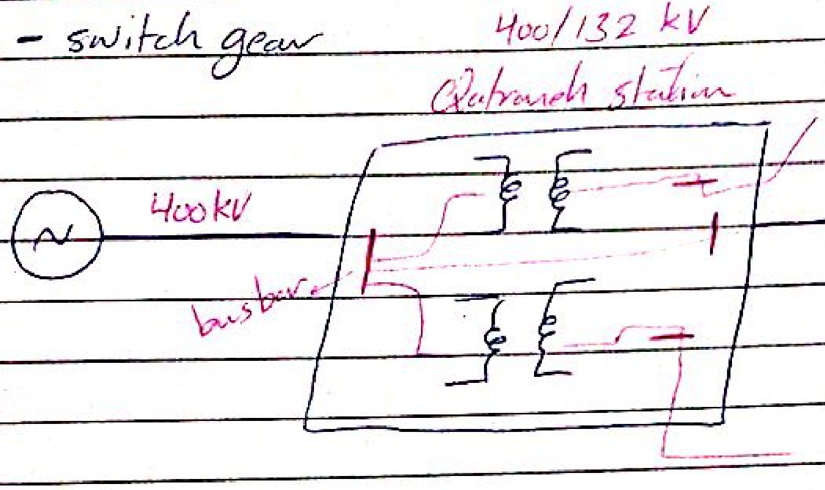
18-9-2017
Monday

- bus bar
- switch gear



Relay
transducer
ckt breaker
relay controller

} → switch gear

* power system protection elements :-

1) Relay : detects the fault, decide what are the faulty conditions.

2) Battery (110 Vdc) system to energize the Relays.

3) Transducer : (current transformer, Voltage transformer sensors). They transform the electrical system Quantity to relay Quantity.

4) ckt breaker : To interrupt the ckt

* properties of relaying function:

→ Fast

→ Automatic

→ cause minimum disruption "Minimize damage"

"Minimize disconnected area"

* prediction of fault condition

it's impossible

but we have what we called incepient fault

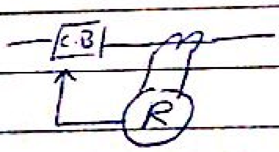
like «Buchholz Relay»

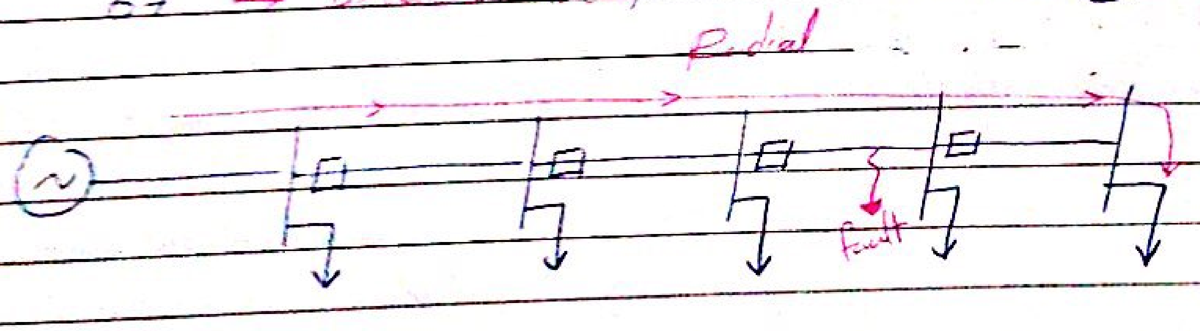
* consideration of ur system configuration:

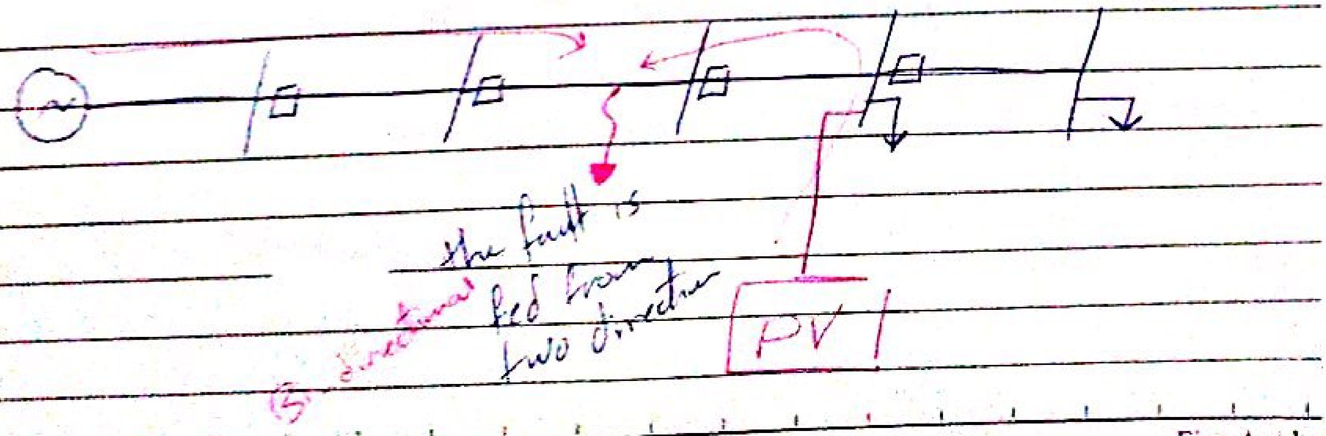
→ Directional elements

50/51 → over current (OC)

67 → Directional (DOC)

□ ≡ 



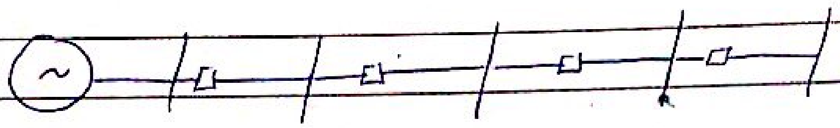


20-9-2017
Wensday

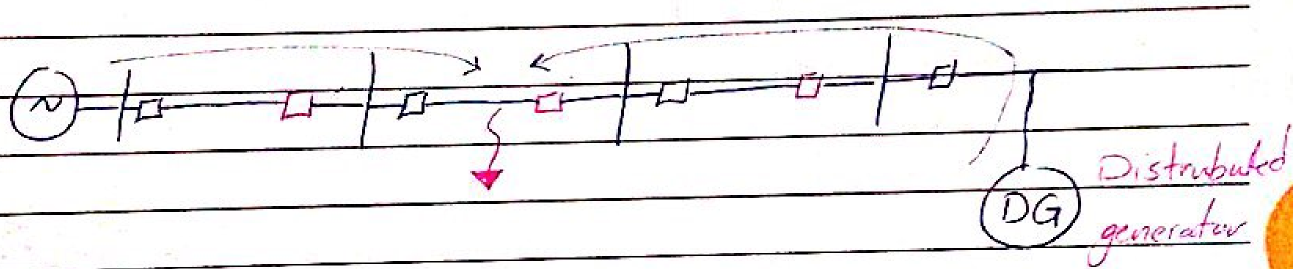
** System configration effect on Relaying system :-

[1] DOC oR OC

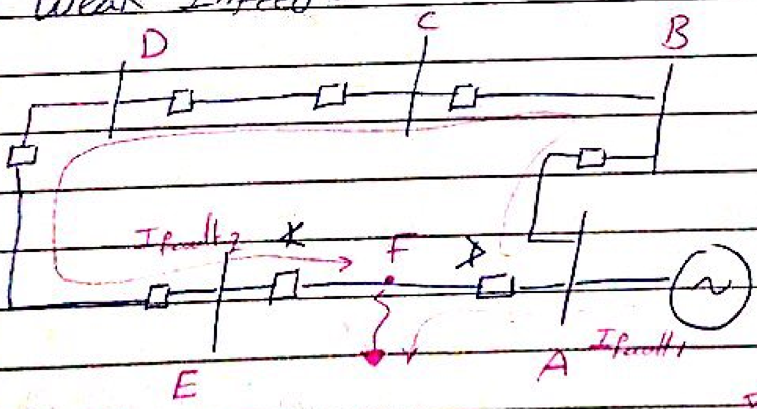
→ uni-directional :



→ Bi-directional :



[2] Weak Infeed :-



⇒ the traditional DOC oR OC will not work

$$I_{fault\,1} = \frac{V_A}{Z_{AF}} \qquad I_{fault\,2} = \frac{V_A}{Z_{AB} + Z_{BC} + Z_{CD} + Z_{DE} + Z_{EF}}$$

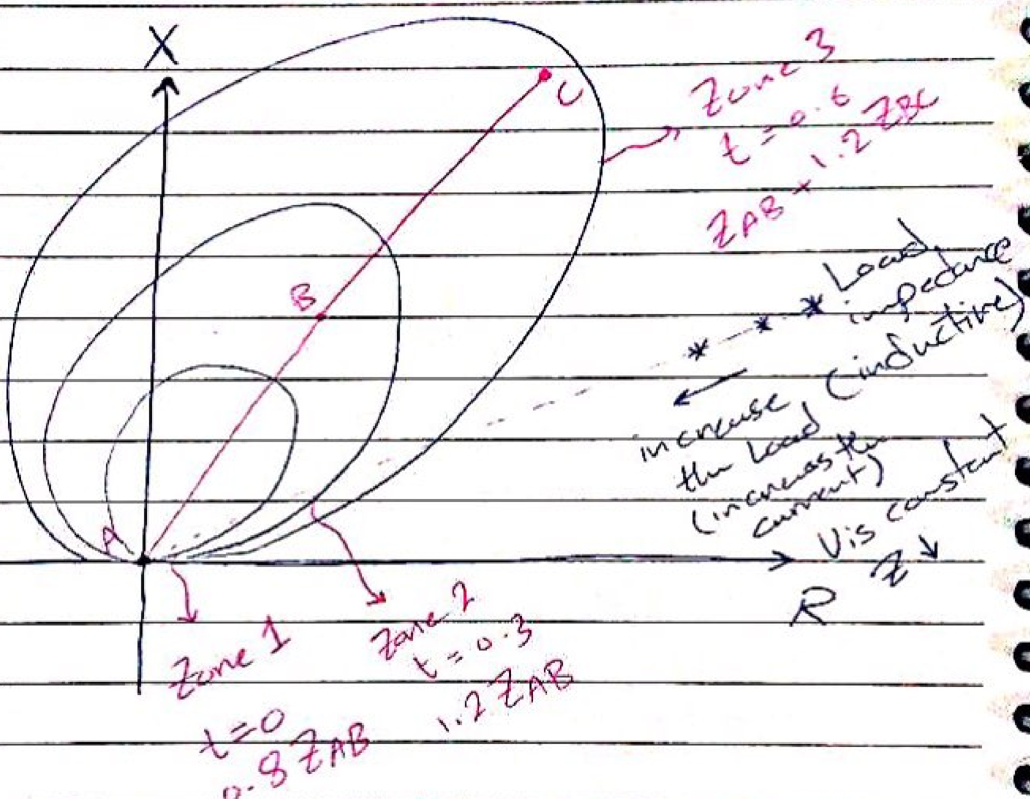
*problem : Relay E & Relay A will see the fault

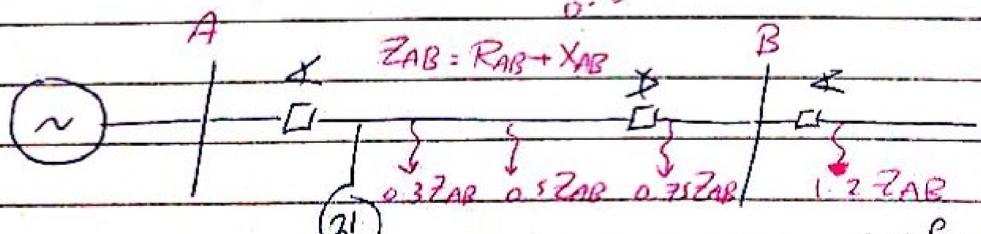
⇒ to solve this problem : use diffrential communication between the Relays.

Five Apple

[3] 3rd Zone of distance Relay.

$\frac{X}{R} \cong 7 \ \Omega$ of the line





Any fault here RB will work, but if didn't work RA work, consider it in Zone 2

⇒ by default:

if $Z_{measured} < Z_{AB}$
Trip
Else
No trip

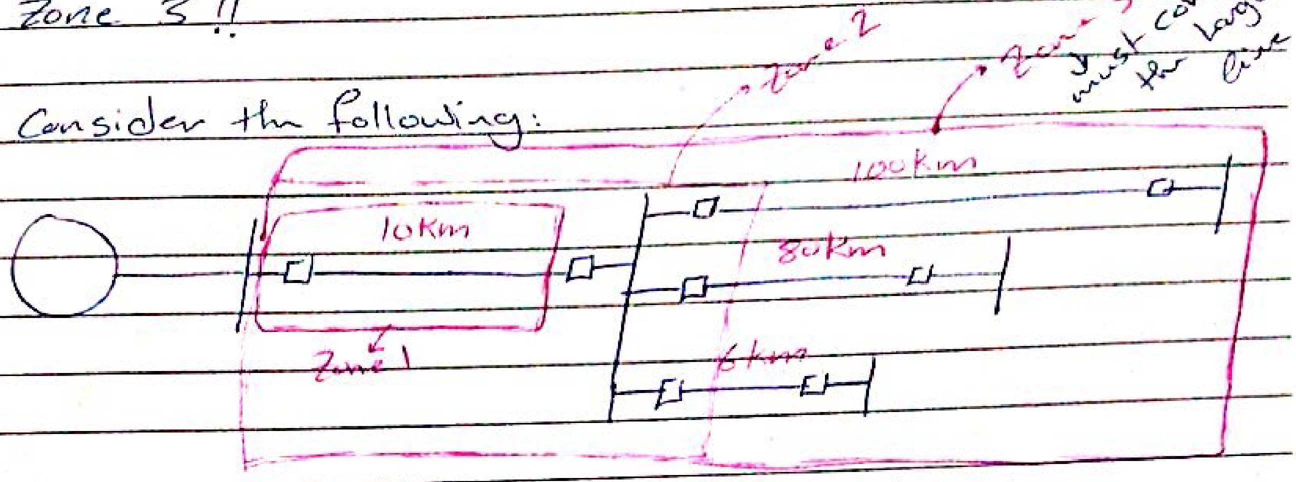
↳ but actually it $0.8 Z_{AB}$

because of : → the inaccuracy of the CT & VT

→ the fault impedance

* So the problem is that the load come closer to Zone 3 !!

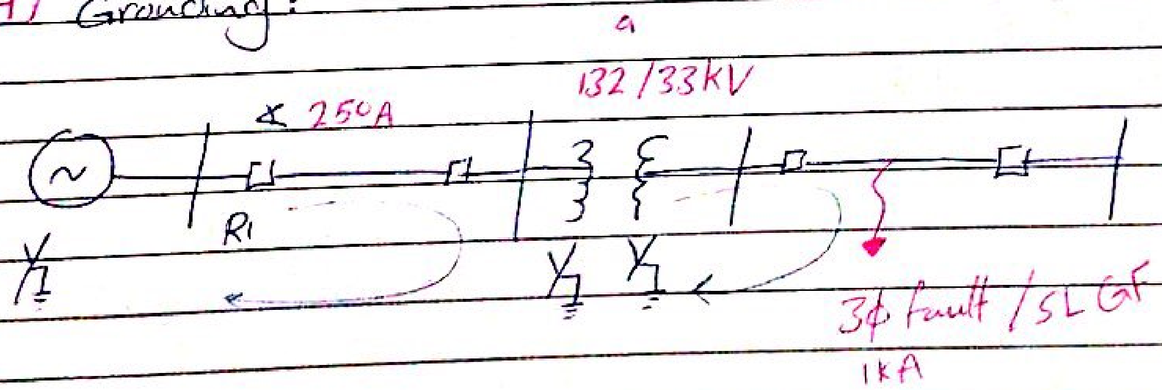
Consider the following:



Also, here will have a problem if the shortest line was connected to many lines, here we need to increase Zone 3 ⇒ So it may touch the load !!

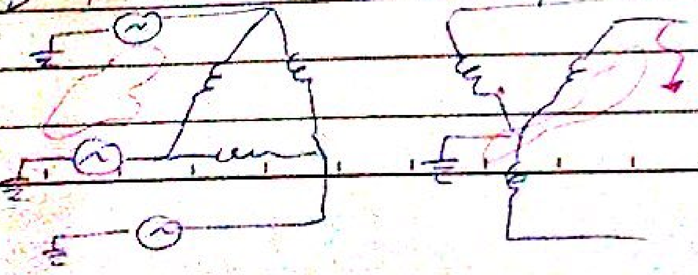
→ Solution: consider only Zone 1 & Zone 2 only.

[4] Grounding:



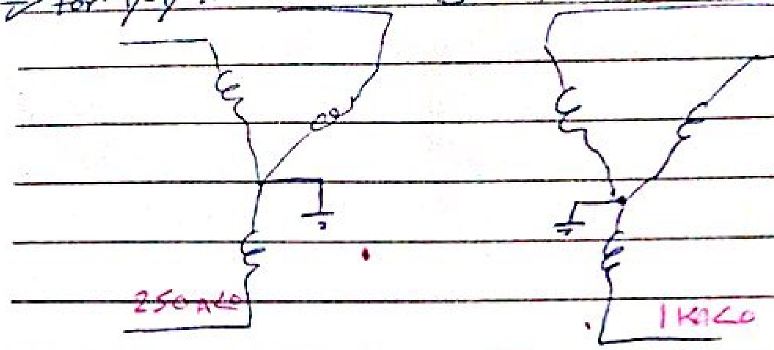
⇒ If the connection of the transformer was Y-Y any type of fault R_1 will see it

⇒ if the connection Δ-Y:



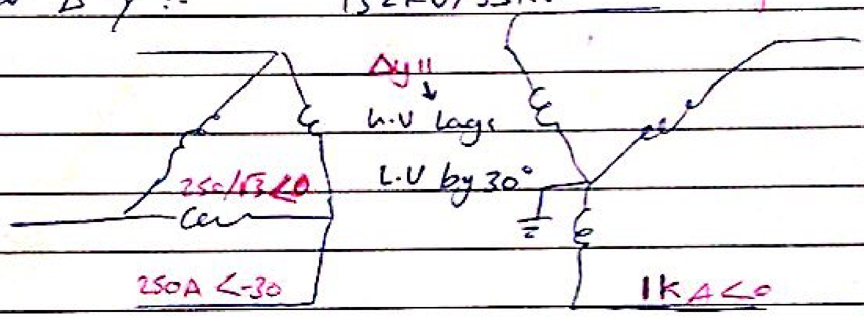
25-9-2017
Monday

⇒ for Y-Y :- 132 KV/33KV

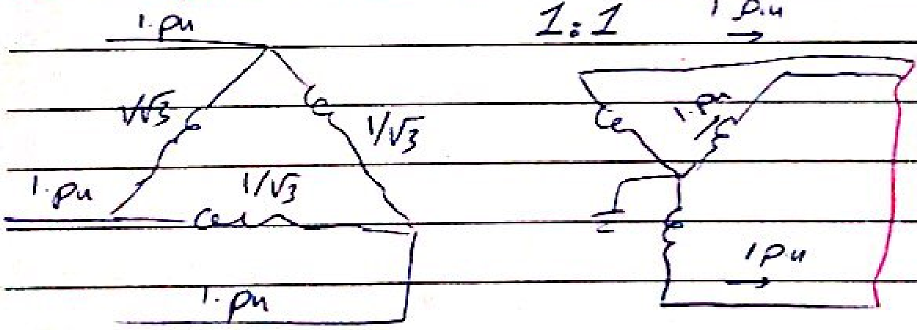


in healthy condition

⇒ for Δ-Y :- 132KV/33KV

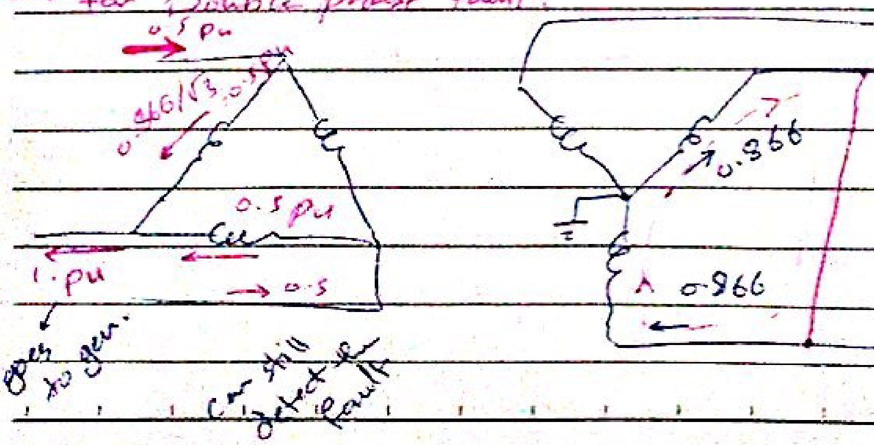


→ for 3ph fault:



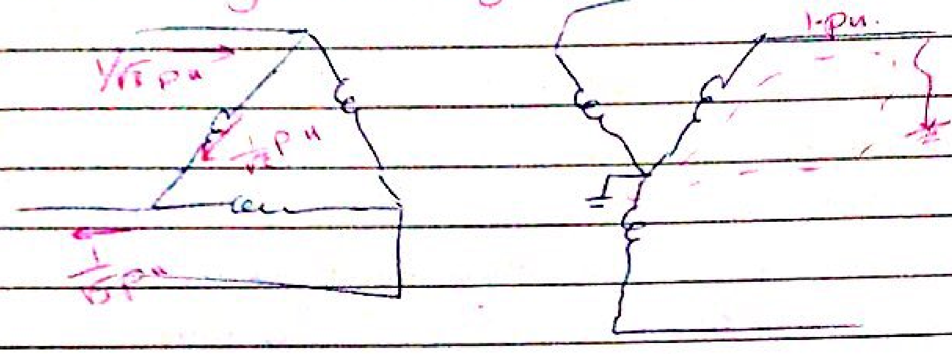
no problem if the settings 1pu the Relay will see it

→ for Double phase fault:



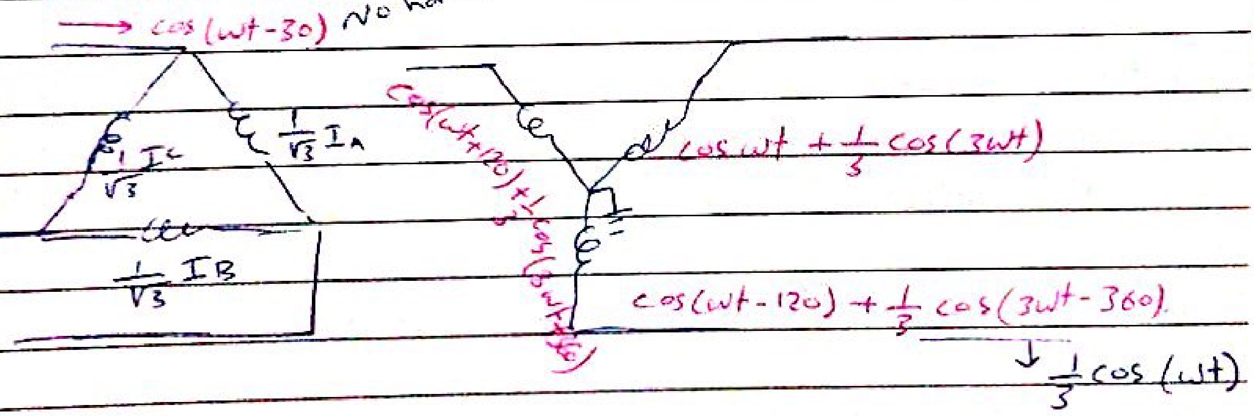
no problem if the settings 1 pu the Relay will see it.

→ For single line to ground fault:

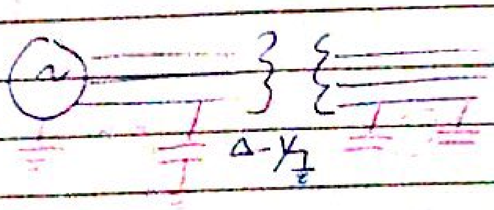


→ if the settings was 1 pu there is a problem. the Relay will not see the fault.

→ the connection usually is Δ-Y, to cancel the third harmonic



⇒ For very Long T.L:
capacitors works as grounding



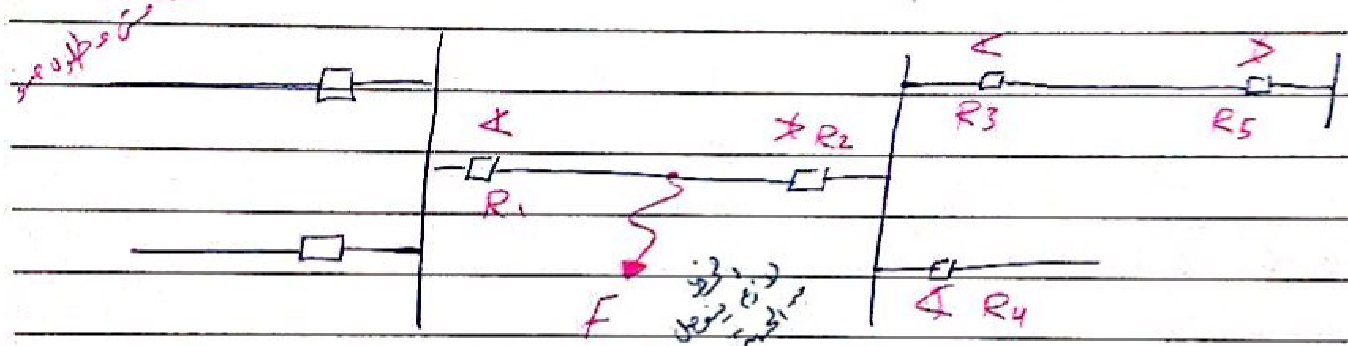
** The nature of Relaying scheme :-

→ Reliable : Work as intended

→ Dependable : operate correctly for faults, it's designed to detect

→ Secure : Do not operate for other fault → Zone, → time.

تعرف - Zone أو وقت كله



Consider DOC Relay (67) every where

** Lets consider diffrent cases: choose one [dependable, not dependable, secure, not secure]

by default is Reliable

→ R_1 detected & interrupted F [Dependable]

→ R_2 did not detect the fault [not secure]

→ R_3 detected the fault [not secure]

→ R_5 detected the fault. [dependable]

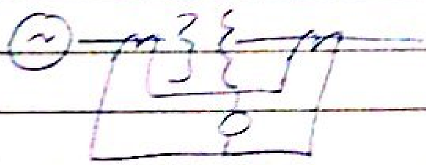
مطلوب بس detect ما بتعرف inst.

→ R_5 detected the fault & send an instatinuos tripping signal. [not secure]

* Selectivity & Zones of protection :-

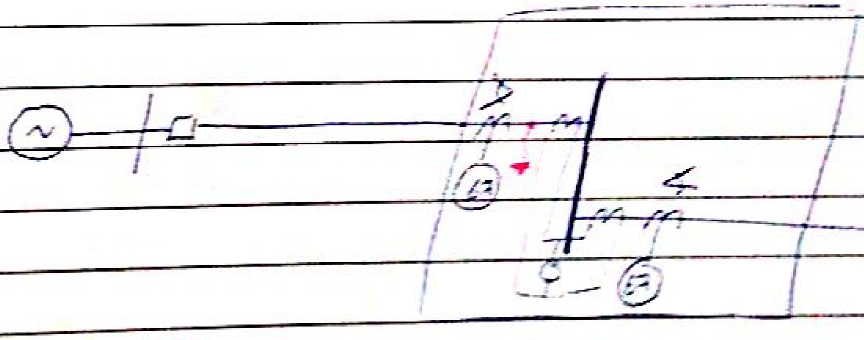
Zones of protection → open [Relatively selective]

→ close Diff [Line, Gen, TR] [absolutely selective]



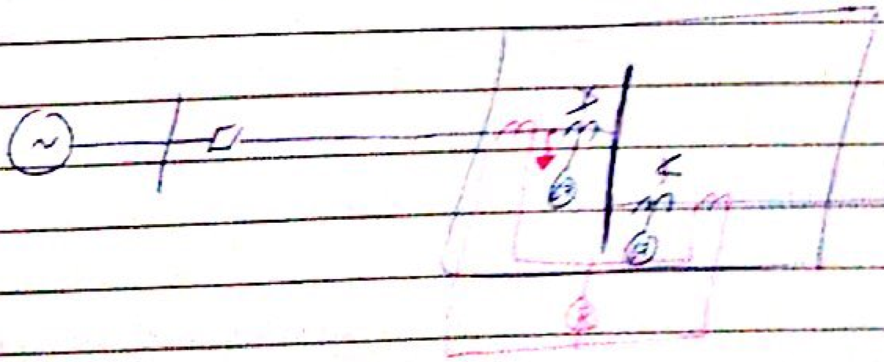
→ every element must be within a Zone

→ Zones over Lap



X No Relay see the fault.

⇒ the solution Zones over Lap



✓ the two Relay see the fault.

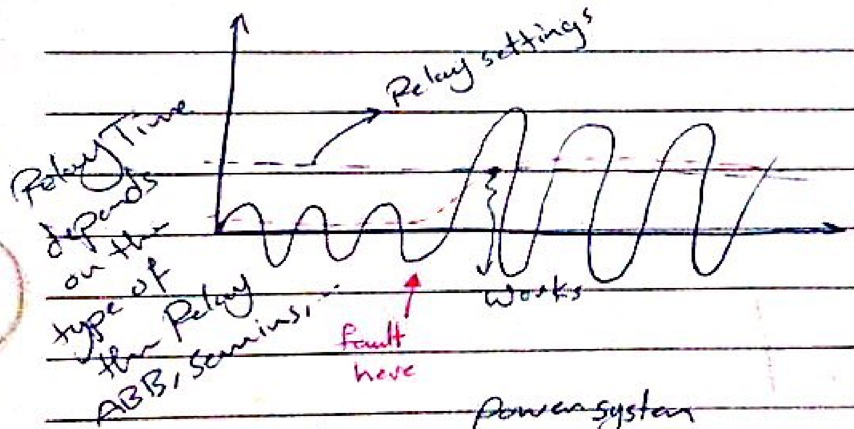
* Relay speed : → instantaneous Relay : 87, 21, 50

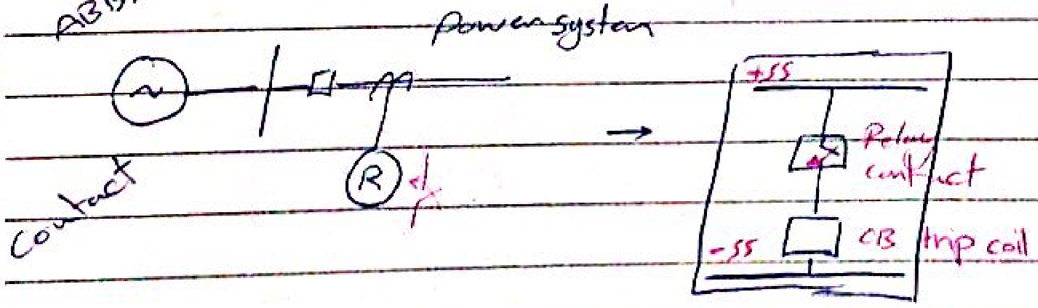
→ with intentional delay : 51 , 21 [Zone 2 & 3]

* fault Isolation time :- (in instantaneous)

= Relay Time + Contact + CB Time

القطع مع ال zero crossing





HW * 1 :

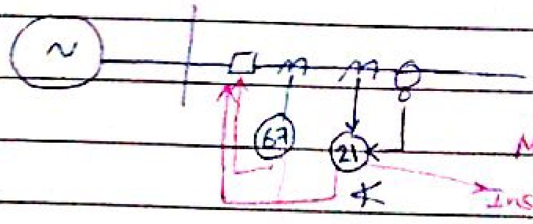
What is the fastest isolation times for high voltage systems ??

consider the time include [Relay + C.B]
neglect contact

→ AREVA → 3 cycles = 60 ms (C.B)
→ ABB → 3 cycles = 60 ms
Siemens
SEI

27-9-2017
Wednesday

**Main & Backup protection:



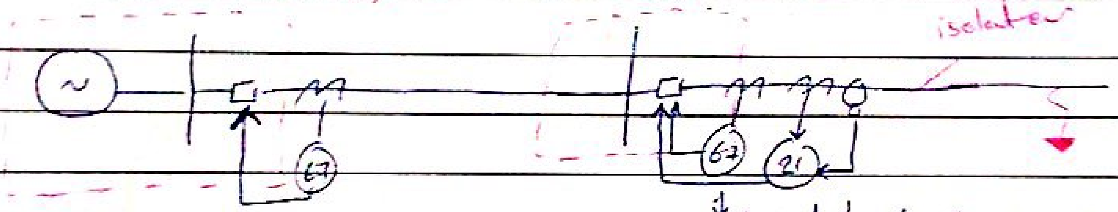
Dublication in protection (Relays, CT, VT)
no Dublication in C.B

Main
Instantenuos

backup
with time delay

⇒ Local Backup VS. Remote back up

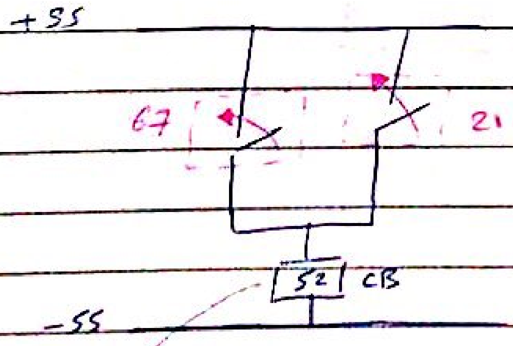
Substation (SS)   SS



عند الفتح اول C.B بعدين isolator
عند الغلق اول isolator بعدين C.B.

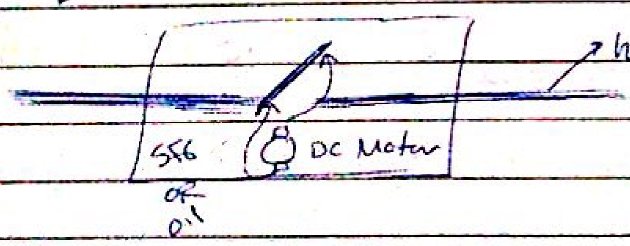
Local backup
بنفس المحطة تحمي خطي
اذا ال C.B ما اشتغل
في Backup بعد

Remote backup
نعمل حماية من مكان بعيد



Tripping ckt

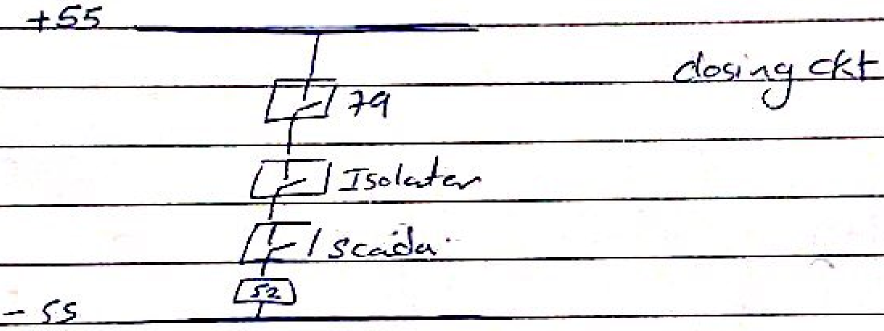
inside the C.B



heavy contact.

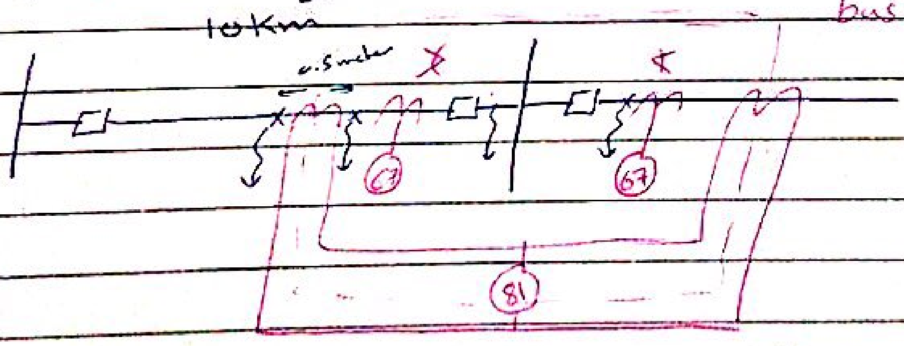
** Automatic Reclosing :- [79] it's a Relay but for closing

→ Most faults are temperory. OHL
→ This mechanizem allows to reconnect the lines, and get them back to the system.
→ not for generators, motors, UG cables, transformer.
→ closing schemes / synchronization



The end of ch. 1 in Horowitz book

** Relaying operating principles :-



→ From electrical point view will consider at same fault level (Distance is low). we have ϕ

⇒ magnitude is not allways the key to detect faults

⇒ Fault detection on : magnitude, phase, fregency, diretion
physical

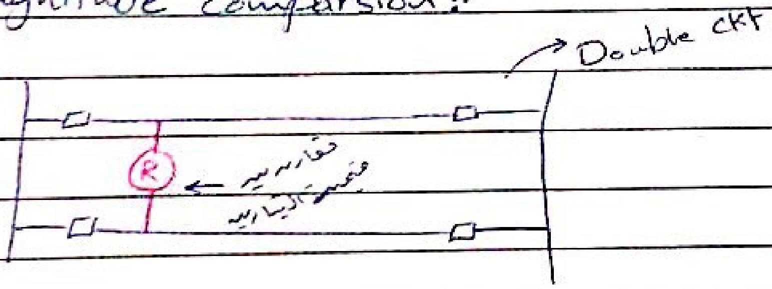
- → Currents
- → Voltages
- → power
- → Impedance
- → temp, pressure, oil colors

[1] level detection :

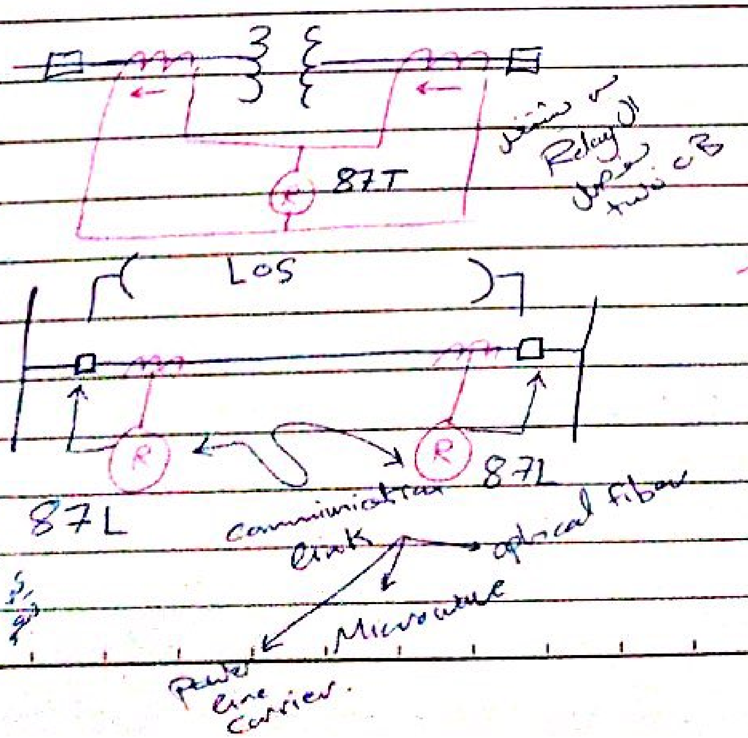
$$I_f > I_{setting} \rightarrow I_{load} + \text{overload margin}$$

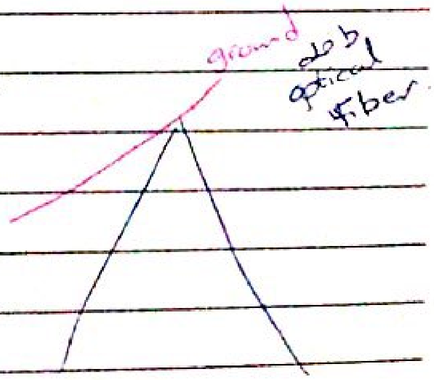
$$V_f \gtrless V_{setting}$$

[2] magnitude comparsion :



[3] Differential comparsion :





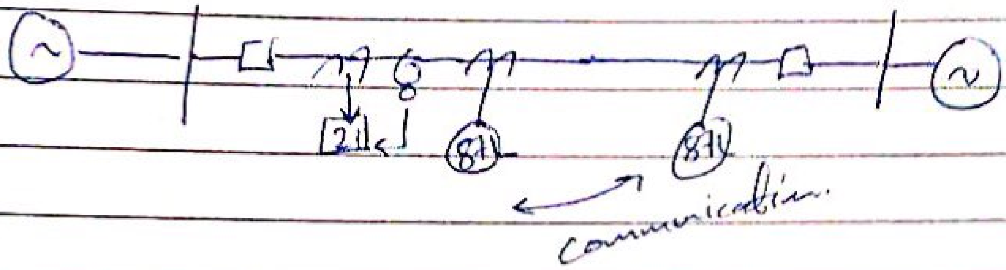
[4] phase angle scheme (can't use in Distribution sys)

→ Load angle : 40° (worst case)

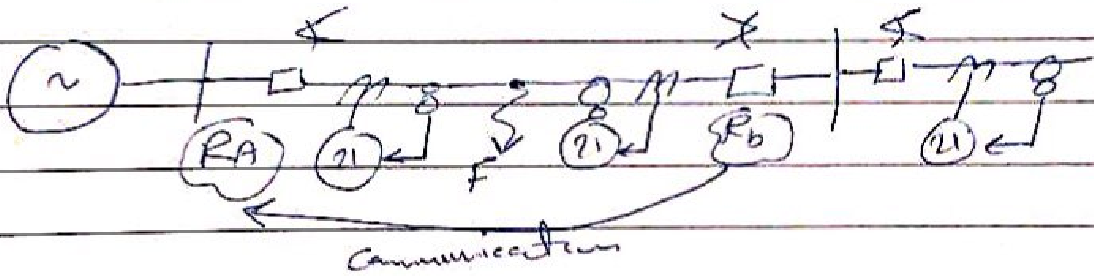
→ fault angle [high voltage system] = ≈ −90

9-10-2017
Monday.

[5] Distance measurements (Z)



[6] pilot Relaying



[7] Harmonics content

→ helps in SLGF

[8] Fregency [81]

P ⇔ F
Q ⇔ V
→ Any miss match will effect the generation
→ load shedding

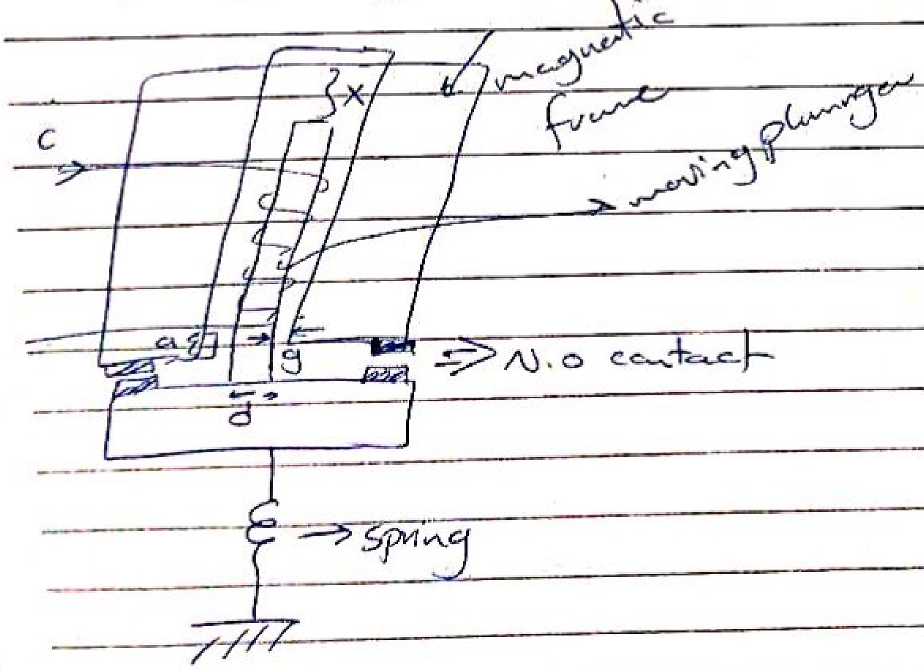
* Relay construction:

(1) electromechanical
(2) static
(3) Digital Numerical

→ electromechanical Relays:-

→ interaction between currents & fluxes [motor action]
→ Real mechanical movement.

1- plungger type.



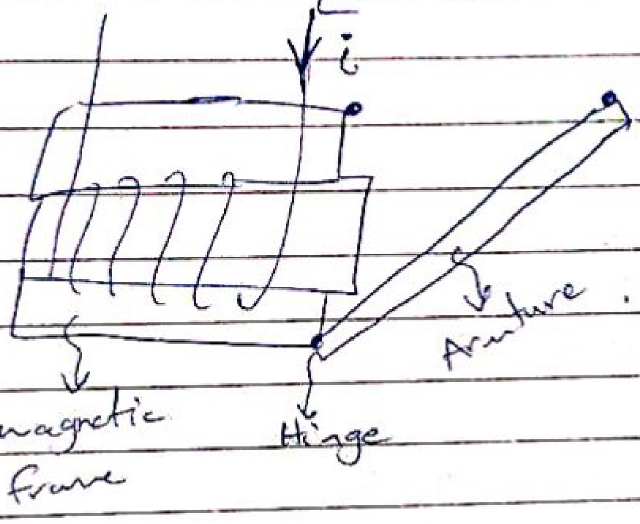
→ instantaneous OC Relay
Time delay OC Relay

F_s : spring force
F_m : the force that will pull the plunger inside the structure.

in Numerical Relay

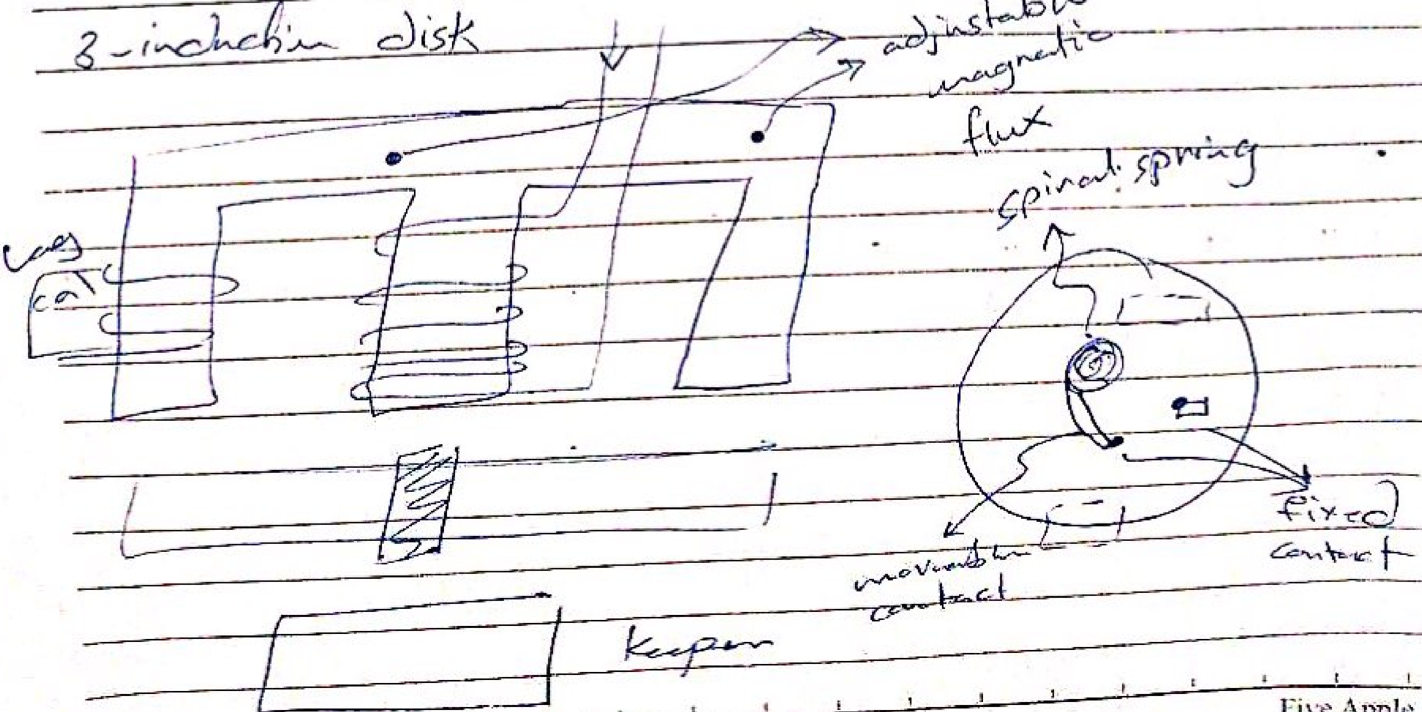
pick up to drop off Ratio = $\frac{1}{0.95}$

2- clapper type [instantaneous o.c Relay]
[time delay o.c Relay]



* note:
Pickup to Drop off Ratio is still a problem
it's better than plunger type.

3- induction disk



if $F_m \geq F_s \rightarrow$ moumVment

$$F_m = k \frac{i^2}{\left(X + \frac{gd}{4a}\right)^2}$$

→ healthy condition : (intial Displacement)

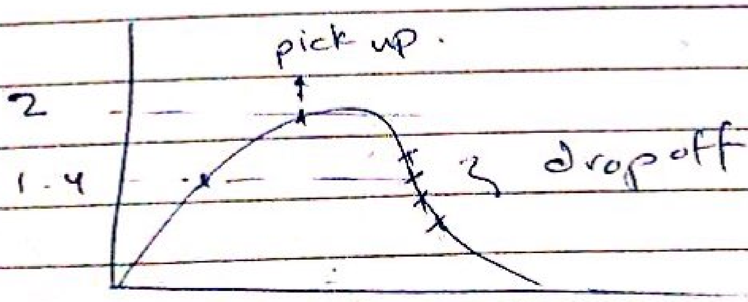
$$I_P = \sqrt{\frac{F_s}{k}} * \left(X_o + \frac{dg}{4a}\right)$$

↑ X_o : intial displacement

$$I_d = \sqrt{\frac{F_s}{k}} \times \left(X_1 + \frac{gd}{4a}\right)$$

↑ X_1 : minimum value that makes the contact close

$$\text{pickup to drop off Ratio} = \frac{1}{0.7}$$



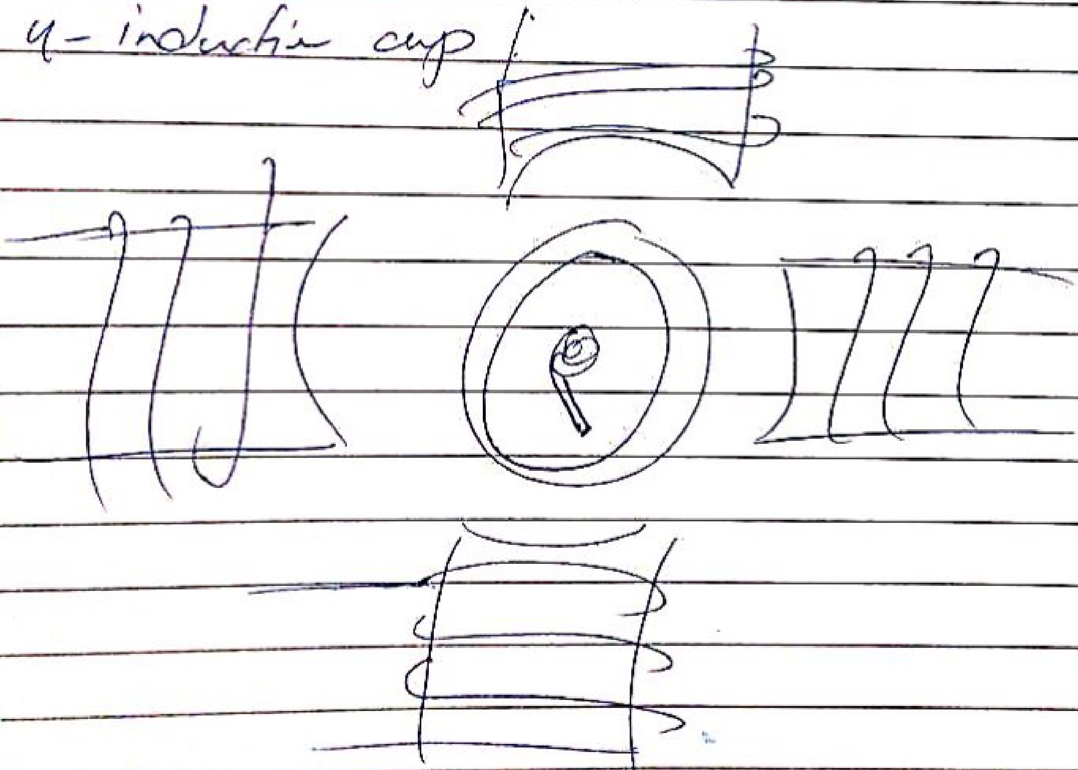
Notes:

* it may has 2 sources of AC source

* level detector : same current in both coil

* phase shift could be done by adding a shunt impedance in parallel with one of the coils.

4- induction cup



* we can have different combination of coils
⇒ leading to diffrent combination of V & I, their product.

$$F_m \sim F_s \longrightarrow \text{balance}$$

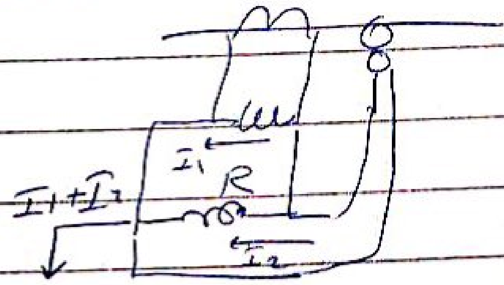
⇒ lets consider 3 coils (I, V, product)

$$\tau = \tau_m - \tau_s = k_1 I_1^2 + k_2 V_2^2 + k_2 V_2^2 + k_3 IV \sin(\theta + \phi) - \tau_s$$

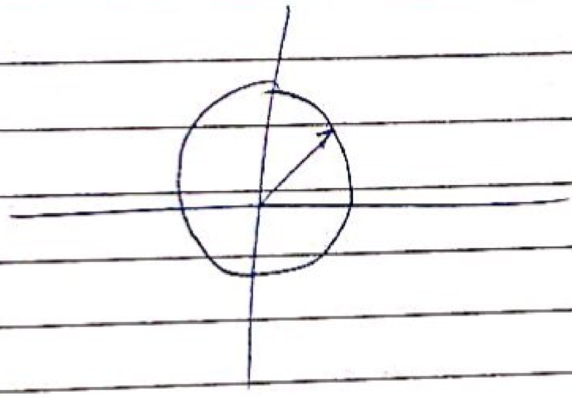
$$\tau_m - \tau_s = 0 \rightarrow \text{balance condition.}$$

⇒ Setting $k_3 = 0$

$$0 = k_1 I_1^2 + k_2 V_2^2$$



$$Z = \frac{V}{I} = \sqrt{\frac{k_1}{k_2}}$$

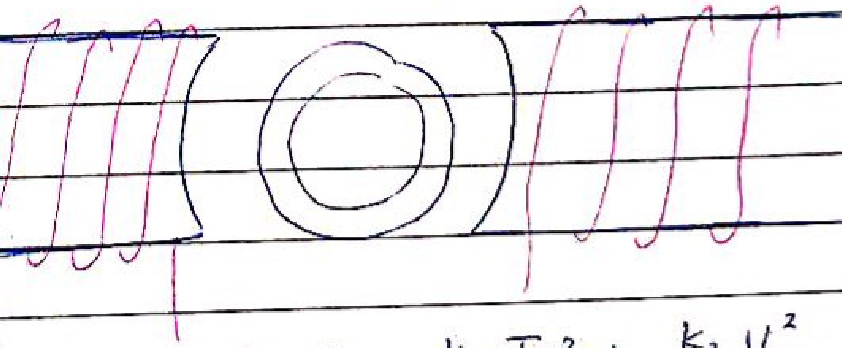


$Z_{measured} < \sqrt{\frac{k_1}{k_2}}$ ⇒ fault condition.

16-10-2017
Monday

Recall :-

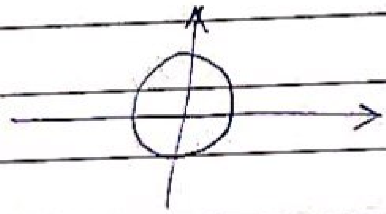
→ induction cup Relay: $(k_3 = 0)$



$k_2 \rightarrow -ve$ نعكس اللفة

$$0 = k_1 I_f^2 + k_2 V^2$$

$$|Z| = \frac{V}{I} = \sqrt{\frac{k_1}{k_2}}$$



[impedance Relaying]

✱ now set $k_1 = 0$, reverse tourqe from k_3 $[k_3 = -k_3]$:-

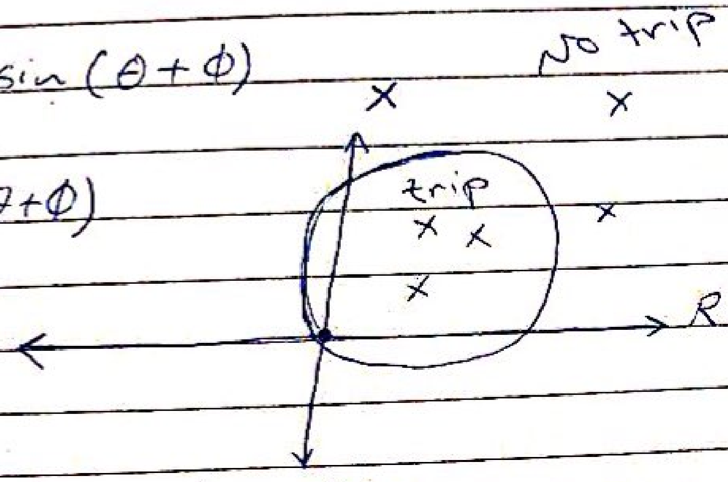
$$0 = k_2 V^2 - k_3 V I \sin(\theta + \phi)$$

divide by VI — يعين من الملف

$$0 = k_2 Z - k_3 \sin(\theta + \phi)$$

circle eqn

$$Z = \frac{k_3}{k_2} \sin(\theta + \phi)$$



at $\theta = -\phi \rightarrow Z = 0$

at other values → circles

[Mho Relay] shifted impedance Relay (Distance Relay)

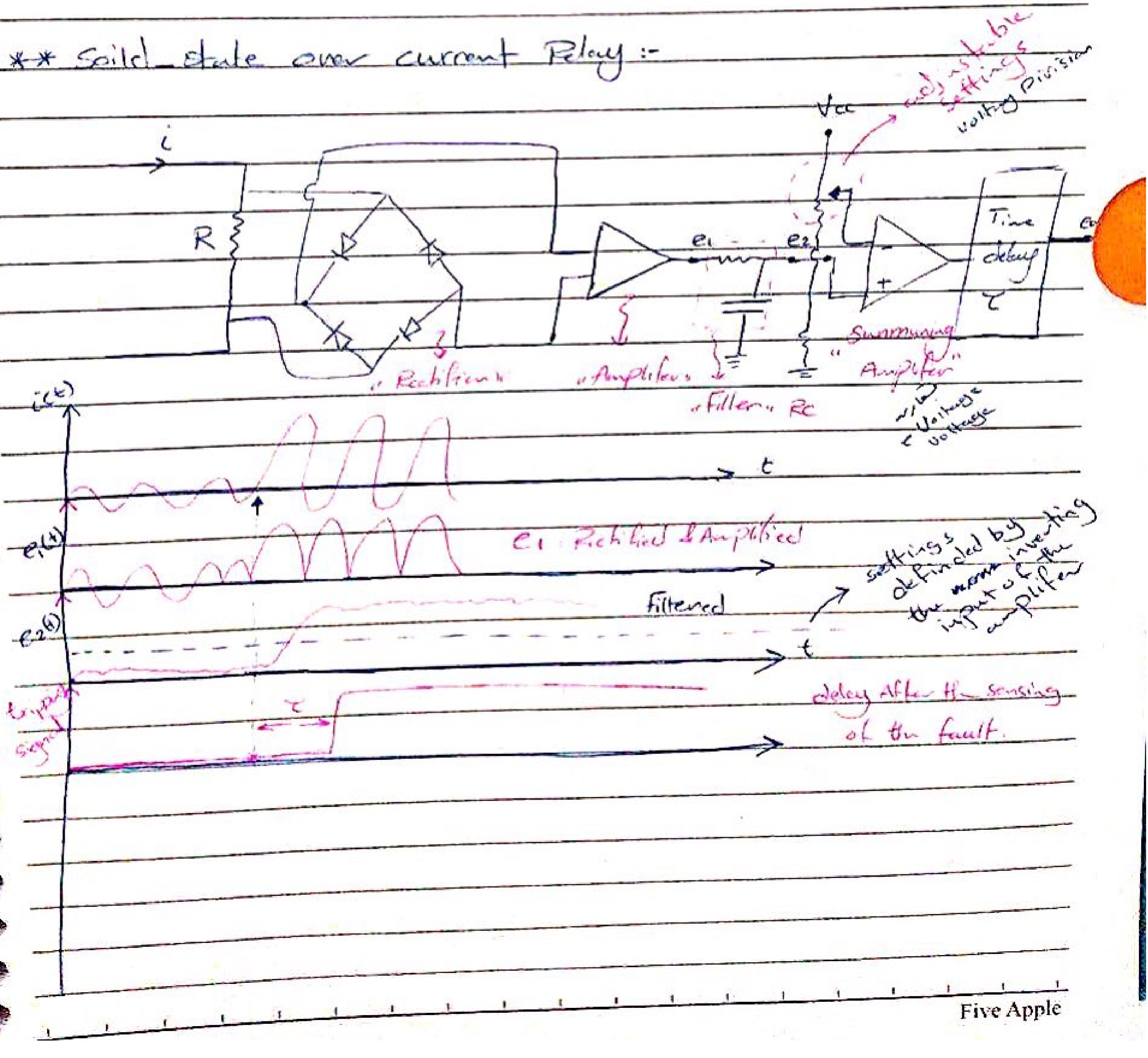
• Soild-state Relays :-

(electromechanical affected by dust)

→ semi-conductor materials
[not affected by dust, vibration]

→ we need independent power source.
→ performance & economical superiority over EM Relays.
→ easy and accurate settings changes

** Soild state over current Relay :-



→ shunt R [they operate on voltage]

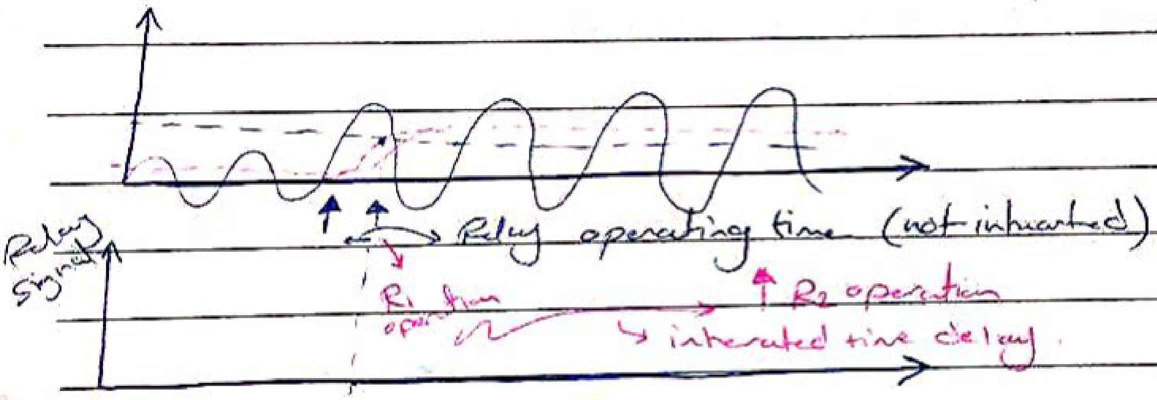
→ Full wave Rectification

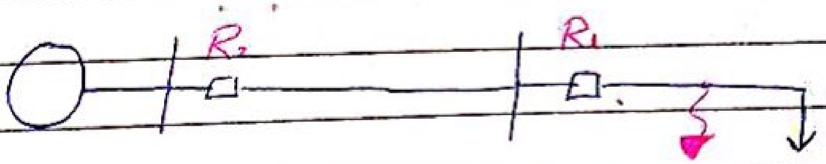
→ RC Filtering to remove the Ripple → operating time of the delay not far according

→ moving Average [τ is not interated time delay]

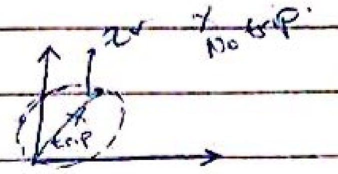
→ Summing amplifier [comparter]

note:





** Soild-state Distance (Mho Relays):



$$Z = \left(\frac{k_3}{k_2}\right) \cdot \sin(\theta + \phi)$$

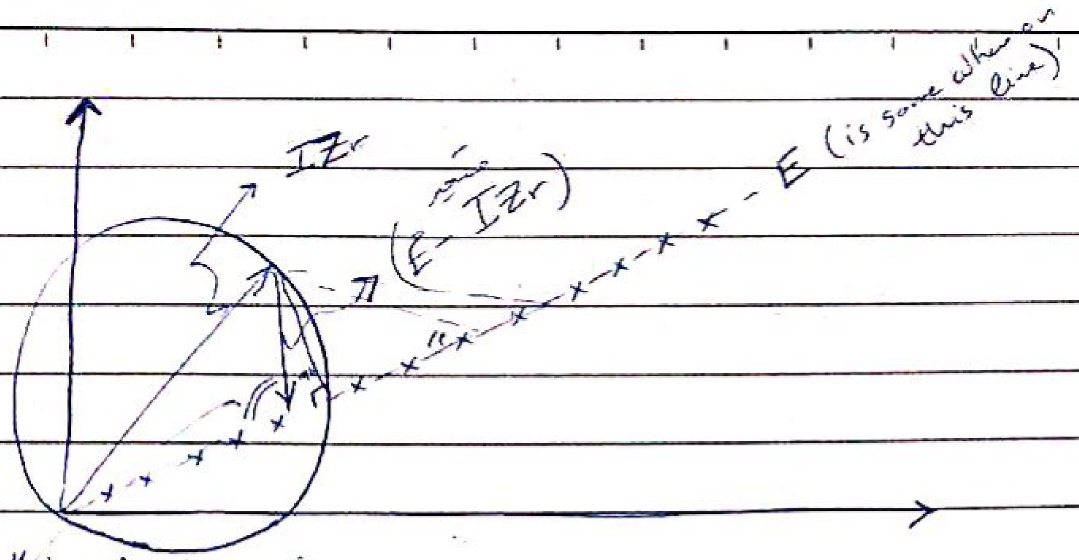
$$Z = Z_r \sin(\theta + \phi)$$

multiplay by I

$$IZ = IZ_r \sin(\theta + \phi)$$

$$E = IZ_r \sin(\theta + \phi)$$

$$E - IZ_r \sin(\theta + \phi) = 0$$



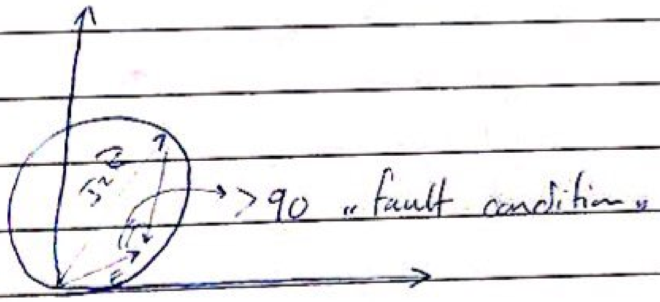
if this Angle is :

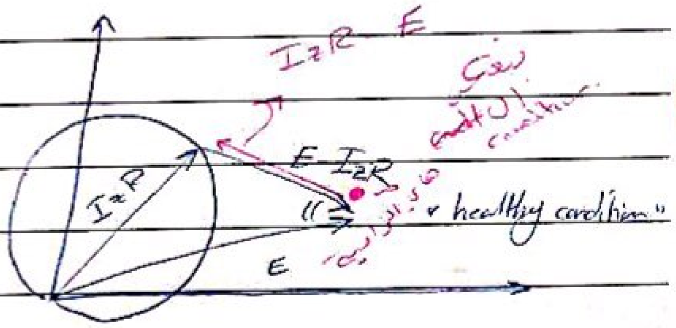
$\angle E - I_z R$ & $\angle E$ $> 90 \rightarrow$ Trip

if

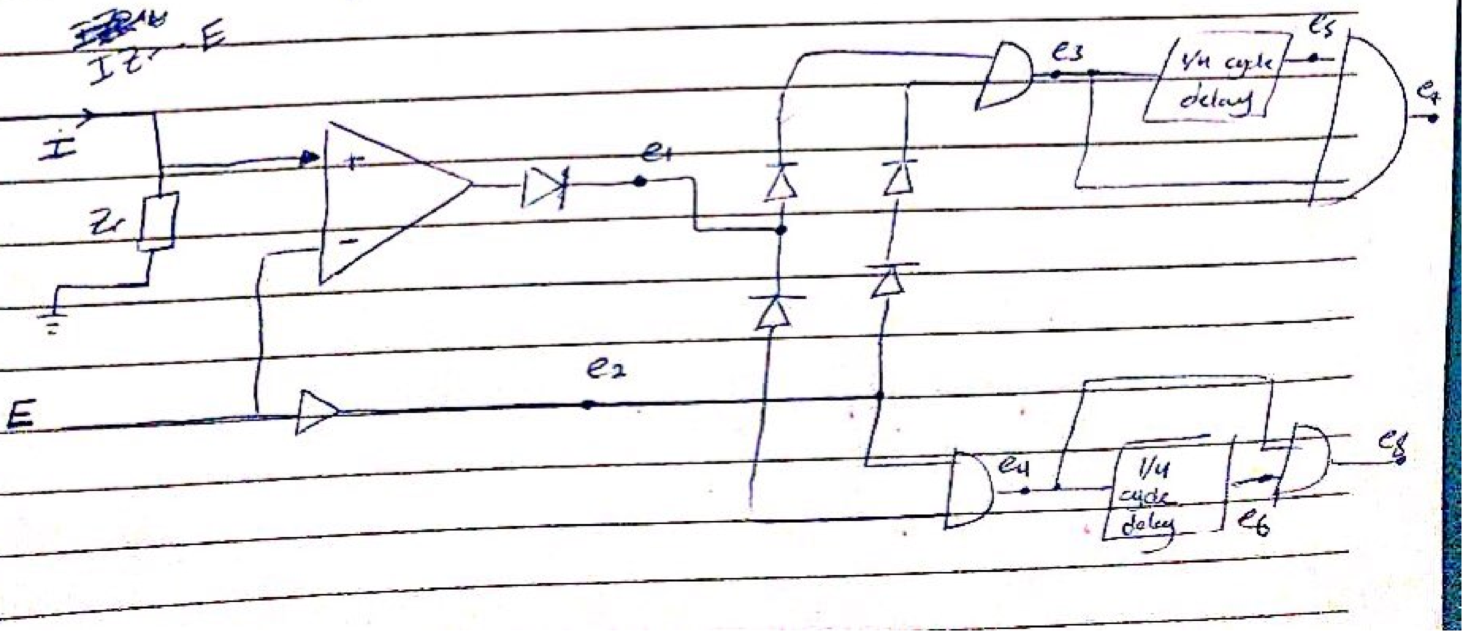
$\angle E - I_z R$ & $\angle E$ $< 90 \rightarrow$ No Trip.

note :

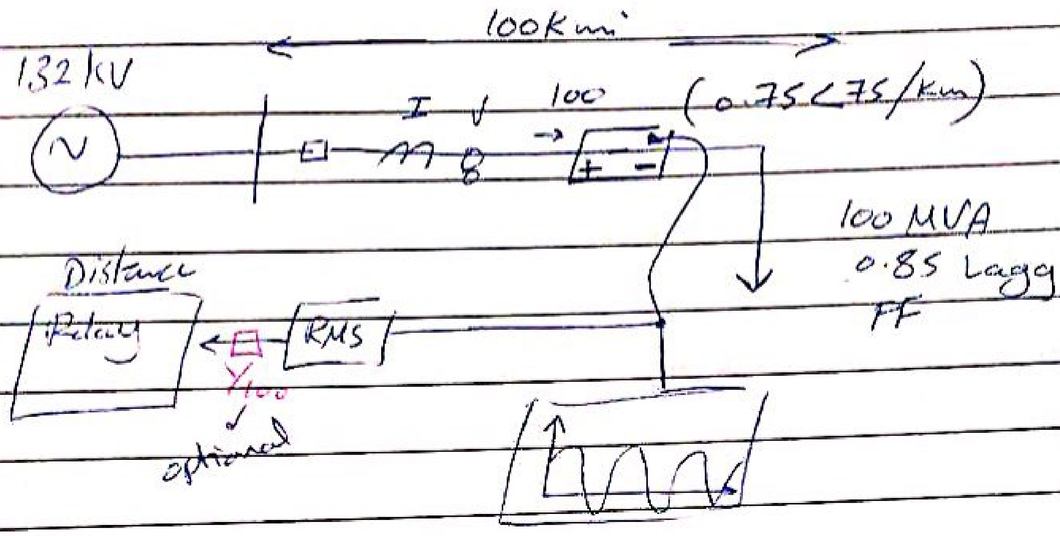




⇒ We have to compare between the Angles $\angle E$ & $\angle E - IZr$



HW # 2 : Due two week from now 6/11/2017



on matlab
- current measurement
- Voltage "
- with gain

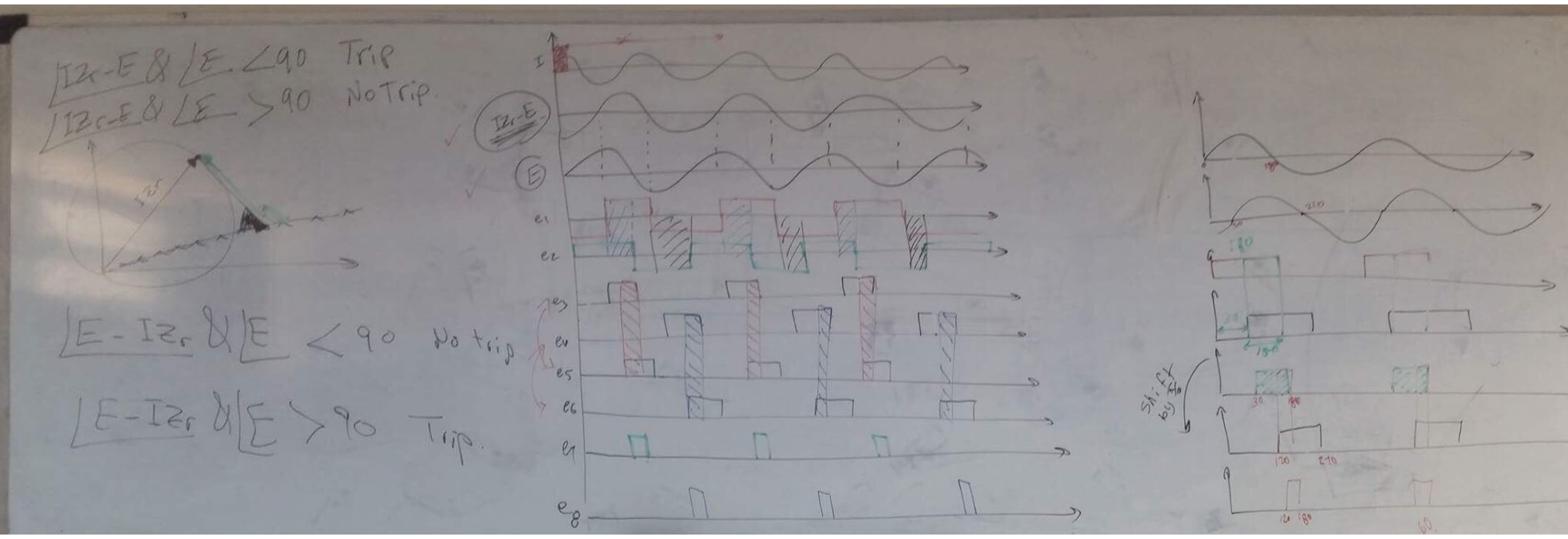
$I = \frac{100}{\sqrt{3} \times 132kV}$

there is a 3phase fault block

$Z_r = 0.85 \times 100 \times (0.75 \angle 75°)$

Simulate :

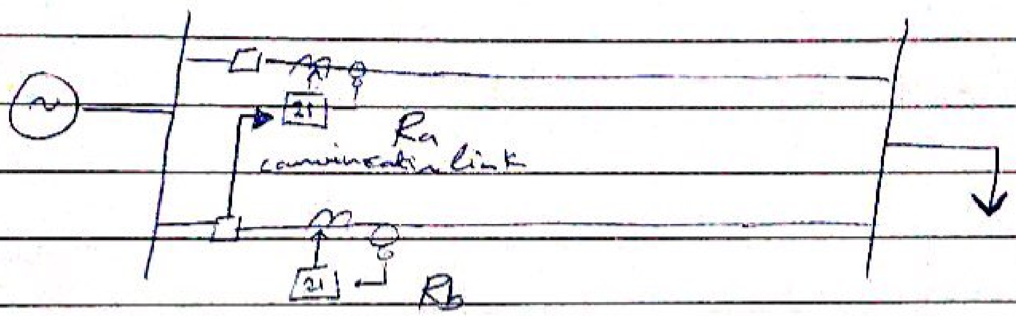
1. fault condition (e_7 & e_8)
2. healthy condition ($e_7 = 0$ $e_8 = 0$)

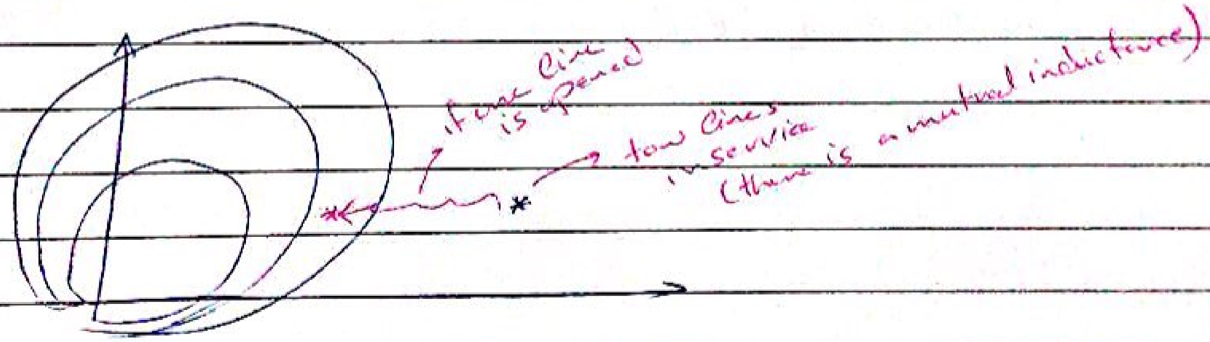


∠IZr-E & ∠E <90 Trip
∠IZr-E & ∠E >90 No Trip
∠E-IZr & ∠E <90 No trip
∠E-IZr & ∠E >90 Trip
IZr-E
E
e1
e2
e3
e4
e5
e6
e7
e8

- Numerical Relay (Digital) :-

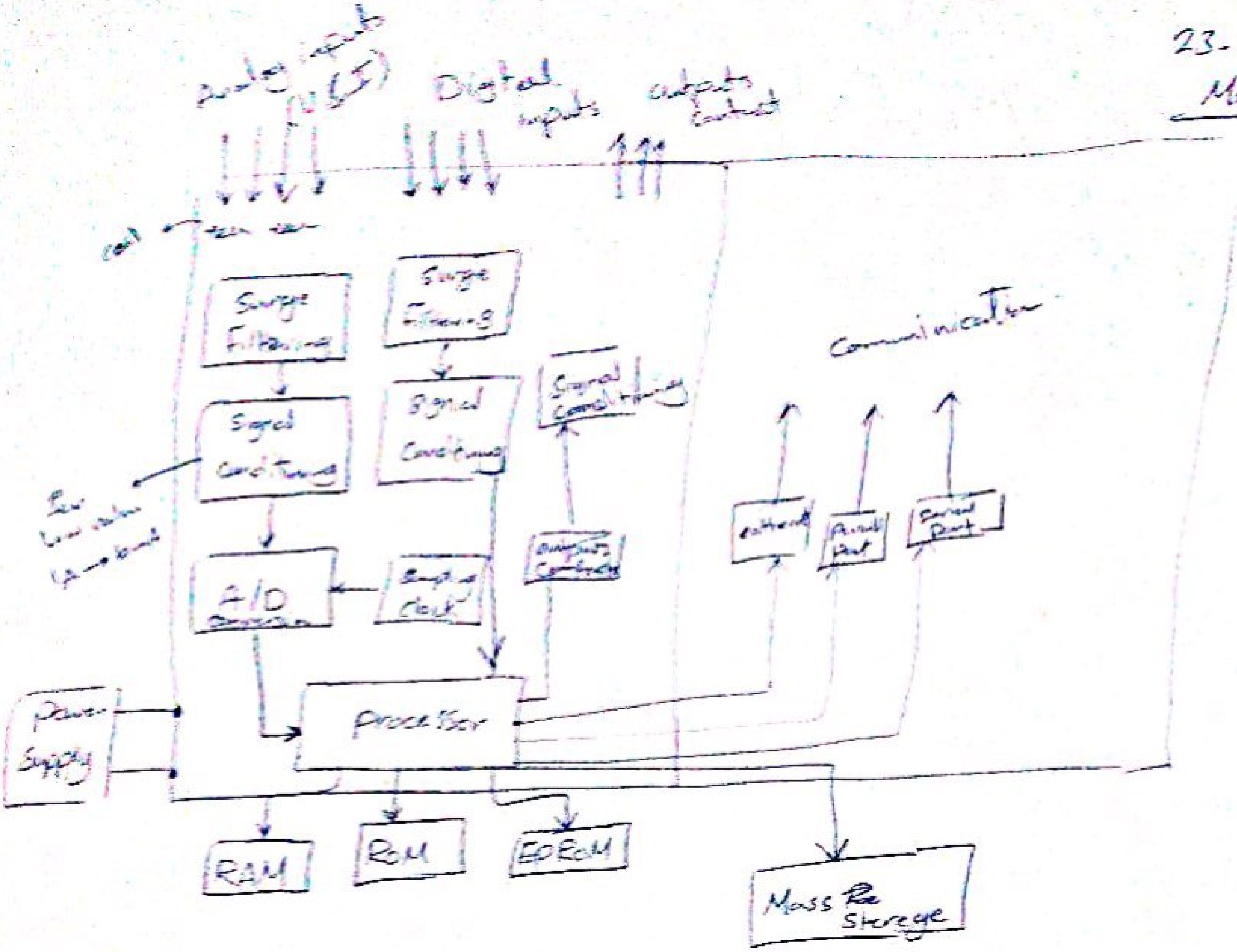
→ microprocessor based relays
→ communication (ability to communicate)
→ Ability to diagonise it self
→ Adaptive Relaying [the ability of Relay to change it's setting online]



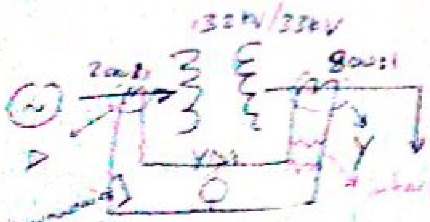


the solution is : Ra [G1 G2 / Z1, Z2, Z3 Z1, Z2, Z3]

23-10-2017
Monday.



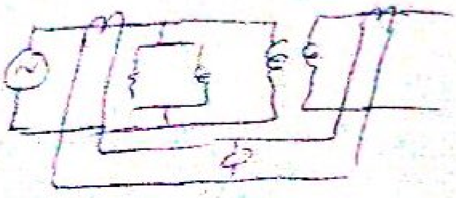
- RAM: to process and hold inputs signals.
- RoM: Relaying algorithm
- EpRoM: Relay settings
- Surge Filltering: → Low pass filter
  → anti aliasing filter
- signal conditioning: convert Voltage and current to values that the Relay with deal with.



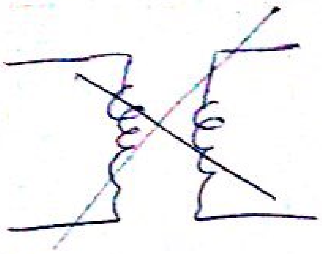
interposing (matching transformer) to solve magnitude and phase problem.

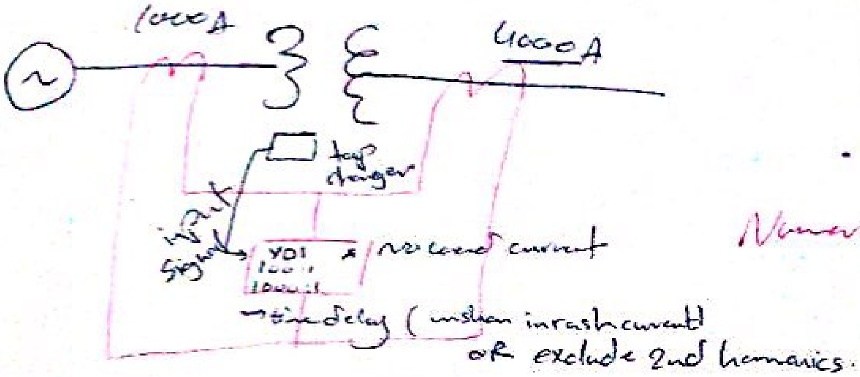
→ inrush current
→ no load current → ↑ settings
→ load nature

electro mechanical



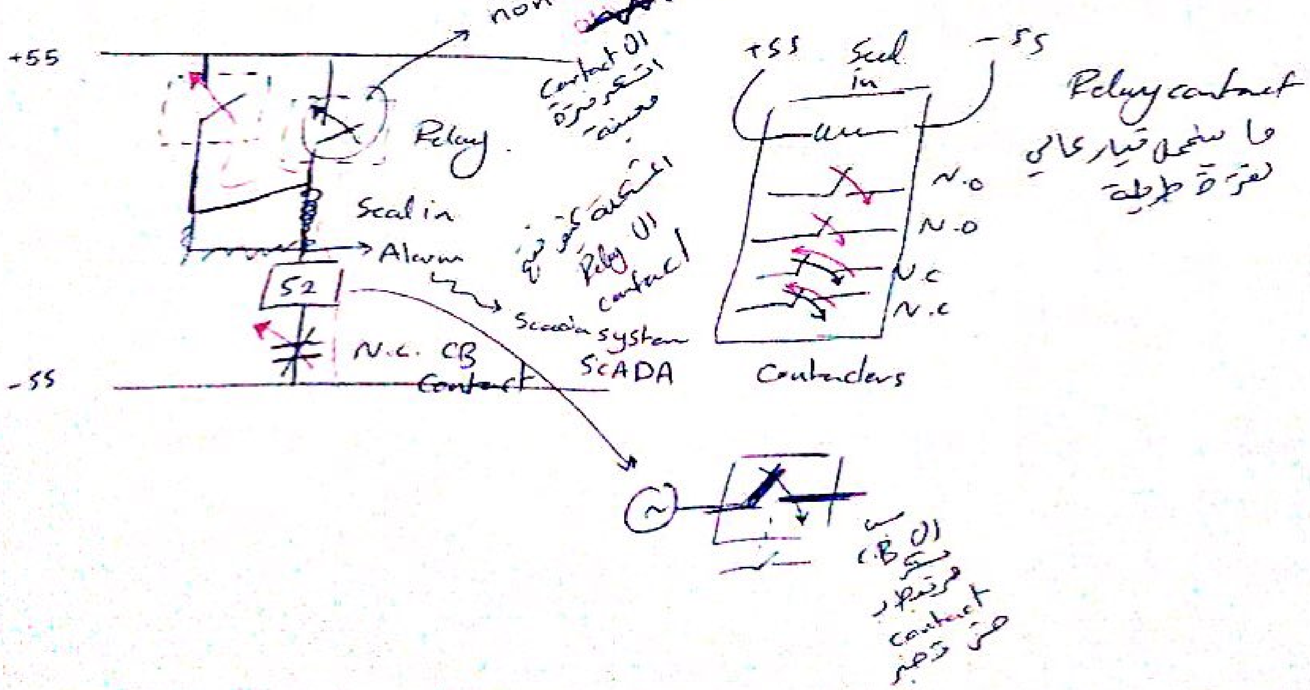
→ tap changer. ↑ settings

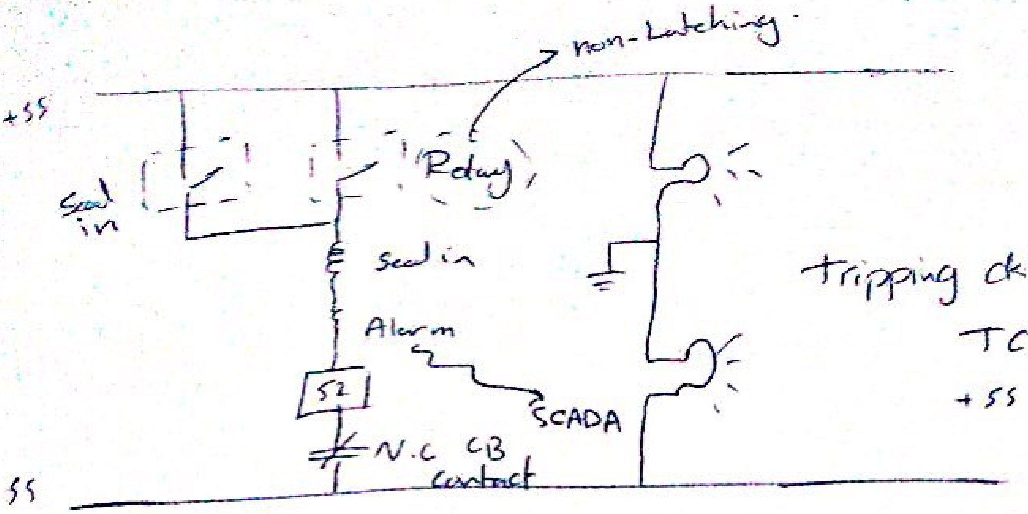




Numerical Relay

→ control ckt : tripping ckt





tripping ckt supervision

TCS

+ss → هتشوف شغال أو لأ

Chapter 3 :

** Transducers : CTs & VTs

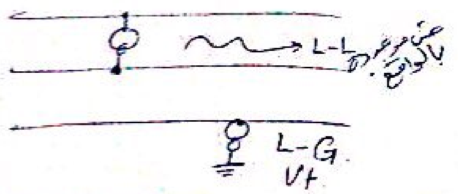
→ convert primary values to some values that the Relay can tolerates.

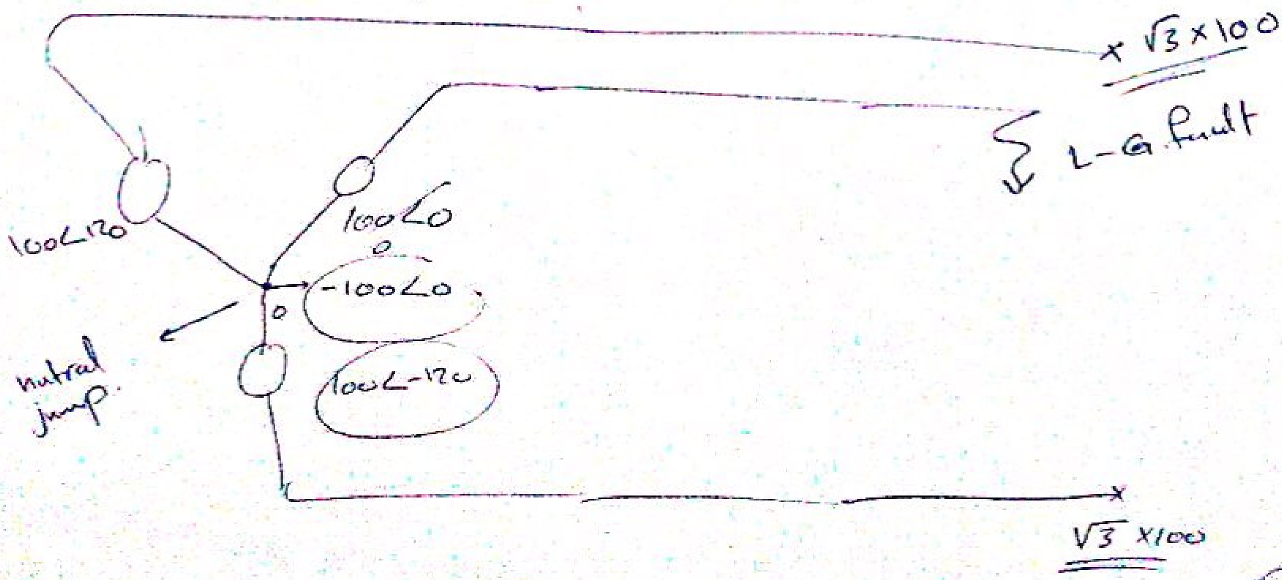
→ They should not affect the power ckt.
(primary)

→ standared outputs:

CTs : 1A & 5A [Secondary]

VTs : 120 L-L Voltage → 69 L-N. } that value in healthy condition.
(min 0, max $120 \times \sqrt{3}$)





→ manufacturers should consider higher values for abnormal conditions

2000 : 1

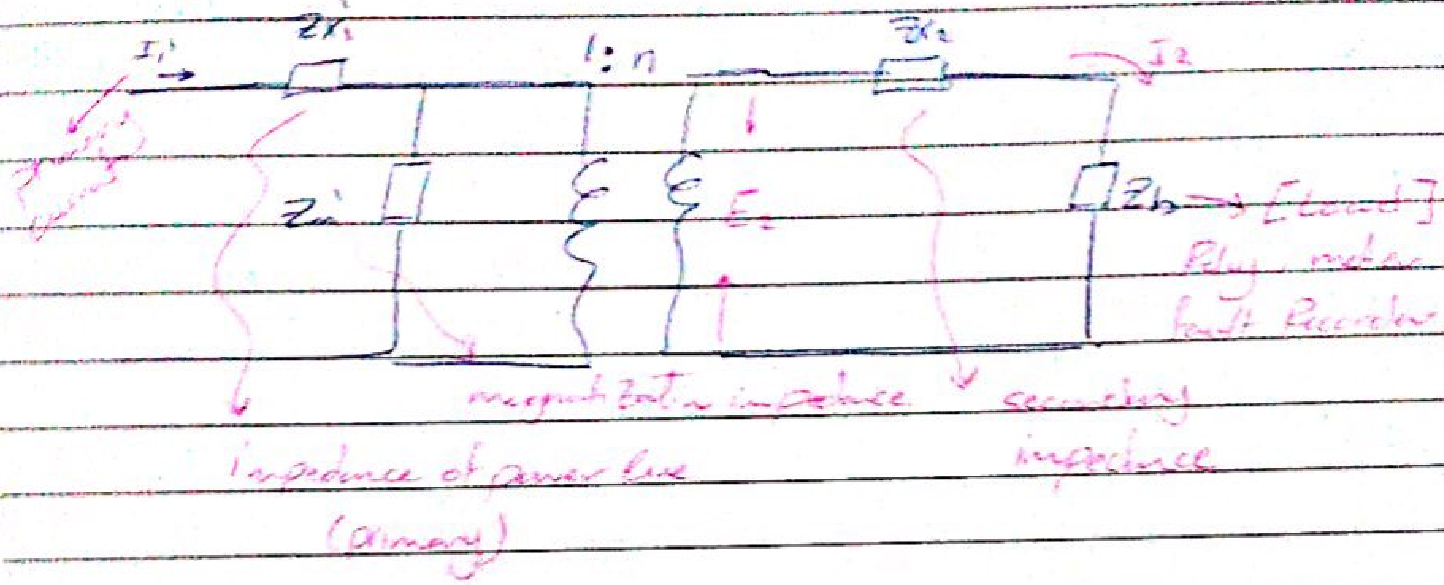
20 A for 3 sec.

CTs
- → metering CTs : Accurate performance in healthy condition
- → Relaying CTs : Accurate performance in fault condition.

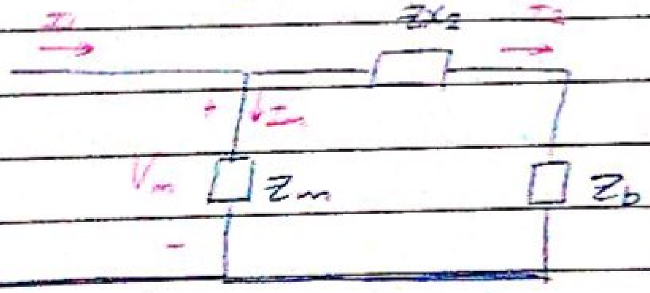
25-10-2017

Wasday

** Steady state performance of CTs :-



⇒ simplified ckt for study purpose :



When Refered to secondary :-

$$I_1 = \frac{I_1'}{n}$$

$$Z_m = n^2 Z_m'$$

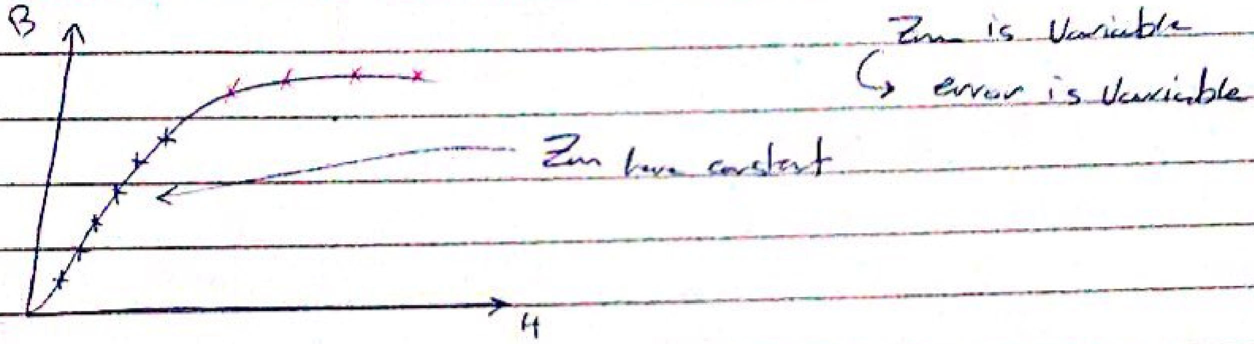
$$I_m = \frac{V_m}{Z_m}$$

$$I_1 = I_2 + I_m$$

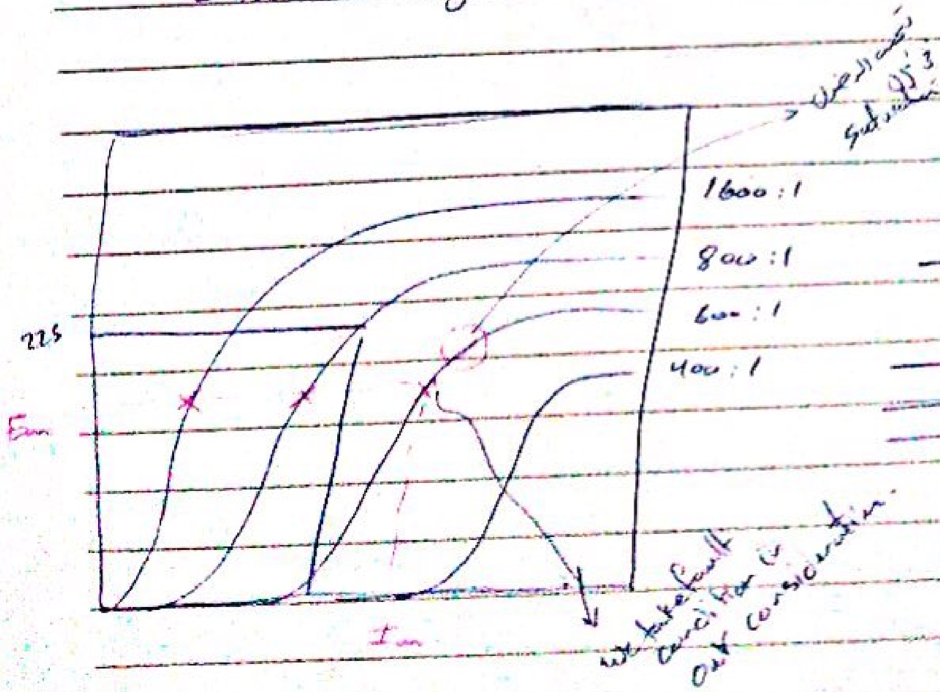
$$E_m = E_b + I_2 Z_{x2}$$

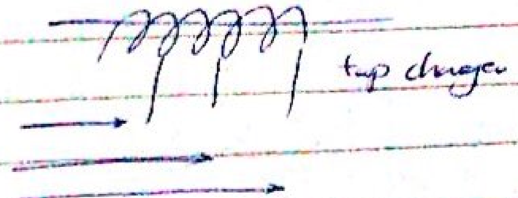
$$\epsilon = \frac{I_m}{I_1} = \frac{I_1 - I_2}{I_1} \quad [\text{CT error}]$$

$$R = \frac{1}{1-\epsilon} \quad [\text{Ratio Correction Factor}]$$



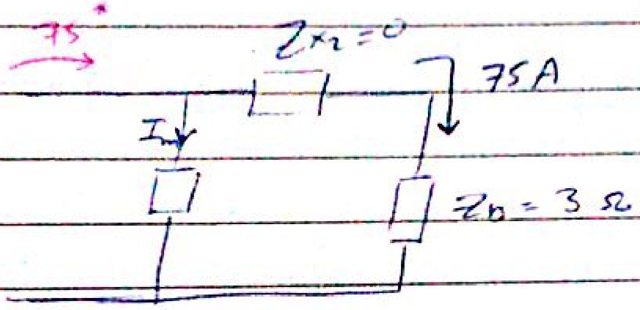
→ CTs are non-linear, Z_m is not constant
→ I_m depends on the characteristic
→ ϵ depends on the characteristic
→ CTs should have multiple Ratios to avoid working in saturation Region





(... accuracy of Ratio ...)

example: Consider a multi-Ratio CT with shown curve, assume CT Ratio is 800:1, the Relay & wires burden are 3 Ω [all at same angle], if the secondary current is 75A, what is the magnitization current & what you conclude?? [neglect Z_{X_2}] ??



$E_m = 3 \times 75 = 225\ V$

goes to CTs curves

⇒ using the curve

$I_m = 5A$

$$\epsilon = \frac{I_m}{I_1} = \frac{5}{75+5} = 0.0625$$

→ if acceptable → ok

→ if not acceptable → choose the immediate highest turns Ratio

* if the current was I_1

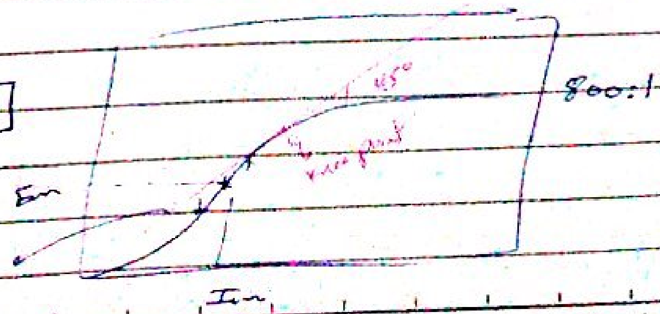
→ Non-linear problem

→ $I_m = f[E_m]$

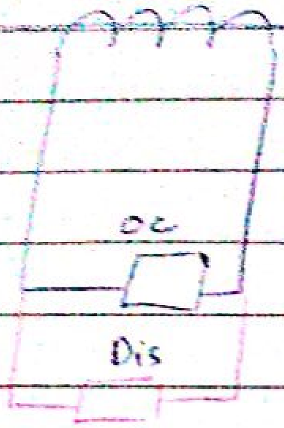
→ $E_m = I_2 \times [Z_{X_2} + Z_b]$

→ $I_2 = 75 - I_m$

$$Z_m = \frac{E_m}{I_m}$$

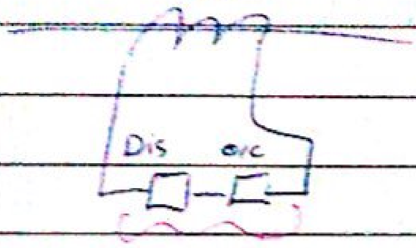


Five Apple

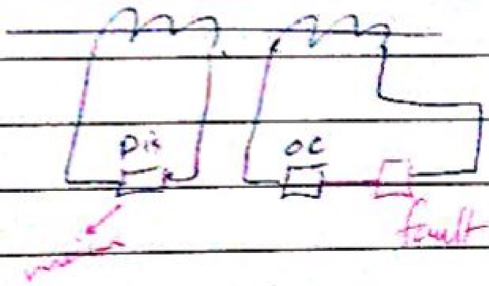


parallel Wiring
the current is not Replica

600:1



$Z_b = Z_{oc} + Z_{Dis}$ $Z_b \uparrow \rightarrow E_m \uparrow = I_2 \times Z_b \rightarrow I_m \uparrow$
$\rightarrow C \uparrow \Rightarrow$ saturation.



fault Recorder

Ease protection and selectivity issue

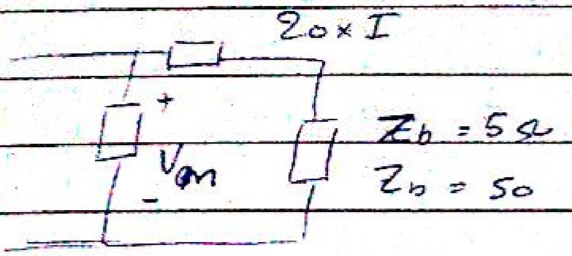
IEC Standard:

5P20
accuracy ↲ ↳ 20 times the current → 1A, 5A secondary

IEEE / ANSI:

10 C 400
error ↲ ↳ Secondary Voltage

→ 20 times the current and error is less than 10% if Em is less than 400



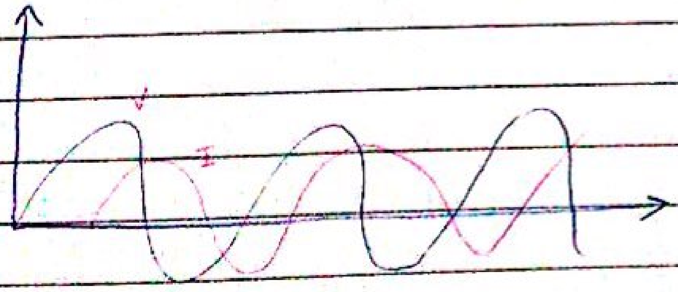
** Transient Analysis of current transformer :-

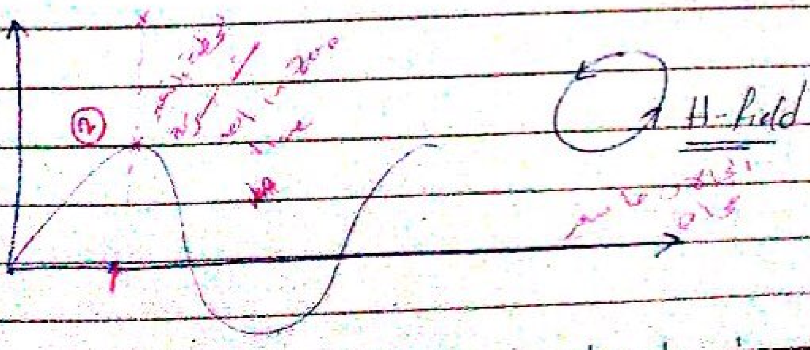
→ a change in power system will produce a dc component in an Ac current

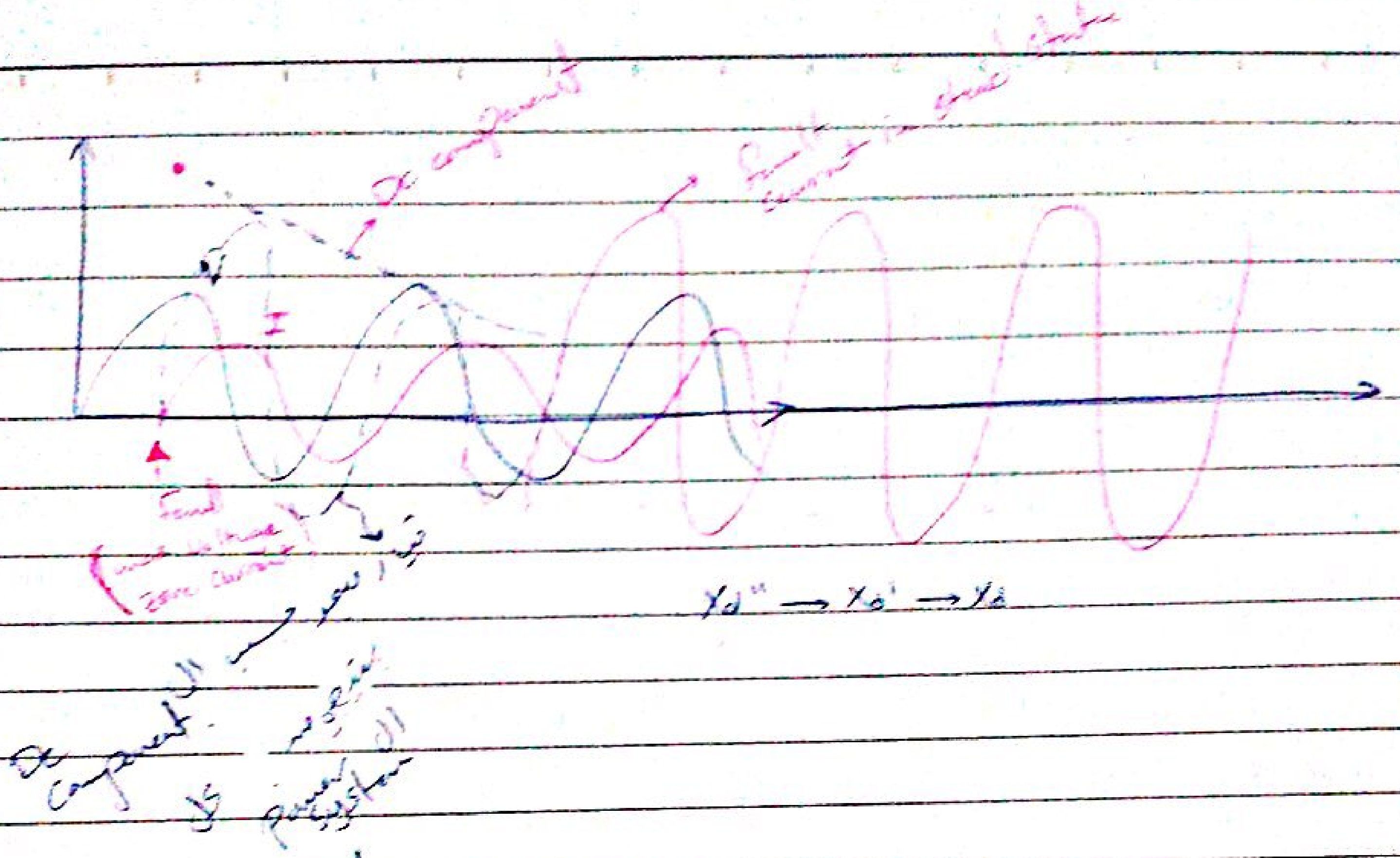
→ This Dc Component comes from the necessity to satisfy two conflicting conditions.

① → In a highly inductive network [Transmission Network] the current wave form must be in it's maximum when the Voltage is at or around Zero

② → the Actual current at a time of change is that determined by the prior network conditions.






DC component
Xd'' → Xd' → Xd
DC component
power system