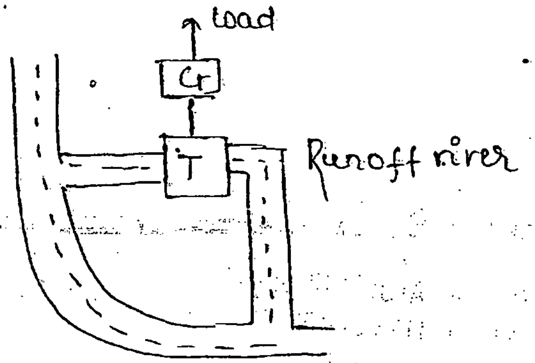
Econonic / variable load factor:

Base load plants:

(i) operating time from No load to full load is maxm

(ii) ex: Thermal, nuclear, Hydro (rainy), Run off river, wind, Solar etc.

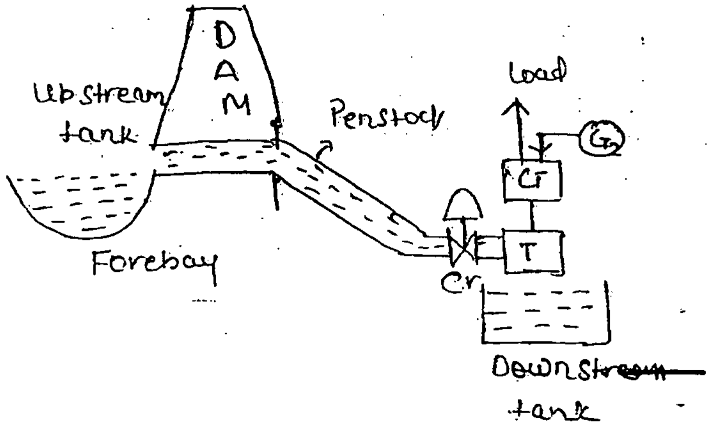


Peak load plants

(i) operating time from No load to full load is minimum.

(ii) plumped storage plant
Hydro plant

Disel plant, Gas plant



Important formulas:

(1) Plant load factor (P_{lf})

$$P_{lf} = \frac{P_{avg}}{P_{max}} = \frac{P_{avg} \times t}{P_{max} \times t} = \frac{\text{Area under load curve}}{\text{(Rectangular area crossponding to } P_{max})}$$

$$\boxed{\begin{array}{ll} \text{Ideal:} & P_{lf} = 1 \\ \text{Practical:} & P_{lf} < 1 \end{array}}$$

(2) Plant capacity factor (P_{cf})

$$P_{cf} = \frac{P_{avg}}{P_c}$$

P_c = Plant capacity.

$$P_{cf} = \frac{\text{Energy produce in total hrs}}{(\text{Energy able to produce as per } P_c \text{ in total hrs})}$$

$$\boxed{P_{cf} < 1}$$

3. Plant usage factor (P_{cf}):

$$P_{uf} = \frac{P_{avg}}{P_c}$$

P_c = plant capacity

$$P_{uf} = \frac{\text{Energy produced in used hrs}}{(\text{Energy able to produce as per } P_c \text{ in used hrs})}$$

$$\boxed{P_{uf} < 1}$$

4. utilization factor (u_f):

$$u_f = \frac{P_{max}}{P_c}$$

5. Reserve capacity (R_c)

$$R_c = P_c - P_{max}$$

$$= \frac{P_{avg}}{P_{cf}} - P_{max}$$

$$= \frac{P_{avg} - P_{max} \cdot P_{cf}}{P_{cf}}$$

$$= \frac{P_{max}\left(\frac{P_{avg}}{P_{max}} - P_{cf}\right)}{P_{cf}}$$

$$\boxed{R_c = \frac{P_{max}(P_{Lf} - P_{cf})}{P_{cf}}}$$

(6) Demand factor (D_f):

$$D_f = \frac{P_{max}}{\text{Sum of connected load}} \qquad \boxed{D_f < 1}$$

(7) Diversity factor (Div_f)

$$Div_f = \frac{\text{Sum of individual ~~max~~ demand}}{P_{max}}$$

$$\boxed{Div_f > 1}$$

Page no 17:

Q8 = 2017: (1) $P_{max} = 150\,mW$

(2) $P_{avg} = \frac{100 \times 10 + 120 \times 2 + 150 \times 6 \times 100 \times 4 + 0}{24} = \frac{2540}{24} = 105.83\,MW$

(3) $P_{Lf} = \frac{P_{avg}}{P_{max}} = \frac{105.83}{150} = 0.705 < 1$

Alternatives

$P_{Lf} = \frac{2540}{} \quad \frac{P_{avg} \times 24}{P_{max} \times 24} = \frac{2540}{150 \times 24} = 0.705$

(4) $P_{cf} = \frac{P_{avg}}{P_c} = \frac{105.83}{200} = 0.529 < 1$

or

$P_{cf} = \frac{2540}{200 \times 24} = 0.529$

(5) $P_{uf} = \frac{2540}{200 \times \underbrace{22}_{\text{used hrs}}}$

$= 0.577$

(6) $U_f = \frac{P_{max}}{P_c} = \frac{150}{200} = 0.75$

(7) $R_c = P_c - P_{max}$

$= 200 - 150 = 50MW$

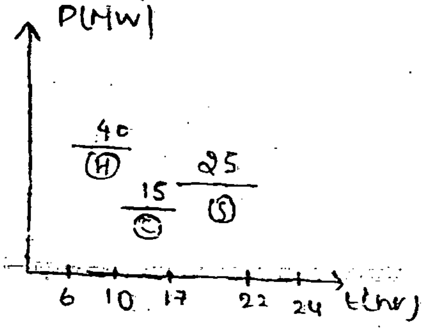
or

$$R_c = \frac{P_{max}\,(P_{if} - P_{cf})}{P_{cf}}$$

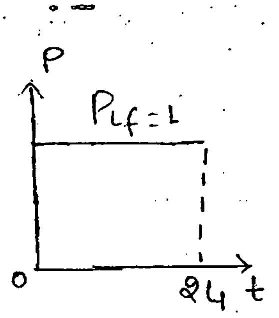
$$= \frac{150\,(0.705 - 0.529)}{0.529}$$

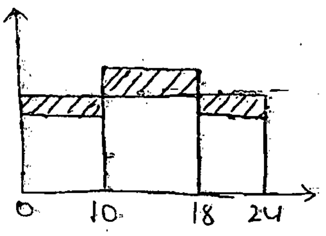
$= 50MW$

		Connected load (KW)	~~Load~~ Ind. maxm demand (KW)
SS	Colleges	20	15
	Shops	30	25
	Hospital	40	35
		$\Sigma = 90$	$\Sigma = 75$



$D_f = \frac{50}{90} < 1$ $\qquad$ $Div_f = \frac{75}{90} > 1$





$\uparrow P_{lf} = \dfrac{P_{avg}}{P_{max}\downarrow}$; $\uparrow D_{ivf} = \dfrac{\Sigma \text{Ind. max}^{m}\text{. Demand}}{P_{max}\downarrow}$

Methods of Improving P_{lf} and Diversity factor

(1) $P_{lf} \geq 1$ and $D_{ivf} > 1$ is practically ~~preffered~~. so intial investment on the electrical equipment like X^r, tr. lines, generator's etc. are reduced and hence cost of electrical energy is reduced.

→ Providing subsidy to the industry for running the electrical appliances during off peak load time.

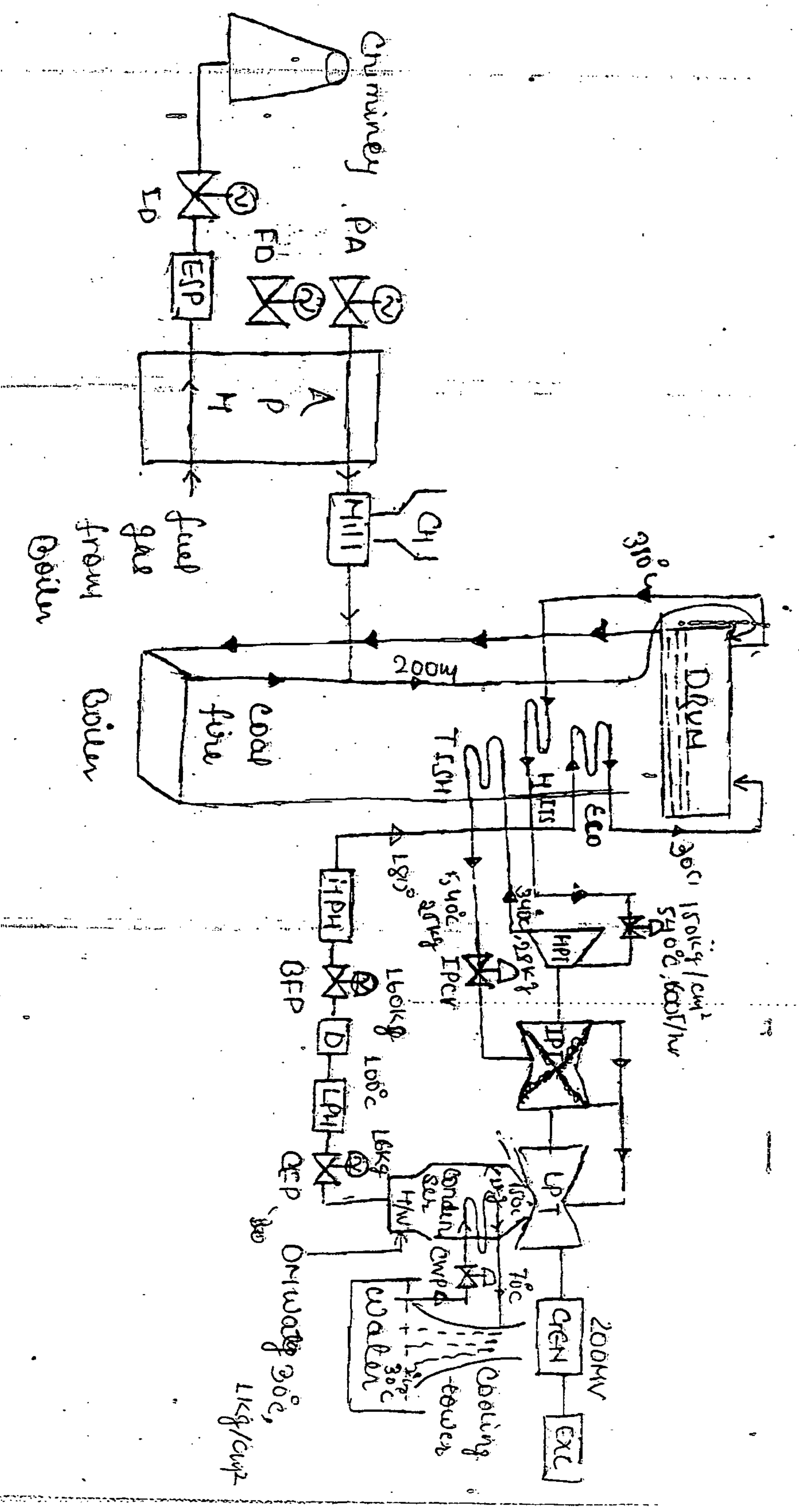
→ Encouraging the farmer running agricultural pump set during off-load (Peak) time.

→ Effective utilization of solar light by maintaining validation b/w building

→ Encouraging the industries for running the p.f load

~~Power~~ generation method:

Thermal power genration



H/W = Hot well

DM = Demineralised

CEP = Condensate Extraction pump

LPH = Low power heater

D = DEAERATOR

BFP = Boiler feed pump

HPH = high pr. heater

ECO = Economiser

HTSH = High temp Super heater

HPGV = High pr. Crovern Valve

HPT = High pressure turbine

ITSH = Intermiatetemp. Super heater

IPCV = Inter pr. Crovein Valve

IPT = Inter pr. turbine

LPT = Low pr. turbine

CWP = Circulating water pump

(v) = Vaccum pump or Steam injector

PA = Primary Air fan

CH = Coal Hopper

FD = Force daught fan

ID = Induced Draft Fan

APH = Air pre heater

ESP = Electrostatic precipitator

Chemical energy (coal) $\xrightarrow{\text{Boiler}}$ Heat $\xrightarrow{\text{Turbine}}$ Mech $\xrightarrow{\text{Gen}}$ Elec

PRNICPLE: Rainkine cycle.

$\eta = 40\%$

$$\boxed{\eta_T = \eta_B \times \eta_g \times \eta_T}$$

Coal energy = Kcal/Kg = colorific value = C_f

$$\boxed{860\,\text{Kcal} = 1\,\text{KWhr}}$$

Bitiminus coal: ~~1600 Kg~~ 1600 Kcal/Kg = C_f $\quad \eta_{Total} = 40\%$

Electrical Energy $= \frac{1600}{800} = 2\,\text{KWhr/Kg}$

$\therefore$ 1 Kg = 2 KWhr

$\eta_{Total} = 40\%$

1 Kg = $2 \times 0.4 = 0.8$ KWhr

$1\,\text{KWhr} = \frac{1}{0.8} = 1.25$ kg of coal.

P = 200 MW, t = 1 day = 24 hrs

Energy/day = $200 \times 10^3 \times 24$ KWhr

$= 4800 \times 10^3$

Total coal per day

$= 4800 \times 10^3 \times 1.25$

$= 6000 \times 10^3$ Kg

= 6000 Tons/day

Ash = 20%

$= 6000 \times \frac{20}{100} = 1200$ T/day.

1 train = 2000 T

$= 2000 \times 10^3$ kg

$= \frac{2000 \times 10^3}{1.25}$

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Head (m)	Turbine:
8-15	Propllar/Kaplan
15-70	Kaplan/Francis
70-500	Francis/Pelton
>500	pelton

Principle: It works on the priciple of Raenkine cycle. The Effmax of Thermal plant is 40%.

→ DM water: protection of boiler from the corrosion.
P_H = 8.9 – 9.2 (Alkaline or base)

→ LP & HP Heaters: improved water temperature to get improves the $\eta_{thermal}$.

→ Dearēator: removing the desert gases from the water so that ~~the~~ turbine blades are protected.

→ BFP: Highest pr. genrating pump. and consumes 4MW electrical power.

→ Economiser: absorb heat flom the flue gases so that improve $\eta_{thermal}$ by ↑ing water temp.
water circulation naturally b/w drum to the boiler and again to the drum due to density diff of steam & water.

- HVSH 170 used for improving steam temp 540°C. Stream send back from HPT to boiler for reheating. So that $\eta_{thermal}$ improved.

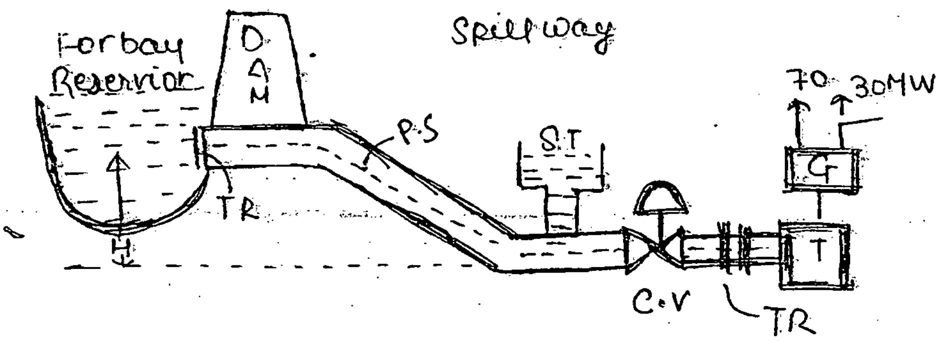
- After work done by stream and IPT is directly send to LPT

- By using vaccum pump steam is absorb in the condenser in the turbine.
  Most of the energy wastage for this process. So that $\eta_{thermal}$ very low (40%)

- PF is used to send the coal powder from mill to the boiler.
- FD fan supply O_2 to the boiler for proper combustion of coal.
- ID fan is used to extract flue gas from the boiler and releases to atm.
- ESP works on the principle of Electrostatic field. used for collection of ash particles from the flue gases.
- APH is used to preheat the PA and FD fan air for removing moisture from coal
- HPCV and IPCV are used to regulate the stream flow rate into the turbine. so that ~~speed~~ & f are regulated.

Hydro power plant :-

Potential → Kinetic → Mech → Elec.



Electrical O/P Power (P)

(1) Discharge (Q) is given

A/C Bernoulis theorem

$$\boxed{\begin{aligned} P &= \frac{0.735}{75}\, \eta \omega Q H \\ &= 9.18 \times 10^{-3}\, \eta \phi H \omega \end{aligned}}\ \text{KW}$$

η = Plant efficiency

ω = Density of water = 1000 kg/m³

H = mean water head (m)

Q = Discharge water m³/s

$$Q = \frac{\text{Total resirvior capacity}}{3600}\ m^3/s$$

(a) Rainfall (F) is given

$$\boxed{P = 3.4 \times 10^{-4} \eta KAFH} \quad KW$$

K = yeild factor

F = Anual rain fall in mm

A = Catchment Area sq. km.

H = Mean water head ... m

η = plant Efficiency

$$\boxed{Energy = P \times t}$$

	Head
$H < 30m$	Low
$30 < H < 300$	Medium
$H > 300$	High

- In hydroplant, water is sending from resirvior to the turbine through the penstock for producting electrical o/p.

Surdge tank is used in medium & high head plant and kept closer to turbine.

S.T is used for

(a) protecting the penstocks from the water hamering Effect.

(b) Applying the water to turbine in case of sudden load demand.

(c) Spill way is used for deverting the water from dam. so that protecting the dam from excess water

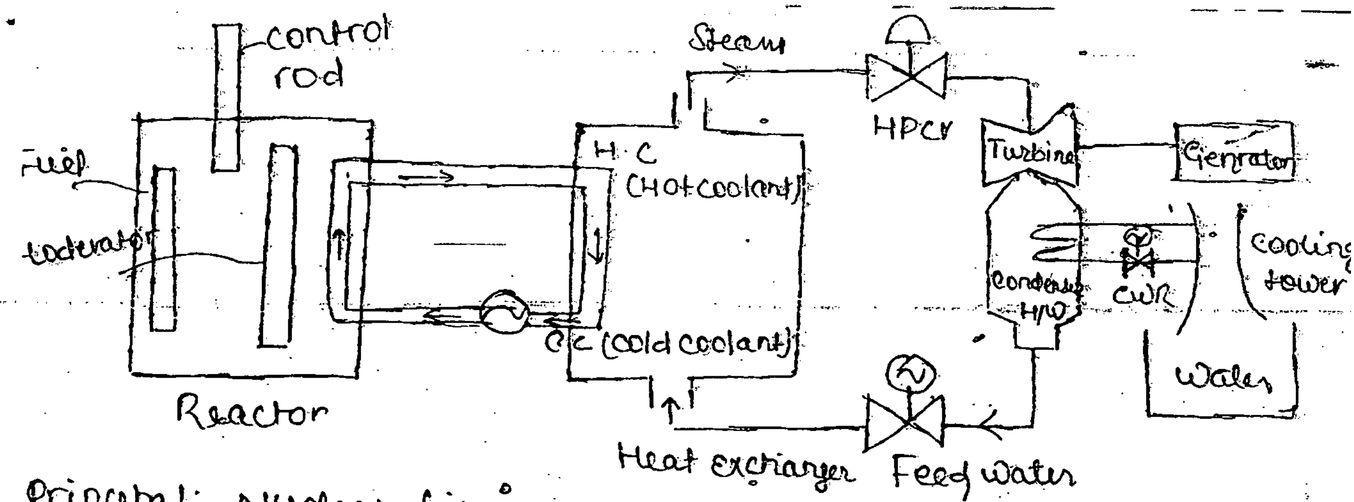
- Trash track is used for the protection of turbine from the debris (waste materials)

Pump storage plant:

- It is one of the type of Hydroplant consisting upstream & down stream tanks. During peak load timing water from up stream tank to down stream to the turbine for meeting the emergency load demand.
- During off peak load time water send back from down to upstream, during this time turbine is working as pump, genrator is working ~~as~~ motor by taking power from other 11 genrator.
- Advantages:

(i) Most economical as a peak load supply plant.
(ii) used as load frequency control units.
(iii) If it is combine with the thermal plant plant load factor is improves.
(iv) Eaisly adoptable for remote control operation.
(v) Less pollution.

Nuclear power plant:-



Principal: Nuclear fission

	BWR	PWR	CANDU	Liquid Na	FBR
Fuel	Enriched	Enriched	Natural	Enriched	Enriched
~~Coolant~~	Water	Water	Heavy water	Liquid Na	Na
Moderate	,,	,,	,,	Graphite	—
Control rod	Cadmium	cadmium	– Boron Cadmium →		Boron /cadmium

BWR = Boiling Water Reactor
PWR = Press. ,, ,,
FBR = Fast breeder ,,
CANDU = Canadium Deuterium uranium reactor

Enriched uranium – U^{238}_{92}
Natural uranium – U^{235}_{92}

Reproduction / Multiplication factor (K)

$$K = \frac{\text{No of Neutron in present cycle}}{\text{" " " previous cycle}}$$

K=1 = Constant power o/p
K>1 = Increased " "
K<1 = Decreased " "
Practical K just higher than 1 is used.

Ex:

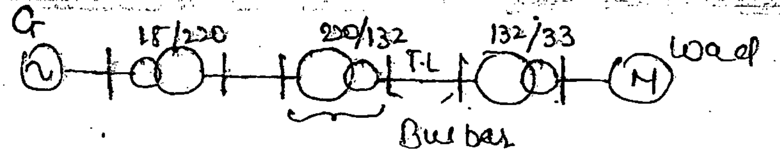
10 AM – 100 MW – 100 Neturon $K = \frac{100}{100} = 1$
11 AM – 100 MW – 100 Neturon
13 AM – 120 MW – 120 Neturon $K = \frac{120}{100} = 1.2$ KW
15 AM – 80 MW – 80 Neturon $K = \frac{80}{100} = 0.8$ KW

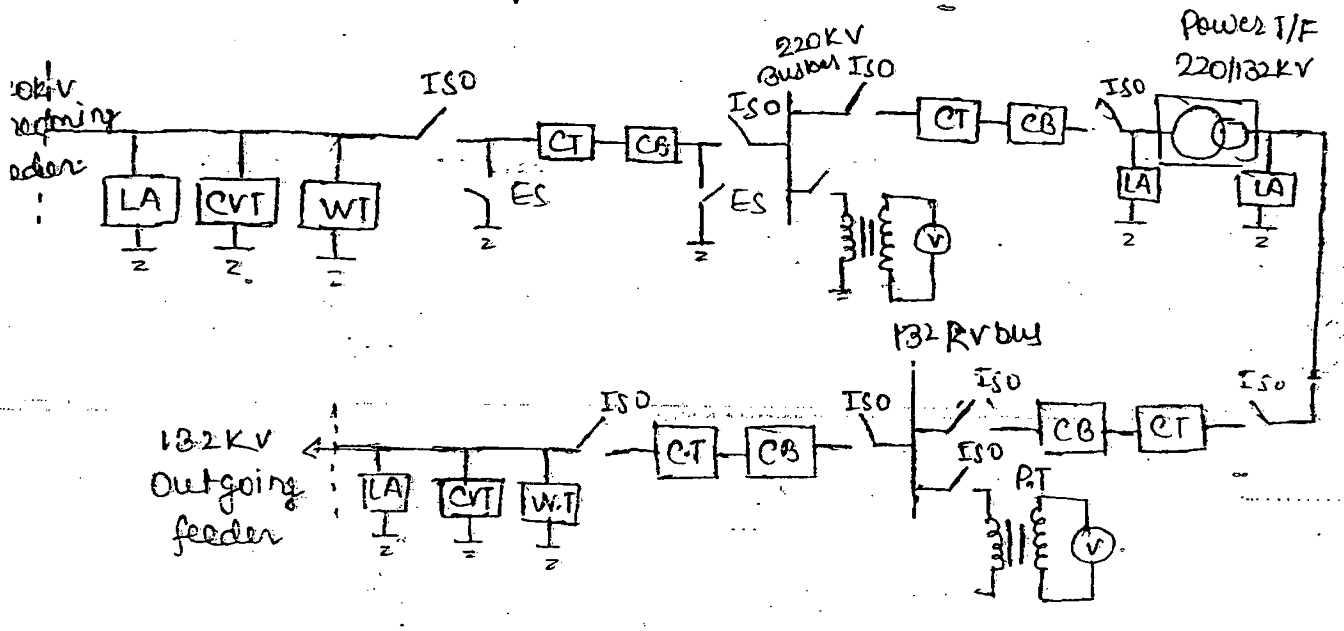
- Nuclear power plant works on principle of nuclear fission chain reaction
- heat produced in the reactor is absorbed by the coolant and this heat is used for converting water into the stream. Stream is sending to the turbine. used to provide electrical O/P.
- Control rod are used for absorbing the excess neutron released during chain reaction.
- Modrator is used for moderating the speed of neutrons.
- Modrator material must have low molecular range so that speed of Neturon is regulated properly.

- In enriched uranium plant ordinary water is used as Moderator.

Protection & switchgear's :-

Practical P.S consisting of electrical equipments likes X^rs, trans. line, Bus bars, load likes motor. This equipment are to be protected from the abnormal condn like [LA] surges, O.C and S.C faults. For protection of these equipment, protecting devices. CB, Isolators, relays, C.T and P.T etc. are to be arranged specific sequence in the substation.





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LA = Lighting Arrester
CVT = capacitive voltage transformer
WT = Wave trap
ES = Earth switch
ISO = Isolators
CB = circuit breaker
C.T = current x^r
P.T = Potential x^r

1. Lighting Arrestor:

The 1st and last-protecting device is LA. this are used to dirvert the lighting occur occurs outside of S.S. two more L.A are used both side of x^r for protection ~~of~~ x^r from lighting occurs inside S.S.

Materials : Zinc oxide, Silicon carbide } which offers low impedence for lighting surge & high impedence for normal supply voltage.

Impulse ratio of LA is unity..

$$= \frac{\text{high frequency surge voltage}}{\text{low frequency surge voltage}}$$

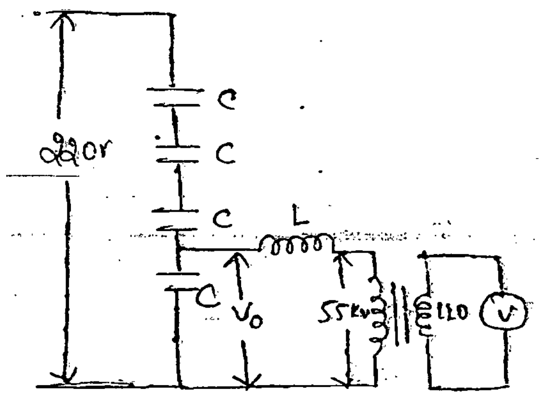
2. Capacity voltage x^r :-

It is working on the principle of capacitance used for:

(a) measuring high voltages of the feeder.
(b) provide voltage signal to wattmeter, energy meter or voltmeters.
(c) " " " " protective relays like distance, derectional, defferential etc.

1

(d) used 78 as a current carrier signal for the protection of tr. lines.



$V_0 = \frac{220}{4} = 55KV$

An each ϕ (Phase) of feeder CVT is used standered secondary voltage is 110 V.

3) P.T:

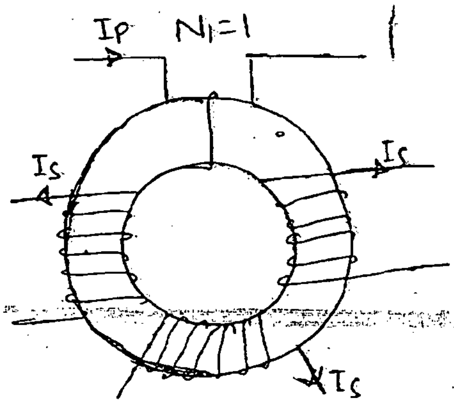
It is working on the princepal of tr. used for measurment of high voltage busbar. this voltage signal provided to voltmeter, wattmeters & protective relays like distance & directional. This uses as backup for the CVT standere voltages. is of one time volts.

1) C.T:

~~It~~ consisting of single turn 1° with multiple 2° turns with multiple wdgs. Normally 3 or 5 2° wdgs are used. taps arraygment are provided on 2° wdgs. Standered 2° current is an 1amp-5amp. 1A CT has less burden (ie power consumption is less) so sensitivity is higher.

It provides I S/g to Ammeters, wattmeters, energy meter & protective relays like overcurrent, distance, directions. etc.

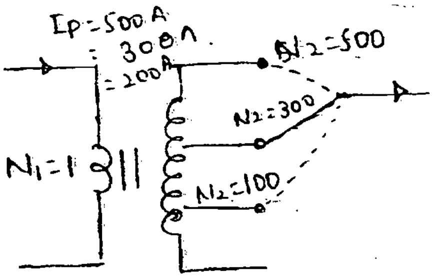
N.B With 1° Excited. CT 2° can be never O.C because huge voltage induced in the 2°. So that insulation failure is occur, which damages the CT and dangerous to the persons working nearer to the CT



Core1 : S_1: 500/300/100A

Core2: S_2 500/300/100A

Core3 : S_3 500/300/100A/0.577 A



Power T/F

$S = 100\,MVA$

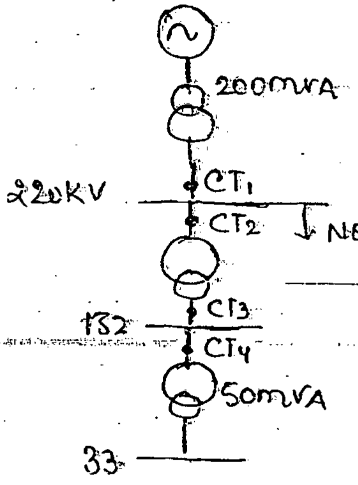
$\sqrt{3}V_1I_1 = \sqrt{3}V_2I_2 = S$

$\sqrt{3}\times 220\times 10^3 I_1 = \sqrt{3}\times 132\times 10^3 I_2 = 100\times 10^6$

$I_1 = 268A \rightarrow 300A$

$I_2 = 437A \rightarrow 500A$

How [illegible] CT with CT4



$$C_1 = \frac{200}{\sqrt{3} \times 220}$$

$$C_4 = \frac{50}{\sqrt{3} \times 132}$$

4. Wave trap: (WT):

It consisting of LC tune circuit used for

(1) power line carrier communication (PLCC)

(2) SCADA

(3) current carrier potection

(4)

5. CB (Circuit Breakers):

It consisting of ~~Gas~~ Arc quinching medium like SF_6, Oil, vaccum, air etc. and ~~it is~~ used for protecting the healthy section from ~~faulty section~~ by isolating the faulty section. It can be operate open or closed through relay or mannual in no load or full load condn.

(6) Isolators:

It doesnot have Arc quinching medium. So it can be open on no load condn only.

(7) Earth switch:-

under normal condition E.S must be in open condn. during maintaince time of equipment, that switch is closed for discharging of Residual Energy present in the electrical Equipment.

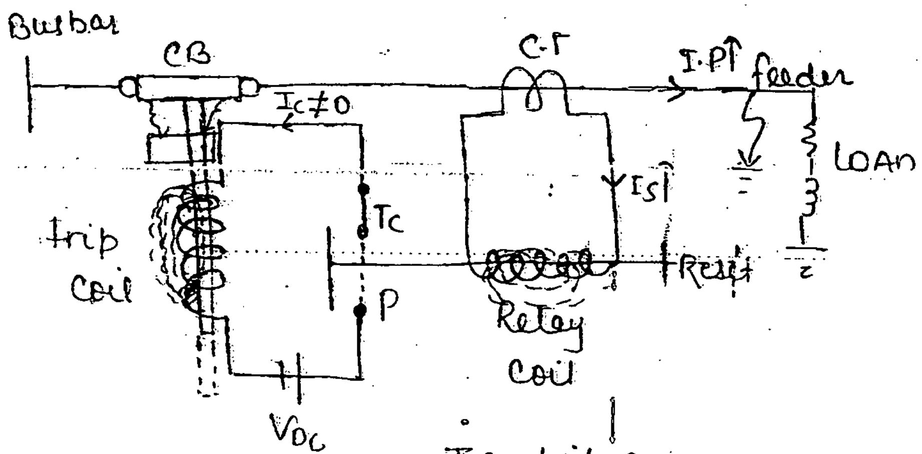
(1) Sequence used before maintaince of equipment:

(a) open C.B is run full load or No load.
(b) Open isolator on no load.
(c) closed Earth switch.

(2) Sequence used before charging or after maintaince

(a) open E.S
(b) close Isolators
(c) close C.B

Relation b/w Relay and circuit breakers



T.C = trip contacts
P = plunger.
---- = faulty condn.

(i) Healthy condition (Block)

Tc – open (Normal open – N.O)
CB – close

(2) Faulty condition (Trip)

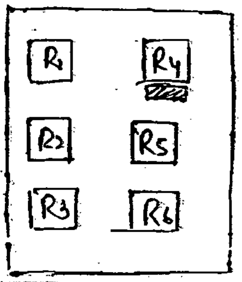
Tc – close (Normal close N.C
CB – open

Total fault clearing time

= Relay time + C.B mechnical operating time + Arching time

It takes 5 to 6 cycles for complet fault clearance.

1 cycle = 20 ms



R1: O/C R2: Directional
3: O/V 4: Offset mho (trip signal)
5: O/S
6: E/F

Types of different relays:-

Depends on,

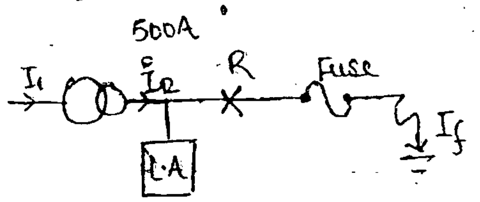
Principle:
(1) Electromagnetic
(2) thermal
(3) Static

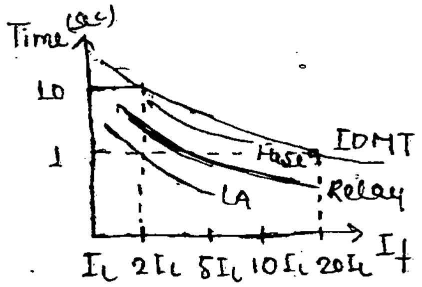
Sensing element
(1) Over current (O/C)
(2) Over voltage
(3) Over flux
(4) Earth fault
(5) Directional
(6) Distance
(7) Differential

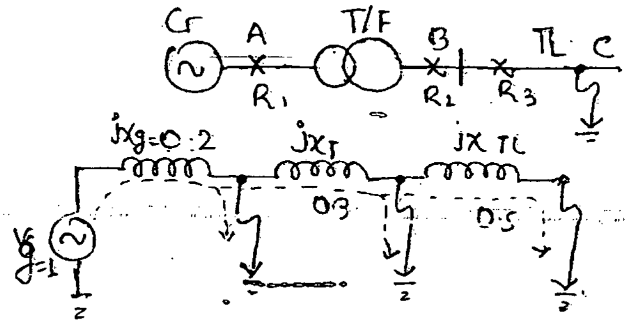
Equipment protected
(i) Genrator
(2) T/F
(3) Tr. line
(4) Busbar
(5) Motor

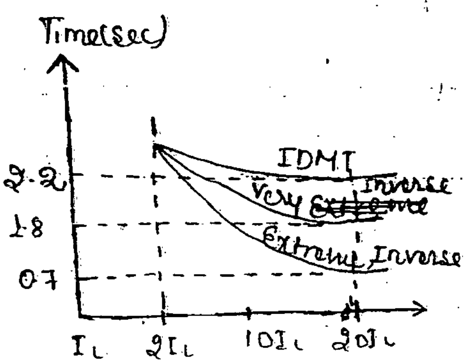
Speed,
(i) Inverse Defnite min. time (IDMT)
(2) Very inverse
(3) Extreme inverse
(4) Instantanious

Speed
(1) Inverse Defnite min^m time.







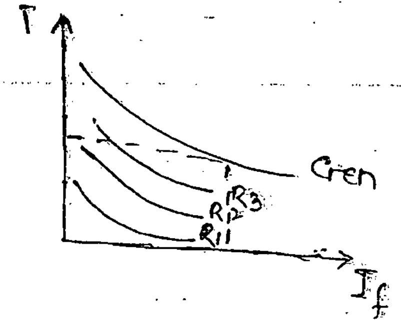


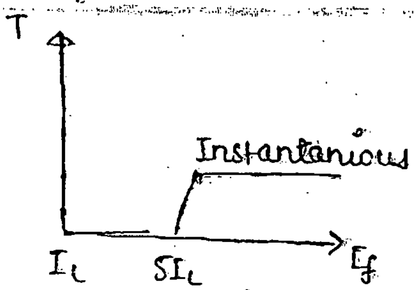
$I_{fA} : \frac{V_g}{X_g} = \frac{1}{0.2} = 5$ sec (IDMT)

$I_{fB} = \frac{V_g}{X_T} = \frac{1}{0.5} = 2$ sec (very inverse)

$I_{fC} = \frac{V_g}{X_{TL}} = \frac{1}{0.1} = 1$ sec (Extrem inverse)

Lock out /Struck breaker:



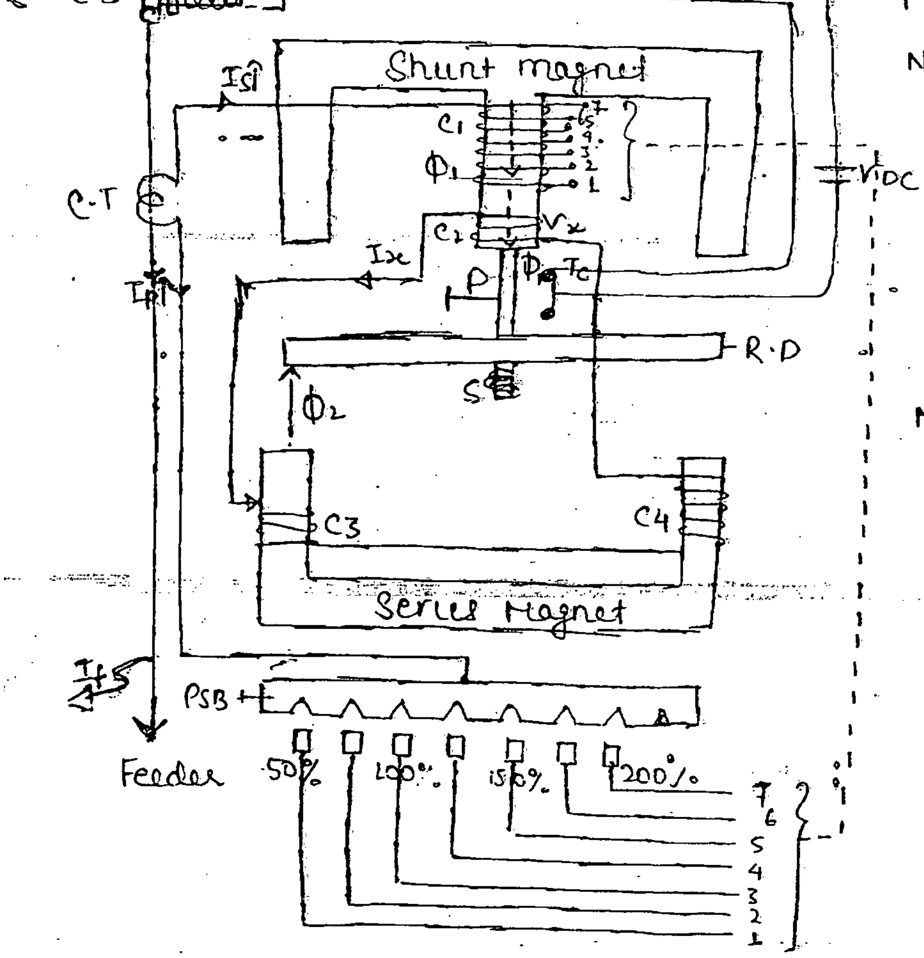


Electromagnetic Relay:

- Attraction
  - Not in use Due to doubling Effect.
- Repulsion
  - Watt ~~meter~~ hours relay
  - Shaded
    - (Watt hours relay, Shaded) → IDMT, very Inverse → O/C, Diff, E/F
  - Induction cup
    - Instantanious
      - Directional
      - Distance

Watt Hour Meter Relay:-

Non directional o/c Relay



N.B: For measurmet of current we use series magnet

For measurmont of voltage we use shunt magnet.

N.B Red line indication operation of energy meter

$C_1 C_2 C_3 C_4$ = coil

P = plunger

T.C = trip contact

R.D = rotating Disc

P.S.B = Pluge setting Bridge

S = spring for controlling/Restraning torque (T_c)

$I_f = I_m \sin \omega t$

$\Phi_1 \propto I_s \propto I_P \propto I_f$

$\Phi_1 = \Phi_m \sin \omega t$

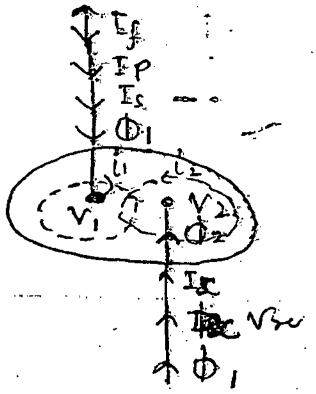
$$V_1 = -\frac{d\Phi_1}{dt}$$

$V_1 \propto \Phi_{m1} \sin(\omega t - 90^\circ)$

$i_1 \propto \Phi_{m1} \sin(\omega t - 90^\circ - \alpha)$

$\phi_2 = \Phi_{m2} \sin(\omega t - \theta)$

$V_2 = -\frac{d\phi_2}{dt}$



$V_2 \propto \Phi_{m2} \sin(\omega t - \theta - 90^\circ)$

$i_2 \propto \Phi_{m2} \sin(\omega t - \theta - 90^\circ - \alpha)$

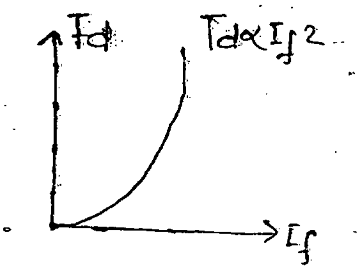
Deflecting /Driving torque

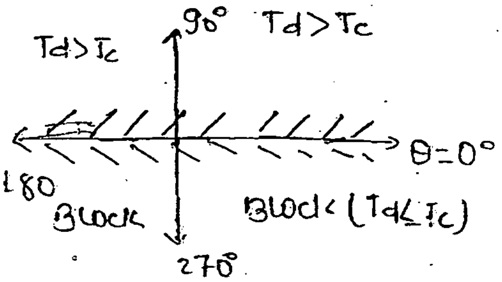
$T_d \propto (\phi_1 i_2 - \phi_2 i_1)$

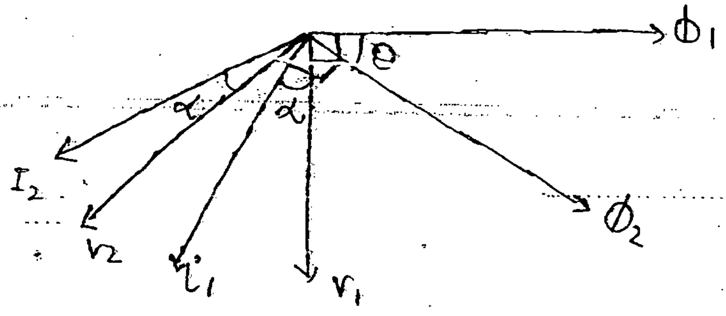
$$\boxed{T_d \propto \Phi_{m1} \Phi_{m2} \sin\theta}$$

$\Phi_{m1} \propto I_f \, , \; \Phi_{m2} \propto I_f$

$$\boxed{T_d \propto I_f^2 \sin\theta}$$





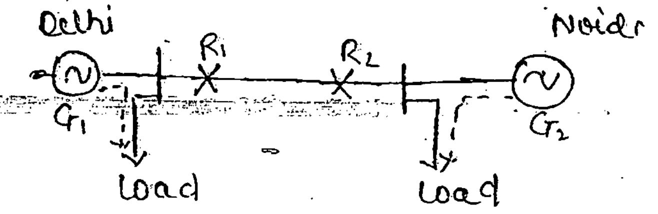


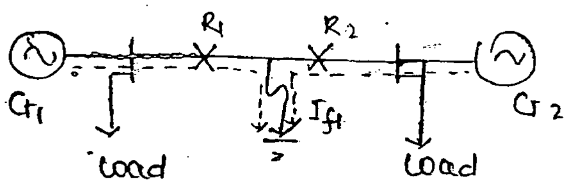
* Spring is used
  1. bringing the trip to its original possition
  2. opposes the deflecting or driving tousque

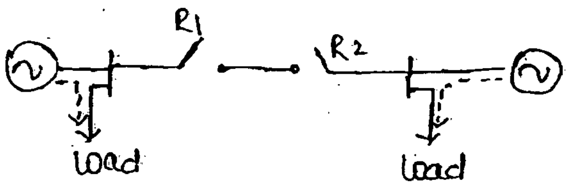
N.B: I_f is more operation time more & vice versa.
This shows IDMT character.

* between $0 \leq \theta \leq 180°$ $T_d = +ve$, produces trip signal.
  $\theta > 18$ $T_d = -ve$, produced blocking condn.

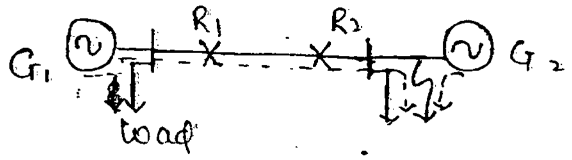
Application
Condition I

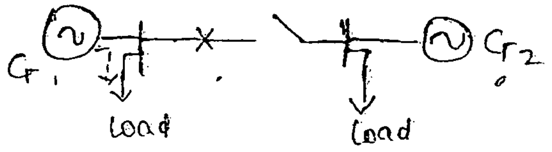






Condition II:





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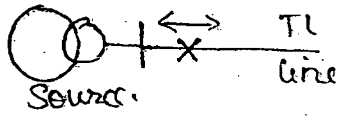
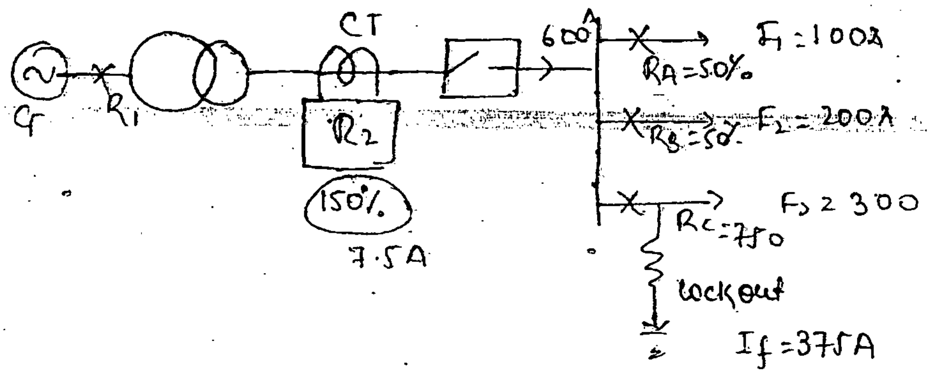
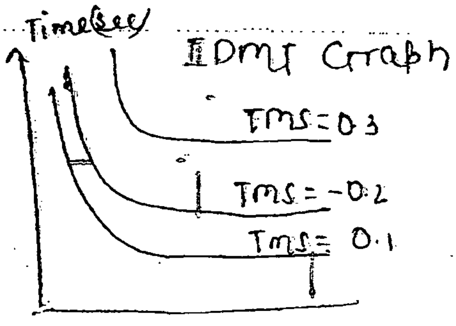
Non-directional over current (O.C) relay is produces trip signal. if the fault current I_f magnitude is more than relay internal setting value and it is indepent from fault current dir^n. So it is called Non directional. It is practically use to source end to identify the fault to the source side & line side.





.5	.75	1	1.25	1.5	1.75	2.0
50%	75%	100%	125%	150%	175%	200%
250 / 2.5	375 / 3.75A	500 / 5A	625 / 6.25A	750 / 7.5A	875 / 8.5A	1000 / 10A

* Current grading is done by PSB
* Time greating is done by shaft.



Current greading

For complete protection of the diff^n equipment the 1° and 2° back relay are to be properly co-ordinated. So that different Plug settings are provided in the relays by changing the PSB setting. This is called current greading.

Time greading:—

Time delay is provided b/w the 1° & backup relays by changing the a distance b/w the plunger & trip contacts. this is called time greading.

1) Pickup current / Plug setting current:

$$I_{pk} = \% \text{ PSB setting} \times \text{C.T secondary current}$$

2) Plug setting multiplier (PSM):

$$PSM = \frac{I_f}{I_{pk} \times \text{C.T ratio}}$$

(3) Time of operation of any relay (T_o)

T_o = TMS × (time calculated by IDMT graph/Table crossponding to PSM)

TMS = Time multiplier setting

(4) $$T_o = \frac{K_1 \times TMS}{(PSM)^{K_2} - 1}$$

K_1, K_2 = constant

5) Time of Back up relay (T_B)

$$T_B = T_p + T_d$$

T_p = Time of 1° relay

T_d = " " backup relay
Delay b/w 1° and

→ If for any feeder if the full load current is given then ~~Select~~ the CT ~~ratio crossponding~~ to this full load current and PSB is equal to 100%.

Ex: if feeder draw a 200A of full load current PSB setting is 100% then CT ratio is to be $\frac{200}{1A}$ or $\frac{200}{5A}$ crossponding to 100%.

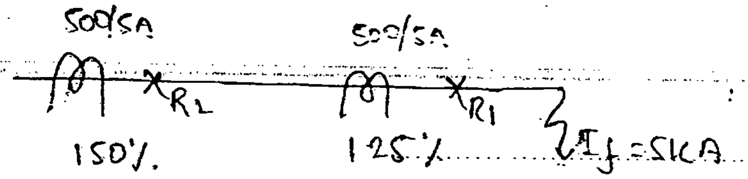
→ if the ~~PSB~~ plug setting is 5A given. this indicates PSB setting of 100% and CT secondary current of 5A. So select the CT ratio $\frac{200A}{5A}$

). if the feeder is protected by 1° and back relays are R_1 and R_2 with crossponding PSB setting and I_f are given in the N/ω calculate

(a) Time of operation of R_1 if TMS = 0.1 for R_1

(b) if the time delay b/ω R_1 & R_2 is 0.5 sec. calculate TMS of R_2

Soln:



PSM	4	6.66	8	20
Time	10	5	3	2

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R_1: $Psm = \dfrac{5KA}{\frac{125}{100} \times 5 \times \frac{500}{5}} = 8$

R_2: $PSM = \dfrac{5KA}{\frac{1500}{100} \times 5 \times \frac{500}{5}} = 6.67$

(i) $T_0 = Tms \times$ (Time cal. from IDMT Graph,)

$= 0.1 \times 3 = 0.3 = T_P$

(ii) R_2 is a back up relay

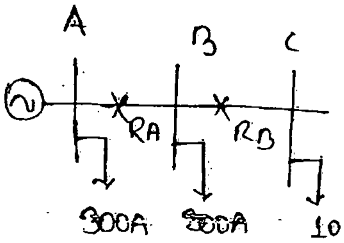
$T_B = T_P + T_d$

$= 0.3 + 0.5 = 0.8$ sec

$T_B = 0.8 = TMS \times 5$

$TMS = \dfrac{0.8}{5} = 0.16$

117. Soln: $t_{op} = \dfrac{0.14 \times TMS}{(Psm)^{0.02} - 1}$



($I_f = 500 - 2000A$)

R_B = TMS = 0.1

Plug setting = 5A = I_{PK}.

C.T ratio = $\dfrac{100}{5A}$ at PSB = 100%

(a) $I_f = 500A$

$Psm = \dfrac{500}{5 \times \frac{100}{5}} = 5A$

$t_{op} = \dfrac{0.14 \times 0.1}{(5)^{0.02} - 1} = 0.427$ sec

(b) $I_f = 2000A$

$Psm = \dfrac{2000}{5 \times \frac{100}{5}} = 20A$

$t_{op} = \dfrac{0.14 \times 0.1}{(20)^{0.02} - 1}$

$= 0.226$ sec

Ans $0.226 - 0.427$ sec.