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MADE EASY
ELECTRICAL ENGINEERING
Power System-1
By.Balaji Sir

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

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(DTDC & INDIA POST)

Standard voltages used in India :-

HVAC RMS line to line voltage / line voltage (kv) :

Transmission Network voltage (kv) —
- 1200 KV (maximum in india) Maharashtra
- 765, 400
- 220, 132
- 66

Distribution Network voltages (KV) —
- 33 KV, 11 KV

Industrials uses — 6.6 KV, 3.3 KV, 1.1 KV, 400V

Houses uses — 230V (phase voltage)

Frequency $f = 50 Hz$

HVDC ± 500 KV, ± 800 KV, $f = 0 Hz$

QN :- The rated voltage of a 3-phase power system is —
— RMS line to line voltage

All India Installed capacity sector : 382.730 GW

Coal : 209294.5 MW	Gas : 24924 MW	Nuclear : 6780W
Hydro : 46209.22 MW	Diesel : 509.71 MW	Renewable Energy source : 95012.59 MW

WR : 74320 MW by coal largest ⎫ power
NER : 770 MW by coal smallest ⎭ utilisation

Thermal : Coal + Lignite + Gas + Diesel

30th June 2021 ⟶ maximum power consumed by 193 GW at 12:46 pm

variable load curve : All india Demand (GW) v/s time

Demand ↑ — Peak load — Base load — time →
↙ maintaine minimum amount of power to supply
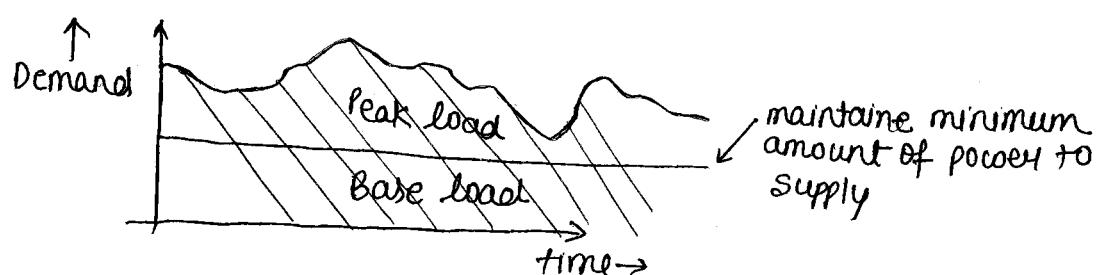
| Base load –: Thermal plant | Next to peak load : Gas, wind, solar |
| Peak load –: Hydro plant | |

Solar power plant
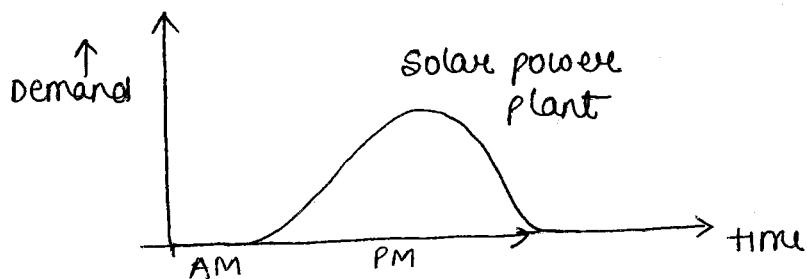
1 kwhr = 1unit

2019-20 1208 kwh per capita consumption

objectives of Power system :–

(i) COST of electric energy must be low.
     – Economic factors
     – Economic load dispatch

(ii) Reliable power supply i·e; no interruption of power supply
     – power generation methods
     – Transmission
     – Distribution
     – load flow studies

(iii) Maintaine constant voltage i·e; supply rated voltage to consumer

$P = 230W$
$\cos \varphi = 0.8$

$P = V I \cos \varphi$
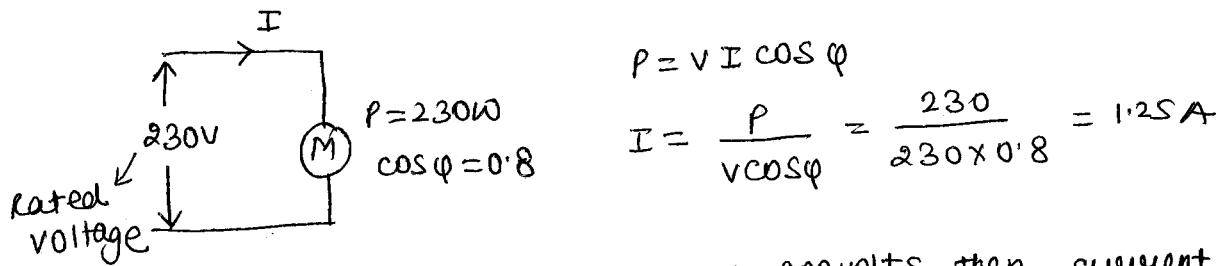
$I = \dfrac{P}{V \cos \varphi} = \dfrac{230}{230 \times 0.8} = 1.25 A$

suppose supply voltage get reduce to $V = 200$ volts then current drawn by motor will be $I = \dfrac{230}{200 \times 0.8} = 1.4375 A.$

% increase in current $= \dfrac{1.4375 - 1.25}{1.25} \times 100 = 15\%$

current drawn by motor is high value. this will causes overheating

To get constant voltage — voltage/Reactive power control

(iv) Maintaine Rated frequency

$$f = 50Hz \pm 1\% \quad (49.5 \text{ to } 50.5)Hz \quad \text{(ideal case)}$$

$$= 50Hz \pm 3\% \quad (48.5 \text{ to } 51.3)Hz \quad \text{(practical case)}$$
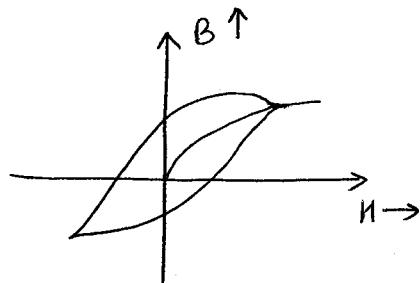
power T/F : $V = 4.44 f \, \varphi_m N$

$$\frac{V}{\downarrow f} \propto \varphi \uparrow \longrightarrow \text{causes core saturation}$$

for this ⟶ Load frequency control

(v) Faster fault identification and clearance of fault in minimum time
   — Fault Analysis
   — Protection

(vi) Stable Generator has to be maintained
   — stability

(viii) Flexible power transfer
   — power cable

Panther	− 132 KV
Zebra	− 220 KV
Moose	− 400 KV

-: Transmission line Parameters & Performance:-

By using transmission line, electric power is transfer from the remote generating station to the load centre (electric power utilised).

Material of Transmission line:-

ACSR - Aluminium conductor steel Reinforced

steel is used at the centre because it has higher mechanical strength to withstand and carry large weight of ACSR conductor.

4 layer ACSR (37-30/7)

$\downarrow \quad \downarrow$

strands $\leftarrow$ Al   steel

5 layer ACSR (61-54/7)

strands $\leftarrow$ Al   steel
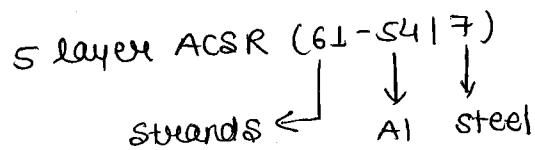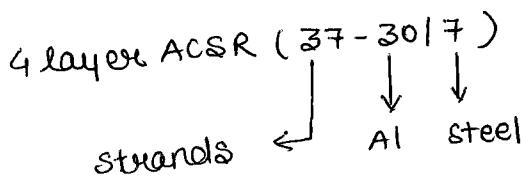
No. of strands: $N = (3x^2 - 3x + 1)$

Total Dia $D = (2x-1)d$

x = layer number
d = Dia of each strands

Technical name of ACSR :- Animal like, Zebra, Panther, Moose, Dog etc is used for Aluminium for european standard and bird name like Swan, sparrow, Raven, Pigeon etc is used as for US standard.

Power carrying capacities at 65°C :-

At 132 KV with 'Panther' ACSR = 75 MVA

At 220 KV with 'Zebra' ACSR = 200 MVA

At 400 KV with 'Moose' ACSR = 500 MVA .

3φ T/L $\Rightarrow \sqrt{3} \ V \cdot I \ \cos\varphi = 3\varphi$

$\sqrt{3} \times 400 \times 10^3 \times I \times 0.95 = 500 \times 10^6$

$I = 759.67 A$ carrying current by Moose

Tower configuration :-

3 bundle conductor not practically used due to mechanical strength.

Classification of Transmission line :—

(i) Short line — $l < 80$ km, $lf < 4000$

(ii) Medium line — $80 \le l \le 200$ km, $4000 \le lf \le 10000$

(iii) Long line — $l > 200$ km, $lf > 10000$

where $l =$ length of Tr. line $f =$ supply frequency $= 50$ Hz

EX-:   Short line $l \times f = 80 \times 50 = 4000$

NOTE-: communication line operating at MHz range hence considered as long transmission line because $lf > 10,000$ for any length of line

Q·N:— A T/L is excited by the frequency of

(i) 300 Hz   (ii) 50 Hz   (iii) 600 Hz

Find the type of T/L if its physical length is 20 km?

Solution :—

(i) 300 Hz $lf = 20$ km $\times 300$ Hz $= 6000$ $\textcircled{lf}$

$\quad \longrightarrow 4000 \le lf \le 10000 \rightarrow$ Medium

(ii) 50 Hz $lf = 20$ km $\times 50$ Hz $= 1000 \longrightarrow$ short line $(lf < 4000)$

(iii) 600 Hz $lf = 20$ km $\times 600$ Hz $= 12,000 \longrightarrow$ long line $lf > 10000$

Transmission line Parameters :—

(i) Inductance (L)

(ii) capacitance (C)

(iii) Resistance (R)

(iv) conductance (G)

Inductance:—
current $\longrightarrow$ produce flux $\longrightarrow$ link with other 2 phase also i·e;
due to flux (self + Mutual) produces inductance in it.
Capacitance:—
Two metal is separated by some distance & operating at some voltage produce capacitance in it & ground capacitance also exists.
Resistance:—
ACSR has certain cross section area & length which will produce resistance.

conductance (G):- The [leakage current] [flowing through] the [supporting insulator] is represented by the conductance parametere. It's [value] is [very small] and hence [neglected] in case of [short & medium line] and consider in the long transmission.

Electrical equivalent of leakage current $\implies$ conductance (G)
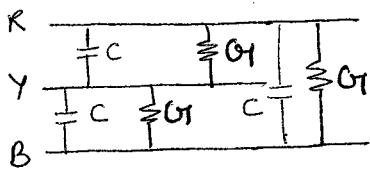
leakage current due to small value of resistance in insulator (Negl.)

R —
Y —
B —

(with C, G shunt elements)
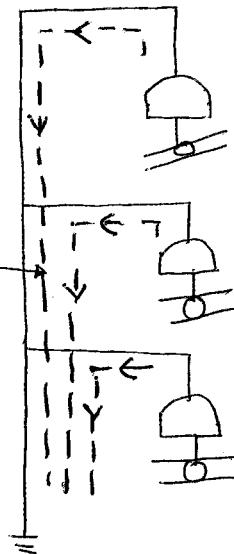
| series element $\implies$ R & L |
| shunt element $\implies$ C & G |
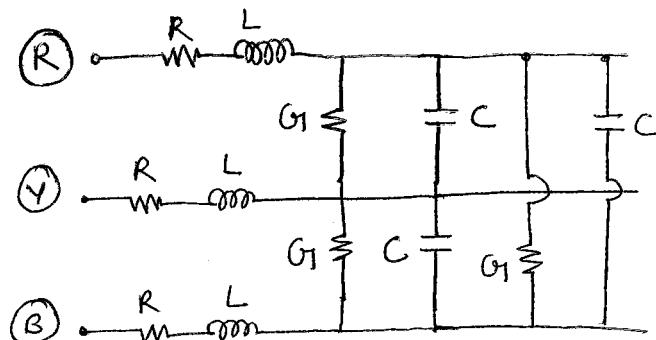
-: Electrical eqt of x-mission line :-

resistance :-

HVAC :-

ACSR

R_{AC}

I_{AC}

V_{AC}
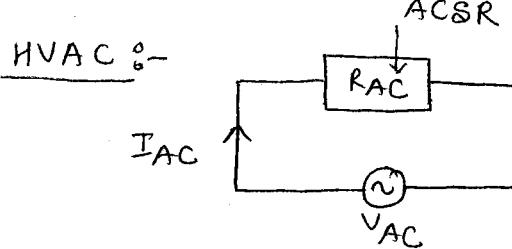
$\boxed{R_{AC} > R_{DC}}$

Due to $\begin{cases} (i) \text{ skin effect} \\ (ii) \text{ proximity effect} \end{cases}$

HVDC :-

ACSR

R_{DC}

I_{DC}

V_{DC}

$\boxed{R_{AC} = 1.5 \, R_{DC}}$

R = 1Ω

2v, I_1, 1Ω load

$I_1 = \dfrac{2}{1+1} = \dfrac{2}{2} = 1 \, A$

R = 1Ω

2v, I_2
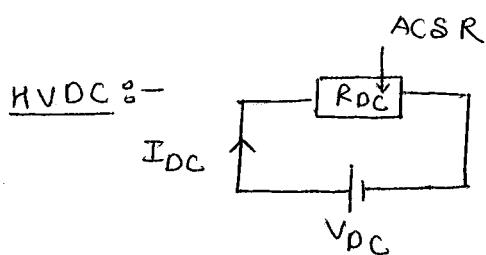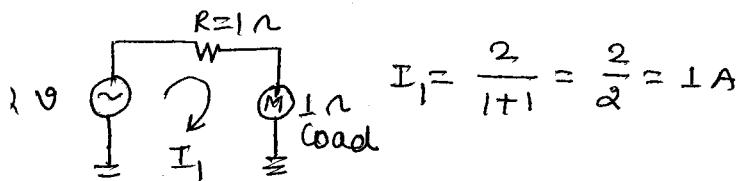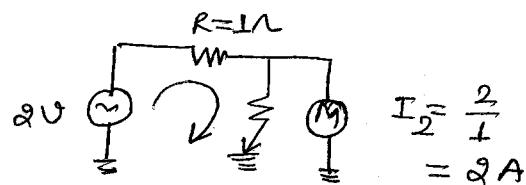
$I_2 = \dfrac{2}{1} = 2 \, A$

$\boxed{I_2 = 2 I_1}$ during short ckt condition

Shaut ckt rating : KA/S [maximum current able to withstand during fa

RTS : KN

(i) skin effect :-

(a) [Accumulation] of the [current on the surface of conductar] is called [skin effect]

⊙ outwards current
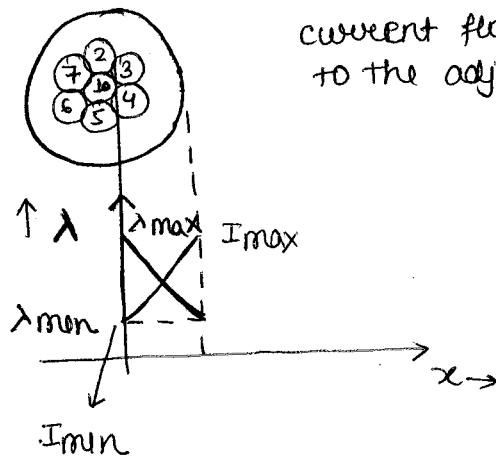
current flowing in the conductar producing flux to the adjacent of conductar

λ_{max} i.e; L_{max} then $X_L \uparrow$

$\downarrow I = \dfrac{V}{X_L} \uparrow$

λ_{min} i.e; L_{min} then $X_L \downarrow$

$\uparrow I = \dfrac{V}{X_L} \downarrow$

HVDC :
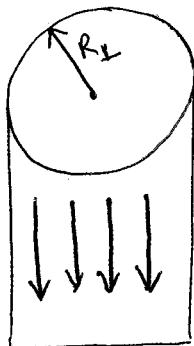
[uniform current] is [flowing] because there is [no rate of change of flux]

$$R_{DC} = \dfrac{\rho l}{\pi R_1^2}$$

HVAC :
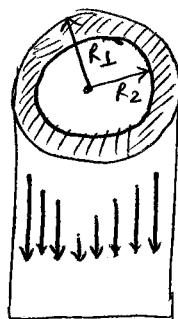
$$R_{AC} = \dfrac{\rho l}{\pi (R_1^2 - R_2^2)}$$

(b) Due to skin effect, [effective area] of [current flowing path] is [reduced] which [causes $R_{AC} > R_{DC}$]. in HVAC system.

(c) [Skin effect] [depends] on [f, σ, μ_r and size of the conductar].

(d) [Skin effect] is [more] in [communication line] because [frequency] is in [MHZ range] and this effect is [neglected in power lines] because the frequency is less [(50HZ) only].

f = supply frequency , μ_r = Relative Permeability σ = conductivity

skin depth (δ) :–
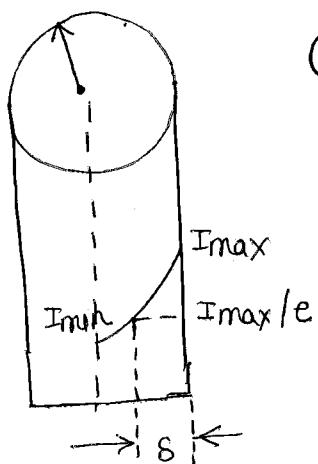
(a) The depth of the conductor at which the current is drop to $(1/e)$ time of the maximum current & that depth is called as skin depth.

$$ \delta = \frac{1}{\sqrt{\pi f \mu_0 \mu_r \sigma}} \quad \propto \quad \frac{1}{\text{skin effect}} $$

(b) when skin depth is less then more accumulation of current on the surface of conductor, then skin effect will be more

(c) In HVDC, no skin effect because $f = 0$

Proximity effect :–

↑ current direction in upward.

flux direction in same direction φ ↑ will add up
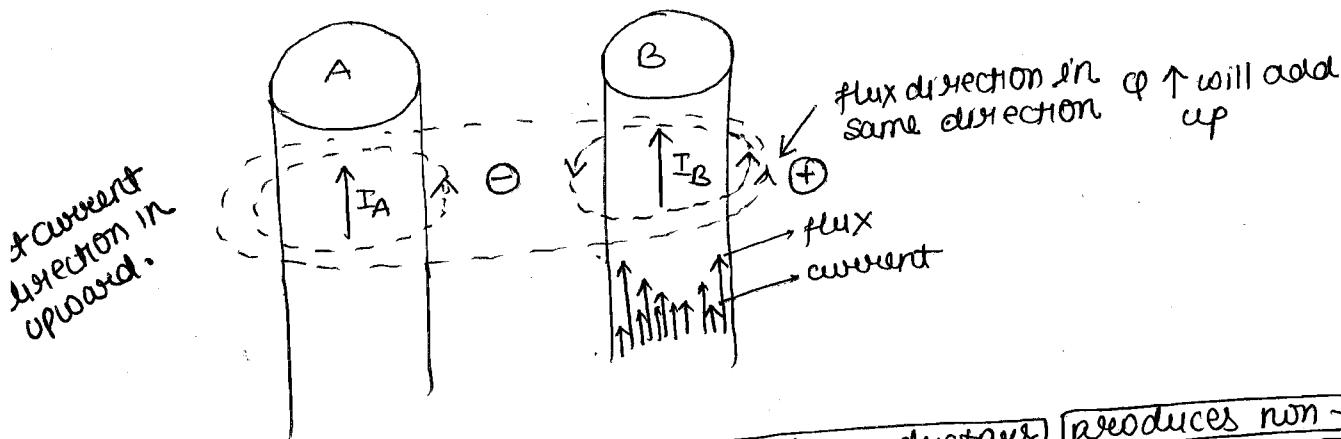
→ flux
→ current

(a) The current flowing in the adjacent conductors produces non-uniform flux linkage which will cause non-uniform current flow so, that the effective area of current flowing path is reduce which causes $R_{AC} > R_{DC}$ (we are not able to utiuse whole area).

(b) Proximity effect depends on f, μ_r, σ & distance between the conductor

(c) this effect is more in power cable and less in overhead transmission line because .