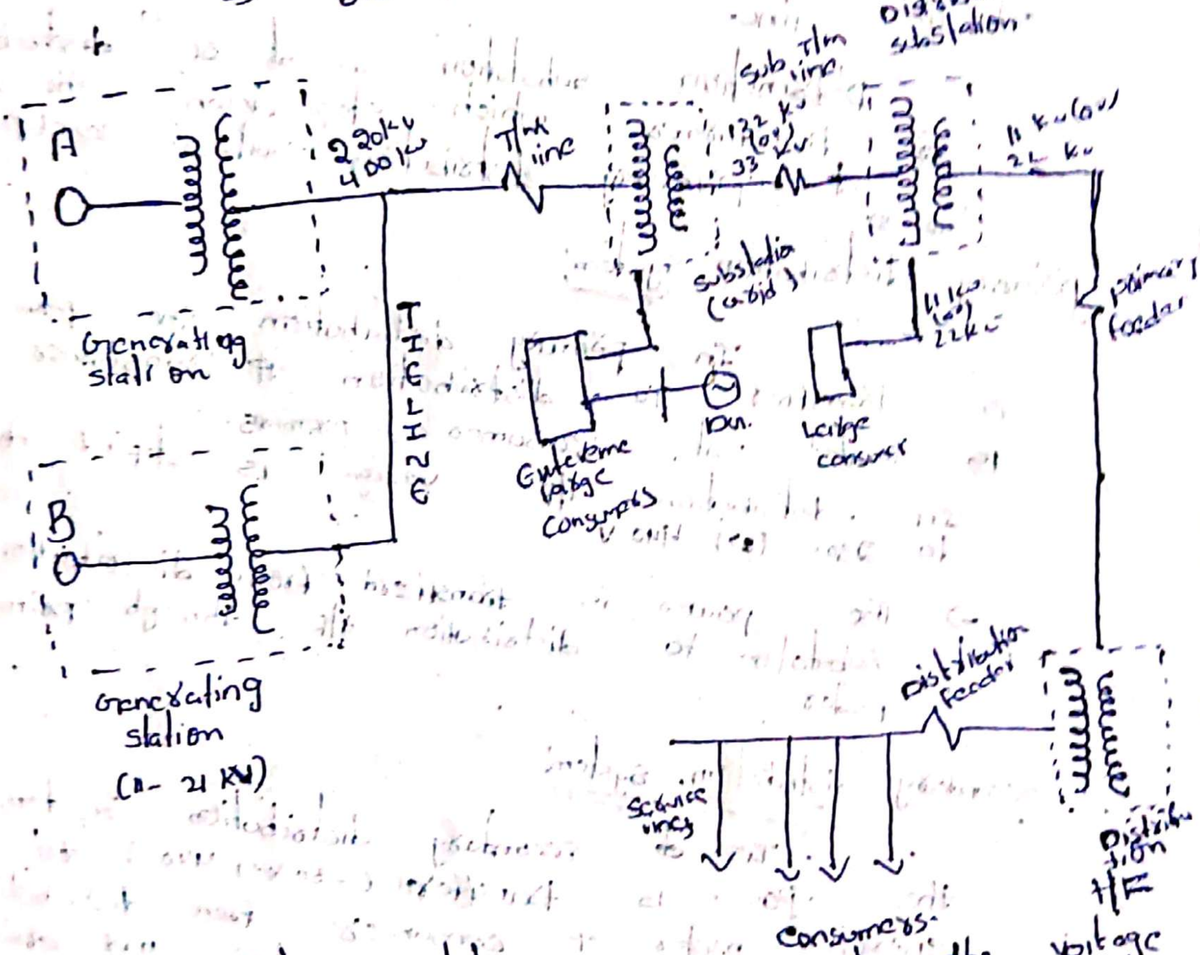
Unit - I

Introduction to Distribution systems:

Power systems are comprised of 3 basic electrical subsystems:

1) Generation
2) Transmission
3) Distribution



→ In generating station we generate the voltage of 11 kV (or) 21 KV.

→ This generated voltage we have to transfer to so far distances. So here we step up the generating voltage to 220 kV (or) 400 kV to overcome the losses.

→ From t/m line the voltage is fed to substation grid. Here the voltage levels are stepped down to 132 kV (or) 33 kV. And in substation grid the power is supplied to extreme large consumers and then to Distribution substation through transmitters to

Sub transmission line.

-> From this point distribution system is being considered.

Distribution system is divided into three distinct subsystems.

1) Distribution substation
2) primary distribution system
3) secondary distribution system.

1) **Distribution substation:**

Distribution substation receives power from sub t/m line.

Distribution substation consist of a ~~distribution~~ transformer which step down the voltage level (11 kv (or) 22 kv) to primary distribution voltage.

primary distribution system:

In primary distribution the power is transfer to distribution transformer which is located at consumer premises. In distribution t/f voltage is stepped down to 230v (or) 440 v.

-> The power is transfered from distribution substation to distribution t/f through primary feeder.

secondary distribution system:

In secondary distribution system: the power is transferred (230 v/) 440v) to! energy meter of consumers from distribution t/f through distribution feeders and service lines.

Some basic definitions:

Connected load:

connected load reffers to that all of load which consume power from a power system when its switch on.

Sum of continous (or) rating of entire load consuming apparatus connected to the system.

1. Maximum demand:-

It means that the maximum power that the circuit is likely draw at any time.

Demand factor:

It is define as the ratio of maximum demand to connected load.

→ It is always less than one.

Average load:

It is defined as total no. of units generated per annum.

$$\text{Avg load} = \frac{\text{Total no. of units generated}}{8760}$$

Diversity factor

It is defined as the ratio of sum of individual maximum demand to maximum demand of whole power system.

→ It is always greater than one.

Coincidence factor:

It is defined as the ratio of maximum demand to the sum of individual maximum demands.

→ It is always less than one.

Load diversity factor:

It is mathematically defined as.

Load diversity = Sum of individual loads - peak of combined load.

Loss factor

It is the ratio of average power loss to power loss at peak load.

Load factor:

It is ratio of average demand to maximum demand.

$$\text{Load factor} = \frac{\text{Energy produced in given time}}{\text{max demand} * \text{hours of operation}}$$

Load factor is alway less than one.

plant capacity factor:-

It is ratio of average annual load to the plant rated capacity.

$$\text{plant capacity factor} = \frac{\text{energy produced in one Year}}{\text{plant rated capacity} \times 8760}$$

plant use factor:

It is defined as.

$$\text{plant use factor} = \frac{\text{Actual energy produced}}{\text{plant capacity} \times \text{operation time in hrs}}$$

utilization factor:

It is ratio of maximum load to rated capacity. (or) installed capacity

problems

1) A residential consumer has a connected load of 6 lamps each of 100 w and 4 fans of 60 w at his premises. His demand is follows.

From 12.00 am – 5 am – 120 w
5 am – 6 pm – no load
6 pm - 7 pm – 380 w
7 pm - 9 pm – 680 w
9 pm – 12 am – 420 w

a) plot load curve.
b) Find energy consumption in 24 hrs.
c) Find demand factor, average load, maximum load and load factor.

Total energy consumption in 24 hours

$= 5\times120 + 380\times1 + 680\times2 + 420\times3$

$= 3600 \text{ wh}$.

demand factor = maximum demand / connected load

$= 680 / (6\times100 + 4\times60)$

$= 0.809$

Average load = energy consumption / no. of hours

$= 3600/24 = 150 \text{ w}$

load factor = Average load / maximum load

$= \frac{150}{680} = 0.22$

2) A generating station has maximum demand of 80 MW, a load factor of 65%, a plant capacity factor of 40% and plant use factor of 85%.

Find:

a) Daily energy produced

b) Reserve capacity of plant

c) maximum energy that could be produced daily if plant was running all time.

d) maximum energy that could be produced daily if plant was running as per operating schedules.

Sol:

Given:

maximum demand = 80 MW

load factor = 0.65

plant capacity factor = 0.4

plant use factor = 0.85

$$\text{load factor} = \frac{\text{Avg load}}{\text{max demand}}$$

Avg load = 0.65 × 80

= 52 MW

$$\boxed{\text{Daily energy produce} = \text{Avg load} \times 24 = 52 \times 24 = 1248 \text{ MWh}}$$

Reserve capacity = installed capacity − max demand

we know plant capacity factor = $\frac{\text{Avg load}}{\text{plant rated capacity}}$

$= \frac{\text{Avg load}}{\text{Installed capacity}}$

$0.4 = \frac{\cancel{\text{Avg load}}\ 52}{\text{Installed capacity}}$

Installed capacity = $\frac{52}{0.4}$ = 130 MW

$$\boxed{\text{Reserve capacity} = 130 - 80 = 50 \text{ MW}}$$

maximum energy that could ploduced daily if it was running all time = Installed capacity × 24

= 130 × 24 = 3120 Mwh

maximum energy that could produced daily if plant was running as per scheduled = daily energy produced / plant use factor.

= 1248/0.85 = 1468.2 Mwh.

<u>Relationship b/w Load factor and Loss Factor</u> :-

problem !

The avg load factor of substation is 0.65. Determine the average loss factor of its feeders, if the substation services; 1) urban area 2) Rural area

For urban area: $F_{LS} = 0.3 F_{LD} + 0.7 (F_{LD})^2$

$= 0.3 \times 0.65 + 0.7 (0.65)^2$

$= 0.49$

For rural area: $F_{LS} = 0.16 F_{LD} + 0.84 (F_{LD})^2$

$= 0.16(0.65) + 0.84 (0.65)^2$

$= 0.53$

classific of loads:

The loads are classified into 6 types:

1) Domestic loads
2) Commercial loads
3) Industrial loads
4) muncipal loads
5) Agricultural loads
6) Traction loads

1) Domestic loads:

Domestic loads consist of lights, fans, home electric appliances (including TV, AC, refrigerator, heaters etc...), small motors for pumping water etc. most of the domestic loads are connected for only some hours during a day.

For Domestic loads:

Demand factor DF = 70 - 100%

Diversity factor = 1.2 - 1.3

Load factor F_{LD} = 10 - 15%

2) Commercial load:

commercial load consist of electrical loads that are meant to be used commercially, such as restaurants, shops, mall's, market areas, Advertisments etc.. This type of load occurs for more hours during the day as compared to domestic load.

Demand factor = 90 - 100%

Load factor = 25-30%

Diversity factor = 1.1 - 1.2

Industrial load:

Industrial load includes all electrical load used in industries along with employed machinery. Industrial load may be connected during the whole day.

These loads are classified into 5 categories

	Load	DF	FLF
1) Cottage industries	< 5 kw		
2) Small scale industries	5-25 kw		
3) Medium scale industries	25-100 kw		
4) Large scale industries	100-500 kw	70-80%	60-65%
5) Heavy industries.	> 500 kw	85-90%	70-80%

Muncipal loads:

This type of load consist of street lighting water supply and drainage systems. Street lighting is practically constant during night hours.

Demand factor, $DF = 100\%$

Diversity factor $F_D = 1.0$

Load factor $F_{LD} = 25-30\%$

Agricultural Loads:

motors and pumps used in irrigation system to supply the water for farming comes under this category.

→ Generally irrigation loads are supplied during off-peak (or) night hours.

Demand factor $DF = 90-100\%$

Diversity factor $F_D = 1-1.5$

Load factor $= 20-15\%$

Traction load:

electric railways, tram cars, trolley bus etc. comes under traction loads.

Demand factor may vary time to time.

problems

Assume that annual peak load of primary feeder is 2000 kw. the power loss i.e; total copper loss is 80 kw per $3-\phi$. Assuming annual loss factor 0.15, determine

a) Average annual power loss
b) Total annual energy loss due to the copper loss of feeder

Sol:-

peak load = 2000 kW
Power loss at peak load = 80 kW
loss factor = 0.15

Average power loss = ?
Annual energy loss = ?

we know

$$\text{Loss factor } F_{LS} = \frac{\text{Avg Power loss}}{\text{Power loss at peak load}}$$

$$0.15 = \frac{\text{Avg power loss}}{80}$$

$$\boxed{\text{Avg power loss} = 12 \text{ kw}}$$

Annual energy loss = 12×8760

$$\boxed{\text{Annual energy loss} = 105120 \text{ kwh}}$$

A generating station has a connected load of 43 Mw and a maximum demand of 20 Mw. The units generated being 61.5×10^6/ annum. Calculat i) Demand factor (ii) Load factor.

Sol: Given,

connected load = 43 Mw
maximum demand = 20 Mw
units generated / annum = 61.5×10^6

i) Demand factor = $\frac{\text{maximum demand}}{\text{connected load}}$

$$DF = \frac{20}{43} = 0.465$$

ii) Load factor = $\frac{\text{Avg load}}{\text{max demand}}$

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Avg load = no.of units generated /annum

$= \frac{\text{Total no.of units generated}}{8760}$

$= \frac{61.5 \times 10^6}{8760}$

Avg load = 7020.54 kW.

$F_{LD} = \frac{7020.54 \text{ kW}}{20 \text{ MW}} = 0.3510$

$= \boxed{35.10\%}$

A diesel station supplies the following loads to various consumers

Industrial consumers = 1500 kW

commercial load = 750 kW

Domestic ~~load~~ Power = 100 kW

Domestic light = 450 kW

If the maximum demand on the station is 2500 kW and no. of kWh generated per year is 45×10^5. Determine i) Diversity factor

ii) Annual load Factor

$\text{Diversity factor} = \frac{\text{Sum of individual maximum demands}}{\text{maximum demand on station.}}$

$= \frac{1500 + 750 + 100 + 450}{2500}$

$= 1.12$

Annual load factor

$F_{LD} = \frac{\text{Avg load demand}}{\text{max demand}}$

$\text{Avg load} = \frac{\text{Total no.of units generated}}{8760}$

$= \frac{\cancel{455}\,45 \times 10^5}{8760}$

= 513.69 kW

$F_{LD} = \frac{513.69}{2500} = 0.2054 = 20.54\%$

Load modeling

Many electrical appliance and devices have an electrical load that varies with change in supply voltag.

The loads are classified into three categories based on how demand varies as a function of voltage.

1) constant power model
2) constant current model
3) constant Impedence model

1) Constant power model:-

Here power is constant regardless of voltage.

$P = VI \cos\phi$

Assum $\cos\phi = 1$

$P = VI$

→ If voltage increase the current get decreases to maintain power as constant.

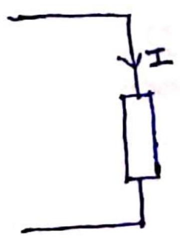
→ If voltage ~~increa~~ decreases the current get increases to main power as constant.

Examples of constant power load is:

Induction motors, air conditioners.

2) Constant current load:

In constant current load whatever may be the voltage across load i.e; if voltage across load increase (or) decreases the current might be constant



$P = VI \cos\phi$

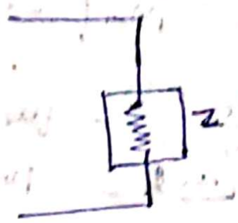
$\cos\phi = 1$

$P = VI$

If current is constant power is proportional to voltage.

Ex:- welding, smelting etc.

3) constant Impedance



Here the impedance of load is constant.

$I = \frac{V}{Z}$

when voltage increases current also increase and voltage decrease current also decreases

$P = VI \cos\phi$ $\qquad I = \frac{V}{Z}$

$\cos\phi = 1$

$P = VI$

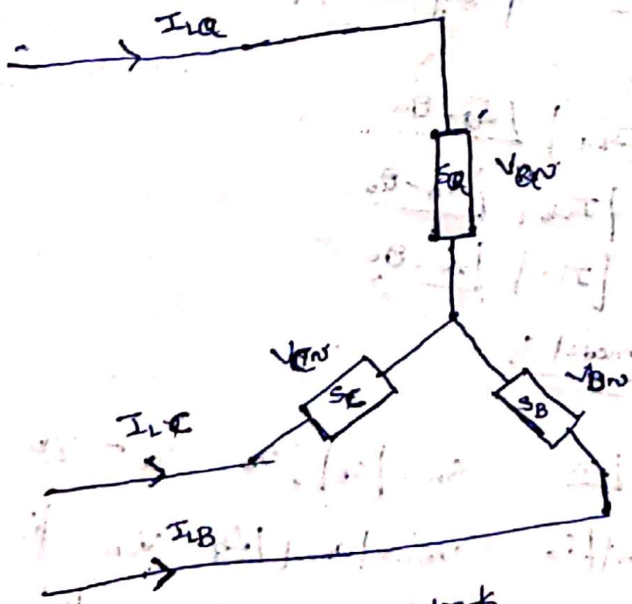
$P = V\left(\frac{V}{Z}\right)$

$P = \frac{V^2}{Z}$

By making impedance as constant power is proportional to square of the voltage.

ex: Incandescent lighting, resistive water heating etc ---

Let us consider a star connected loads:-



consider constant power loads

$S_a = |S_a| \angle\theta_a \quad S_b = |S_b| \angle\theta_b \quad S_c = |S_c| \angle\theta_c$

$V_{an} = |V_{an}| \angle\delta_a \quad V_{bn} = |V_{bn}| \angle\delta_b \quad V_{cn} = |V_{cn}| \angle\delta_c$

$$I_{La} = \frac{|S_a| \angle\theta_a}{|V_{an}| \angle\delta_a} = \frac{|S_a|}{|V_{an}|} \angle\delta_a - \theta_a = I_{La} \angle\alpha_a$$

$$I_{Lb} = \frac{|S_b|}{|V_{bn}|} \angle\delta_b - \theta_b = I_{Lb} \angle\alpha_b$$

$$I_{Lc} = \frac{|S_c|}{|V_{cn}|} \angle\delta_c - \theta_c = I_{Lc} \angle\alpha_c$$

Constant current load

$S_a = |S_a| \angle\theta_a \quad S_b = |S_b| \angle\theta_b \quad S_c = |S_c| \angle\theta_c$

$$|I_{La}| = \frac{|S_a|}{|V_{an}|}$$

$$|I_{Lb}| = \frac{|S_b|}{|V_{bn}|}$$

$$|I_{Lc}| = \frac{|S_c|}{|V_{cn}|}$$

The load current might be constant where as voltage might change.

The voltages be

$|V_{an}| \angle\delta_a, \ |V_{bn}| \angle\delta_b, \ |V_{cn}| \angle\delta_c$

$$I_{La} = |I_{La}| \angle\delta_a - \theta_a$$

$$I_{Lb} = |I_{Lb}| \angle\delta_b - \theta_b$$

$$I_{Lc} = |I_{Lc}| \angle\delta_c - \theta_c$$

Constant impedance model:

$S_a = |S_a| \angle\theta_a \quad S_b = |S_b| \angle\theta_b \quad S_c = \angle\theta_c$

$V_{an} = |V_{an}| \angle\delta_a \quad V_{bn} = |V_{bn}| \angle\delta_b \quad V_{cn} = |V_{cn}| \angle\delta_c$

These are actual voltages

$Z_{\cancel{ab}} =$

nominal voltage of phase A = V_{an}^{0}
nominal voltage of phase B = V_{bn}^{0}
nominal voltage of phase C = V_{cn}^{0}

$$Z_a = \frac{|V_{an}^{0}|^2}{S_a^*} = \frac{|V_{an}|^2}{|S_a|\angle{-\theta_a}} = \frac{|V_{an}^{0}|^2}{|S_a|}\angle{\theta_a}$$

$$Z_b = \frac{|V_{bn}^{0}|^2}{|S_b|}\angle{\theta_b}$$

$$Z_c = \frac{|V_{cn}^{0}|^2}{|S_c|}\angle{\theta_c}$$

Throught out the operation this impedance will remain constant.

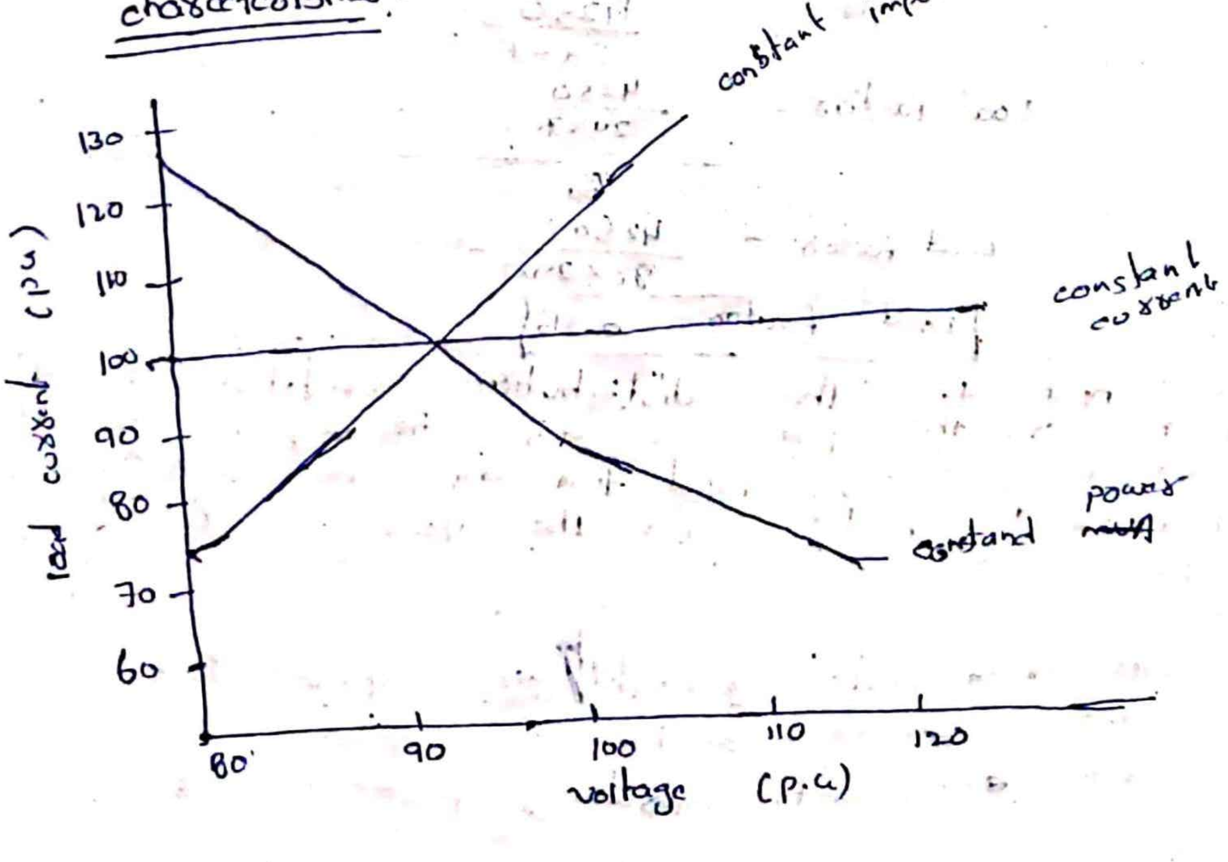
The load currents as a function of constant load impedances are given by:

$$I_{La} = \frac{|V_{an}|\angle{\delta_a}}{|Z|\angle{\theta_a}} = \frac{|V_{an}|}{|Z_a|}\angle{\delta_a-\theta_a} = |I_{La}|\angle{\alpha_a}$$

$$I_{Lb} = \frac{|V_{bn}|\angle{\delta_b}}{|Z_b|\angle{\theta_b}} = \frac{|V_{bn}|}{|Z_b|}\angle{\delta_b-\theta_b} = |I_{Lb}|\angle{\alpha_b}$$

$$I_{Lc} = \frac{|V_{cn}|\angle{\delta_c}}{|Z_c|\angle{\theta_c}} = \frac{|V_{cn}|}{|Z_c|}\angle{\delta_c-\theta_c} = |I_{Lc}|\angle{\alpha_c}$$

characteristics!.



-) In case of constant current : whatever may be load voltages the current might be constant

-) In case of constant power, If voltage increase current might be decreases, ($P = VI$).

-) In case of constant impedence. If voltage increase current also increases ($I = \frac{V}{Z} \to$ const)

A load of 100 kW is connected to the substation. The 15 minutes weekly maximum demand is given by 80 kW. and weekly energy consumption is 4250 kwh. Find the demand factor and 15 minutes weekly load factor.

Sol:- Given:-

connected load = 100 kW

maximum demand = 80 kW

Total no. of units generated = 4250

$$\text{demand factor} = \frac{\text{max demand}}{\text{Connected load}}$$

$$= \frac{80}{100} = 0.8$$

$$\text{Load factor} = \frac{\text{Avg demand}}{\text{max demand}}$$

$$\text{Avg demand} = \frac{\text{Total no. of units generated}}{\text{Time}}$$

$$= \frac{4250}{24 \times 7}$$

$$\text{Load factor} = \frac{\frac{4250}{24 \times 7}}{80}$$

$$\text{Load factor} = \frac{4250}{80 \times 24 \times 7}$$

$$\boxed{\text{Load factor} = 0.316}$$

The input to the distribution substation is 90,600 mwh. on the peak load day the peak is 30 Mw and the energy input that day is 300.5 mwh. Find load factor for the year and for the peak load day?

Given:-

Total no. of units generated / annually = 90,600 Mwh

max demand = 30 MW

Total no. of units generated on peak load day = 300.5 mwh

~~annual~~ ~~load factor~~ = $\frac{\text{Total no of units generated}}{\cancel{\text{max demand}}}$

~~annual load factor~~ =

load factor = $\frac{\text{Avg load}}{\text{max demand}}$

annual Avg load = $\frac{\text{Total no.of units generated}}{\text{Time}}$

$= \frac{90600}{8760}$

load factor = $\frac{90600}{30 \times 8760} = 0.344$

load factor on peak load day = $\frac{\text{Avg load on that day}}{\text{max demand}}$

Avg load on that day = $\frac{\text{Total no. of units generated on that day}}{\text{Time}}$

$= \frac{300.5}{24}$

Daily load factor = $\frac{300.5}{30 \times 24}$

$= 0.417$

The annual peak load ~~Assume that there are six~~ input to a primary feeder is 1500 kw. The voltage drop, and losses shows that the total losses of the time of peak load is 100 kw. The total anual energy supplied to the sending end feeder is 5.5×10^6 kwh.

a) Determine annual loss factor

b) calculate the annual energy loss and the annual cost if unit charge is 2.5

sol:-

Loss factor = $0.3(L.F) + 0.7(L.F)^2$

Load factor = $\frac{\text{Avg load}}{\text{max demand}}$

Avg load = $\frac{\text{Total no.of units generated}}{\text{Time}}$

$= \frac{5.5 \times 10^6}{8760}$

Load factor = $\frac{5.5 \times 10^6}{8760 \times 1500}$

Load factor = 0.418

Loss factor = $0.3(0.418) + 0.7(0.418)^2$

= 0.2477

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ii) Total annual energy loss :

$$\text{Loss factor} = \frac{\text{Avg power loss}}{\text{Power loss at peak load}}$$

$$0.2477 = \frac{\text{Avg power loss}}{100}$$

$$\text{Avg power loss} = 24.77 \times 10^3 \text{ W}$$

Total annual power loss = 24.77×8760

$$\boxed{\text{Total annual energy loss} = 216.99 \times 10^3 \text{ kWh}}$$

Total annual cost of loss. = $216.99 \times 10^3 \times 2.5$

$= \boxed{5,42,477.5 \text{ Rs}}$

Assume that there are six residential customers connected to distribution transformer. The connected load is 8 kW per house. and that the demand factor and diversity factor for the group of six houses are 0.65 and 1.2 respectively. Determine the diversified (or) coincident max demand of group of six house on transformer.

Total connected load = 10×8 = sum of individual load

Demand factor = 0.65

Diversity factor = 1.2

Coincident max demand = ?

$$\text{Demand factor} = \frac{\text{maximum demand}}{\text{connected load}} \rightarrow (1)$$

$$\text{Diversity factor} = \frac{\text{sum of individual loads}}{\text{max demand}} \rightarrow (2)$$

from (1) max demand = demand factor $\times$ connected load

from (2) max demand = $\dfrac{\text{sum of individual loads}}{\text{Diversit factor}}$

from (1) and (2)

$$\text{coincident max demand} = \frac{\text{connected load} \times \text{demand factor}}{\text{diversity factor}}$$

$$= \frac{10 \times 8 \times 0.65}{1.2}$$

$= 26$ kW

A substation has a connected load of 45 MW and max demand of 22 MW, the units supplied being 60×10^6 per annum. Determine a) demand factor b) load factor.

Sol:- Demand factor = $\frac{\text{max demand}}{\text{connected load}}$

$= \frac{45}{22} = 0.488$

Load factor = $\frac{\text{Avg load}}{\text{max demand}}$

Avg load = $\frac{\text{Total no. of units generated}}{\text{Time}}$

$= \frac{60 \times 10^6}{8760}$

$= 6849.3$ kW

Load factor = $\frac{6849.3 \times 10^3}{22 \times 10^6} = 0.311$ (or 31.1%)

A substation is to supply in an urban area. having the following particulars.

i) 1000 houses with average connected load of 2 kW in each house, the demand factor is 0.4

ii) 15 factories having overall maximum demand of 100 kW

iii) 10 bore wells of 7 kW each operating together in morning

The diversity factor among above three types of customers is 1.2 what should be minimum capacity of substation?

Sol:- minimum capacity of substation is sum of max demands of all loads.

i) ~~to~~ Total connected load = 1000×2

~~demand factor~~ = ~~$\frac{\text{connected load}}{\text{max demand}}$~~

~~$0.4 = \frac{1000 \times 20}{\text{max}}$~~

~~max demand = 1000×20~~

$$\text{Demand factor} = \frac{\text{max demand}}{\text{connected load}}$$

$$0.4 = \frac{\text{max demand}}{1000 \times 2}$$

max demand = 800 kw.

~~ii) 15 Total connected load = 15 x 100~~
~~= 1500 kw~~

ii) maximum ~~Demand~~ demand for factories = 100 kw

iii) Total connected load = 10x7
= 70 kw

Sum of max demand = 800 + 100 + 70
= 970

As diversity factor among three types of load is 1.2

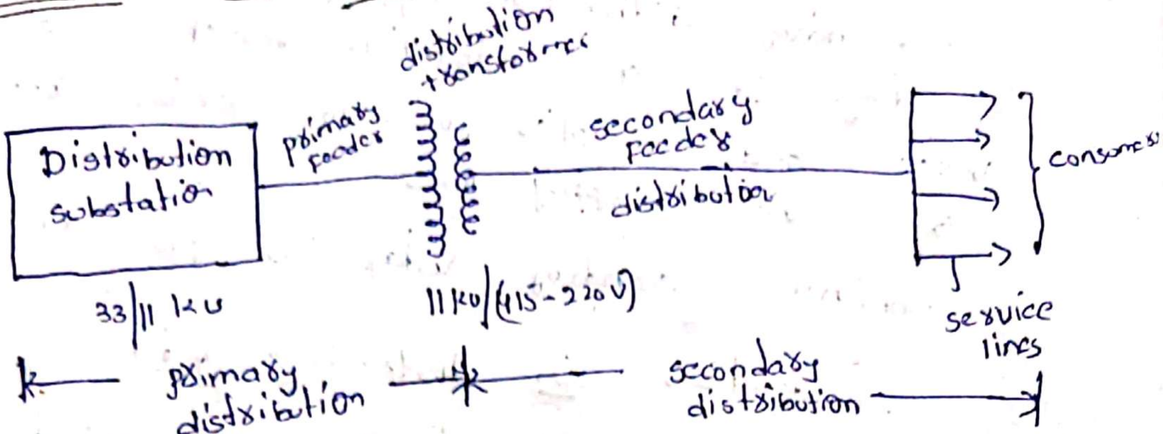
$$\text{diversity factor} = \frac{\text{sum of individual max demand}}{\text{max demand on station}}$$

$$1.2 = \frac{800 + 100 + 70}{\text{max demand on station}}$$

$$\text{max demand on station} = \frac{970}{1.2}$$

$$\boxed{= 808.33 \text{ kw}}$$

Introduction to distribution system



Distribution system starts from distribution substation. Distribution substation consist of a transformer which stepped down the voltage from 33 kV which comes from trasmission line to 11 kV.

-> This 11 kV is traffered ~~through~~ to distribution transformer through primary feeder. This is called primary distribution.

-> Distribution t/f again stepped down the voltage from 11 kV/415V - 220V. This voltage is transffered to service lines and from service line we can got the power to our energy meter. This is called secondary distribution.

-> Distribution system is a part of power system existing b/w distribution substation and the consumers.

Distribution system is further classified on basis of supply voltage

1) primary distribution
2) secondary distribution

primary distribution:

primary distribution system exist between distribution substation and Distribution transformer.

-> The power can be trannsffered ~~the~~ from Distribution station to distribution transformer through primary feeders.

-> Nominal primary voltage is 11 kV.

secondary distribution:

secondary distribution system receives power from secondary side of distribution transformer at low voltage and supplies power to various connected loads via supply lines.

-> nominal secondary voltage is 440v, 220v.

Design considerations in distribution systems:

-> Good voltage regulation is the most import factor in a distribution system for delivering good service to consumer.

~~primary~~ feeder:

feeders are the conductors that are connected between distribution substation and primary of distribution transformer to transfer power. ~~and from second of distri.~~

-> current loading of the feeder is unifor alon the whole of its length since no tappings are taken from it.

-> Design of feedr is mainly based on the current that is to be carried

~~se~~ Distributor

Distributors are the conductor which run along the street (or) an area to supply power to consumers.

-> current loading of distributor is not uniform and it varies along the length.

-> Design of distributor is mainly influenced by voltage drop along the length

Service main:

service mains are the conductors connecting b/w ~~Distribution~~ distributor and metring point or consumer terminals

Sub main:

Sub main refers to several connection given to the different loads (light, fans motor etc) from the energy meter.

Area of cross section of sub main conductor is greater than service main.

Factors affecting distribution system losses:-

1) Inadequate size of conductor
2) Feeder length
3) Location of distribution transformer
4) Low voltage
5) Use of over rated distribution transformer
6) Low power factor.

1) **Inadequate size of conductor:**

Conductor size of feeder must be adequate. If not the losses may get increases

-> we know $R = \frac{\rho l}{A}$

If Area of conductor ~~increases~~ decrease the resistance may increases. If resistance increase the losses of system gets increased.

-> So the conductor size for the ~~same~~ rating current should be adequate.

-> If The conductor size for rating current should be less the losses may get increased

2) **Feeder length**

The losses may depend on feeder length.

-> If the feeder length is high the losses are also high. $(R = \frac{\rho l}{A})$ $\boxed{R \propto l}$
i.e; If length is high, the resistance is also high. i.e I^2R loss is increased.

-> If length of feeder is low the losses is also low.

~~Redn~~ ~~length~~ :-

3) Low voltage :

we know $P = V \times I \cos\phi$

Assume $\cos\phi = 1$

$P = VI$

→ So If voltage is decreased inorder to maintain power constant the current may get increases. which increases the line losses.

→ So Inorder to reduce the loss, the voltage should be in a pre defined value.

4) Low power factor :

In most of distribution system, it is found that the power factor varies from 0.65 to 0.75. A low power factor contributes towards high distribution losses. For a given load, if power factor is low, the current drawn is high, consequently the loss is propotional to square ov current will be more.

Thus line losses owing to the poor P.F can be reduced by improving the P.F. This can be done by application of shunt capacitor.

5) Use of over rated distribution transformer's

methods of reducing Distribution System losses :-

1) HV distribution system
2) feeder Reconfiguration.
3) Reinforcement of the feeder.
4) Grading of conduction
5) construction of new substation
6) Reactive power compensation.

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Classification of distribution Systems

1) **Based on nature of current :-**

A) DC distribution System

B) AC distribution system

-> primary distribution system

-> Secondary distribution system

2) **Based on type of construction**

A) over head distribution system

B) under ground distribution system

3) **Based on Type of service.**

A) General lighting and power

B) Industrial Power

c) Railways

d) street lights

4) **Based on scheme connection**

-> Radial distribution system.

-> Ring distribution system. (loop)

-> Interconnected distribution system.

Requirment and design Features of distribution System.

Requirments :-

-> The continuity in the power supply must ensure system reliability

-> The efficiency of the lines must be high as possible.

-> The system should be safe and no leakage from consumer point of view

-> The line should not be overload.

-> The system should be economical

-> A considerable amount of effort is necessary to maintain an electric power supply within the requirements of various types of consumers.

-> Some of requirements of good distribution system are:

1) proper voltage
2) Availability of power on demand
3) Reliability.

1) proper voltage :-

-> One important requirment of distribution system is that voltage variation at consumers' terminals should be as low as possible.

-> The changes in voltage are generally caused due to variation of load on the System.

-> Low voltage cause inefficient lighting and possible burning out of motors.

-> High voltage cause lamps to burn out permanently and may cause failure of other appliances

-> ∴ A good distribution system should ensure that the voltage variation at consumer terminals are within permissible limits

-> The limits of voltage variation is ±6% of rated value at consumer terminals.

-> Thus if rated voltage is 230v, then the highest voltage of consumer should not exceed 244 v, while the lowest voltage of consumer should not be less than 216v.

2) Availability of Power on demand:-

-> Power must be available to consumer in any amount that they may require from time to time.

-> As electrical energy can not be stored, therefore, the distribution system must be capable of supplying load demands of consumers.

-> This neccessitates that operating staff must continously study load patterns to predict in advance load changes.

3) **Reliability**:-

modern industry is almost dependent on electric power for its operation.

-> Homes and office buildings are lighted, heated, cooled and ventilated by electric power. This calls for reliable service.

-> unfortunately electric ~~service~~ power, like everything else that is man made, can never be absolutely reliable.

However the reliability can be improved by:

a) Interconnected system
b) Reliable automatic control system.
c) providing additional reserve facility

Design Feature of distribution system

-> The distribution System should be designed so as to be economical.

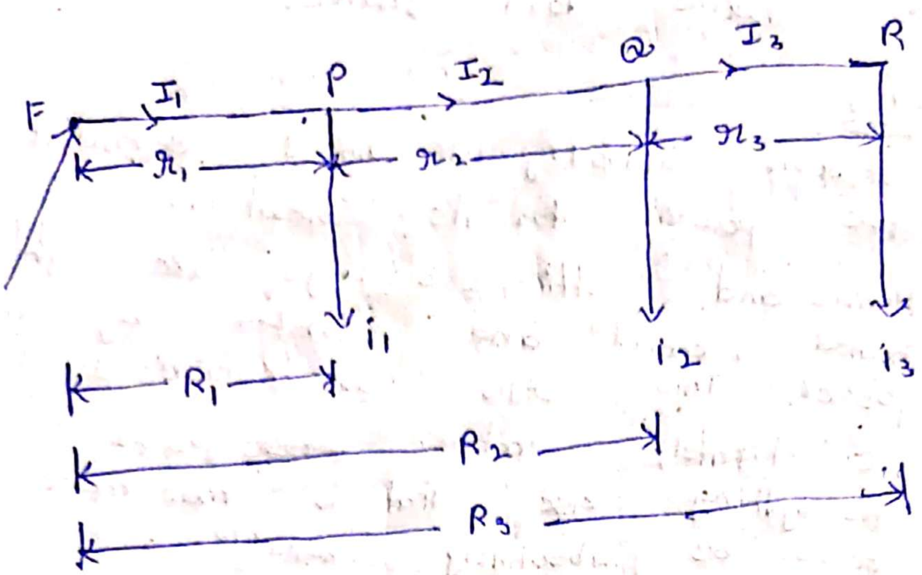
-> Both voltage drop and current ratings in additional to overall economy are important consideration in design of distribution system.

-> The cross sectional area of feeder is determined on basis of current to be carried and for overall economy.

-> The consideration of voltage drop is not import in design of feeder because no consumer is tapped off from it.

-> The voltage regulation is very important in the design of distribution. ~~becau~~ The voltage variations permissable at consumer terminals is ± 6%.

DC distribution fed at one end with concentrated load:



i_1, i_2, i_3 are the currents tapped off from distributor.
I_1, I_2, I_3 are currents passing in various branches.
r_1, r_2 and r_3 and R_1, R_2 and R_3 are resistance of various sections and total resistance fed from point F to the successive tapping points respectively.

$\therefore$ the voltage drop from F to R is

$$V_{FR} = I_1 r_1 + I_2 r_2 + I_3 r_3$$

$I_1 = i_1 + i_2 + i_3$
$I_2 = i_2 + i_3$
$I_3 = i_3$

$$V_{FR} = (i_1+i_2+i_3)r_1 + (i_2+i_3)r_2 + i_3 r_3$$

$\cancel{V_{FR} = i_1+i_2+i_3}$

$R_1 = r_1$
$R_2 = r_1 + r_2$
$R_3 = r_1 + r_2 + r_3$

$$V_{FR} = i_1 r_1 + i_2 r_1 + i_3 r_1 + i_2 r_2 + i_3 r_2 + i_3 r_3$$

$$V_{FR} = i_1 r_1 + i_2 (r_1 + r_2) + i_3 (r_1 + r_2 + r_3)$$

$$\boxed{V_{FR} = i_1 R_1 + i_2 R_2 + i_3 R_3}$$

Thus the drop at far end of the distributor fed at one end is equal to sum of drops at different tappings.

voltage drop any intermediate point Q is

$V_{FQ} = I_1 r_1 + I_2 r_2$

$= (i_1+i_2+i_3) r_1 + (i_2+i_3) r_2$ for r_1

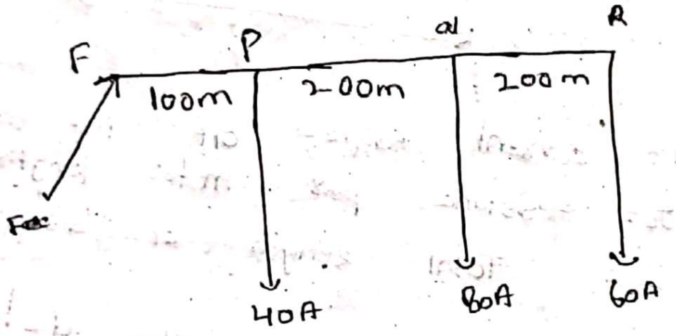
$= \cancel{(i_1+i_2+i_3)}$

$= i_1 r_1 + i_2 r_1 + i_3 r_1 + i_2 r_2 + i_3 r_2$

$= i_1 r_1 + i_2 (r_1 + r_2) + i_3 (r_1 + r_2)$

$\boxed{V_{FQ} = i_1 R_1 + i_2 R_2 + i_3 R_2}$

A DC two wire distributor, 500m long and fed at one end is shown in Fig. The total resistance of the distributor is 0.02Ω. Determine the voltage at the fed end F when voltage at the far end is 220 V.



Given data:

Total length = 500 m

Resistance of distributor = 0.02Ω

Resistance for $1m = \frac{0.02}{500} = 40 \times 10^{-6}\ \Omega/m$

Resistance for point P $\cancel{100m} = 100 \times 40 \times 10^{-6}\ \Omega/m$

Resistance for point Q $\cancel{300\ m} = 300 \times 40 \times 10^{-6}\ \Omega/m$

Resistance upto point R $= 500 \times 40 \times 10^{-6}\ \Omega/m$

voltage drop

$V_{FR} = i_1 R_1 + i_2 R_2 + i_3 R_3$

$= (40 \times 100 \times 40 \times 10^{-6}) + 80 \times 300 \times 40 \times 10^{-6} + 60 \times 500 \times 10^{-6}$

$V_{FR} = 2.32V$

Drop $= 2.32V$

Voltage at receiving end $V_R = 220V$

voltage at sending end = voltage at receiving end + drop

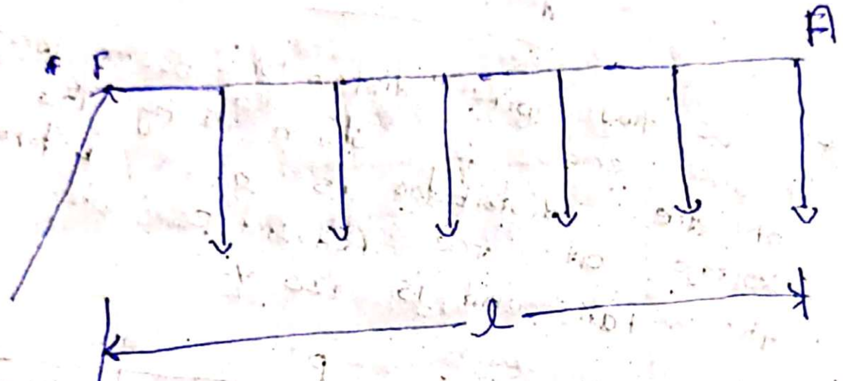
$V_F = 220 + 2.32$

$V_F = 232.32\,V$

DC distributor fed at one end with uniform load:

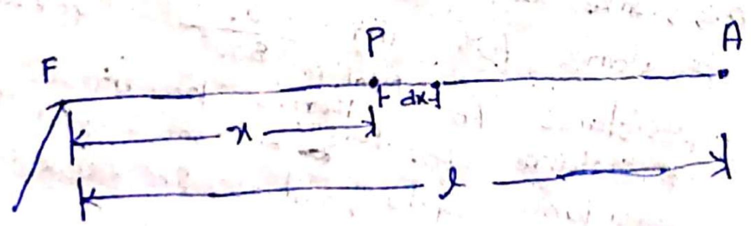
uniform load means current is same at all tappings.

A single line two wire dc distributor "FA" fed at one end is loaded uniformly with i A/m and the length "l" as shown in fig.



i = current tapped off per meter length.
r = resistance per meter length
l = Total length of distribution.

consider a point P on the distributor at a distance of "x" from feeding point "F" as shown in fig.



∴ current at p $i(l-x)$

consider a small section dx from point p. And the voltage drop is small section dx is dv

$dv = \int i(l-x)\, r\, dx$

resistance of section $dx = r\,dx$

voltage drop at any point x from feed end F is

$$V_{Fx} = \int_0^x dv$$

$$V_{Fx} = \int_0^x i(l-x)\, r\, dx$$

$$V_{Fx} = ir \int_0^x (l-x)\, dx$$

$$V_{Fx} = ir \int_0^x l\,dx - \int_0^x x\, dx$$

$$= ir \left[lx - \frac{x^2}{2} \right]_0^x$$

$$\boxed{V_{Fx} = ir \left[lx - \frac{x^2}{2} \right]}$$

The voltage drop over the whole distributor can be obtained by substituting $x = l$

$$V_{FA} = ir \left[l(l) - \frac{l^2}{2} \right]$$

$$= ir \left[l^2 - \frac{l^2}{2} \right]$$

$$V_{FA} = ir \left[\frac{l^2}{2} \right]$$

$$\boxed{V_{FA} = \frac{1}{2}\, ir(l^2)}$$

$$V_{FA} = \frac{1}{2}(i \times l) \times (r \times l)$$

$$\boxed{V_{FA} = \frac{1}{2} IR}$$

where I is total current feeding at point "F".
R is total resistance of distributor

Power loss over a length dx is

$$P_{Loss} = I^2 R$$

P_{Loss} at lent dx = (current in length dx)^2 × (resistance of length dx)

$$P_{Loss} \text{ at length } dx = i(\cancel{\ } l-x)^2 \times r\, dx$$

Total power loss on distributor

$$P_{Loss} = \int_0^l (i(l-x))^2\, r\, dx$$

$$P_{Loss} = i^2 r \int_0^l (l-x)^2\, dx$$

$$= i^2 r \int_0^l (l^2 + x^2 - 2lx)\, dx$$

$$= i^2 r \left[l^2 x + \frac{x^3}{3} - 2l \cdot \frac{x^2}{2} \right]_0^l$$

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$$P_{Loss} = i^2 r \left[l^3 + \frac{l^3}{3} - l^3 \right]$$

$$= i^2 r \left[\frac{l^3}{3} \right]$$

$$\boxed{P_{Loss} = \frac{i^2 r l^3}{3}}$$

$$P_{Loss} = \frac{1}{3} (il)^2 \times (rl)$$

$$\boxed{P_{Loss} = \frac{1}{3} I^2 R}$$

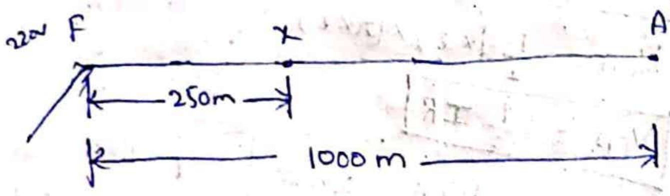
A DC two wire distributor of length 1000 m is loaded uniformly at 2A/m. The distributor is fed at one end at 220V. Determine

i) voltage drop at distance 250 m from feeding point

ii) voltage drop at far end.

Assume loop resistance = 3×10^{-5} Ω/m

Sol:-



Given:-

$i = 2$ A/m

$r = 3 \times 10^{-5}$ Ω/m

$l = 1000$ m

$x = 250$ m

i) voltage drop at distance 250 m from feeding

$$V_{Fx} = ir \left[lx - \frac{x^2}{2} \right]$$

$$= 2 \times 3 \times 10^{-5} \left[1000 \times 250 - \frac{(250)^2}{2} \right]$$

$$\boxed{V_{Fx} = 13.125 \text{ V}}$$

ii) voltage drop at far end is

$$V_{FA} = \frac{irl^2}{2}$$

$$V_{FA} = \frac{2 \times 3 \times 10^{-5} \times 1000^2}{2}$$

$V_{FA} = 30V$

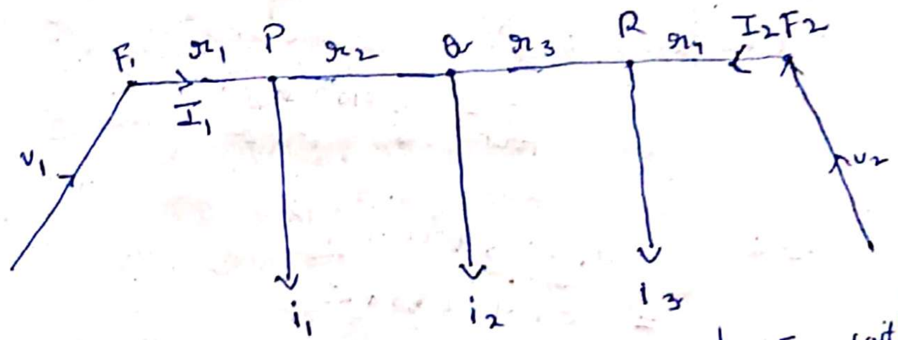
DC distributor fed at both ends with concentrated load

-> Drawback of dc distributor fed at on end is that the consumer who is far away from the feeding end suffers with low voltage problem.

-> In order to reduce the voltage drop, the distributor fed at both ends ~~neither~~

-> Thus the distributor fed at both ends is more economical compared to distributor fed at one end

-> when the voltage is fed at both ends, the point of minimum potential occurs in between feeding points (i.e., at centre of feeder) and it varies with load on diffrent sections of distributor



consider a distributor fed at F_1 and F_2 with voltages V_1 and V_2 respectively as shown in fig.

I_1 and I_2 are the current supplied from F_1 and F_2

$$\therefore I_1 + I_2 = i_1 + i_2 + i_3$$

The sum of voltage drop in diffrent section from F_1 is equal to the difference of feeding voltage at F_1 and F_2.

$$V_1 - V_2 = I_1 r_1 + (I_1 - i_1) r_2 + (I_1 - i_1 - i_2) r_3 + (I_1 - i_1 - i_2 - i_3) r_4$$

DC a wire distributor F_1 and F_2 are fed at both ends with same voltage of 220V. The length of distributor is 250m and the loads tapped off from the end F_1 are

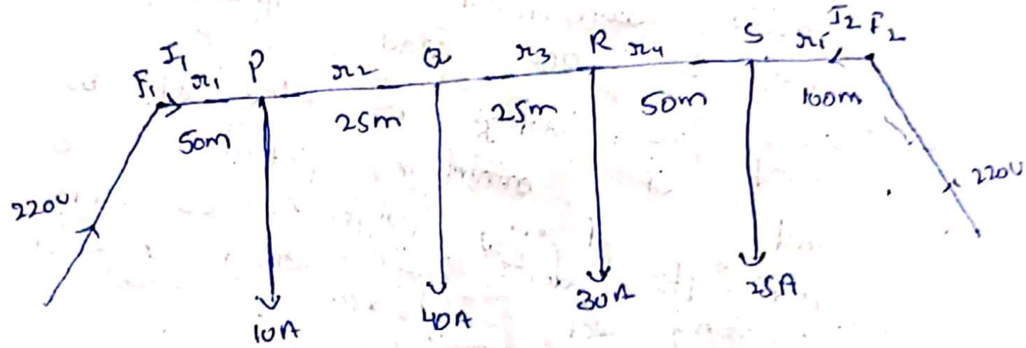
Distance in (m) : 50 75 100 150

Load in (A) : 10 40 30 25

The resistance per km of both distributor is 0.2 Ω/km. Find the

-> current in each section

-> voltage at each load point



Resistance/km = 0.2Ω

$$= \frac{0.2}{1000} = 2\times10^{-4}\ \Omega/m$$

$$I_1 + I_2 = i_1 + i_2 + i_3 + i_4$$

$$= 10 + 40 + 30 + 25$$

$$= 105\ A$$

voltage drop

$$V_1 - V_2 = I_1 r_1 + (I_1 - i_1) r_2 + (I_1 - i_1 - i_2) r_3 + (I_1 - i_1 - i_2 - i_3) r_4 + (I_1 - i_1 - i_2 - i_3 - i_4) r_5$$

$$0 = I_1 \times 50 \times 2\times10^{-4} + (I_1 - 10)\times 25 \times 2\times10^{-4} + (I_1 - 10 - 40)\times 25\times 2\times10^{-4} + (I_1 - 10 - 40 - 30) \times (50 \times 2\times10^{-4}) + (I_1 - 10 - 40 - 30 - 25) \times (100 \times 2\times10^{-4})$$

$$0 = 0.01 I_1 + 0.005 I_1 - 0.05 + 0.005 I_1 - 0.25 + 0.01 I_1 - 0.84 - 2.1$$

$$0 = 0.05 I_1 - 3.2$$

$$\boxed{I_1 = 64\ A}$$

length

OF R

$I_1 + I_2 = 105$

$I_2 = 105 - I_1$

$I_2 = 105 - 64$

$\boxed{I_2 = 41\ A}$

i) current in each section $I_1 = 64A$

$I_{F_1P} = I_1 = 64\ A$

$I_{PQ} = I_{FP} - 10$

$\boxed{I_{PQ} = 64 - 10 = 54}$

$I_{QR} = I_{PQ} - 40$

$\boxed{I_{QR} = 54 - 40 = 14A}$

$I_{RS} = I_{QR} - 30$

$= 14 - 30 = -16$ (i.e current flow from S to R)

$\boxed{I_{SR} = 16A}$

$\boxed{I_{F_2S} = I_2 = 41\ A}$

ii) voltage drop at point P is $V_P = V_{F_1} -$ voltag drop (V_{F_1P})

voltag drop at F_1P = current x resistance

current at $F_1P = 64A$

resistance $= 2\times10^{-4} \times 50$

$V_P = 220 - (64 \times 50 \times 2\times10^{-4})$

$\boxed{V_P = 219.36V}$

voltage at point Q $V_Q = V_P -$ voltag drop at V_{PQ}

$= 219.36 - (54 \times 2\times10^{-4} \times 25)$

$\boxed{V_Q = 219.09V}$

voltage at point R is $V_R = V_Q -$ voltage drop at V_{QR}

$= 219.09 - (14 \times 25 \times 2\times10^{-4})$

$= 219.02V$

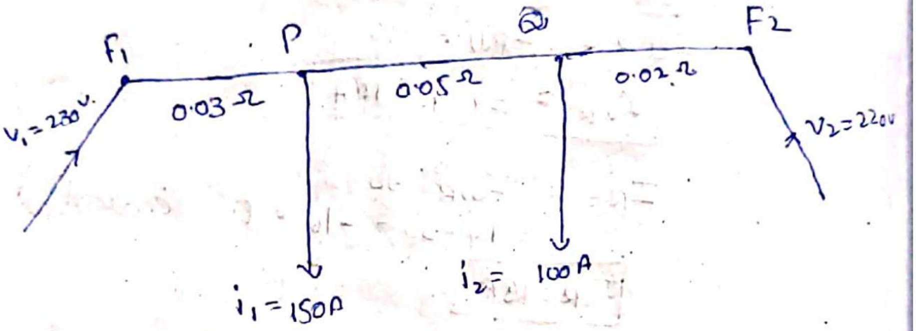
voltage at point S $V_S = V_{F2} - V_{F_2S}$

$= 220 - (41 \times 100 \times 2\times10^{-4})$

$\boxed{V_S = 219.18V}$

A Two wire DC distributors is fed at both ends F_1 and F_2 with 230V and 220V respectively. Load of 150 A and 100 A are tapped off at load points P and Q. Resistance of the distributor section F_1 and P is 0.03Ω, Resistance of distributor section P and Q is 0.05Ω, resistance of distributor section Q and F_2 is 0.02Ω respectively. Determine the current in each section of distributor and voltage at each load point?

Sol:-



$I_1 + I_2 = 150 + 100 = 150$ A

$V_1 - V_2 = I_1 \times r_1 + (I_1 - i_1) \times \overset{r_2}{\cancel{0.03}} + (I_1 - i_1 - i_2) \times r_3$

$230 - 220 = I_1 \times 0.03 + (I_1 - 150) \times 0.05 + (I_1 - 150 - 100) \times 0.02$

$10 = 0.03 I_1 + 0.05 I_1 - 7.5 + 0.02 I_1 - 5$

$10 = 0.1 I_1 - 12.5$

$\boxed{I_1 = 225A}$

$I_1 + I_2 = 250$

$225 + I_2 = 250$

$\boxed{I_2 = 25A}$

i) current at each section.

$I_{F_1P} = I_1 = 225A$

$I_{PQ} = I_{F_1P} - 150$

$= 225 - 150 = 75A$

$I_{F_2Q} = I_2 = 25$ A

ii) voltage at point p is $V_p = V_{F_1} - \text{drop}$

$= 230 - 225 \times 0.03$

$\boxed{V_p = 223.25\,V}$

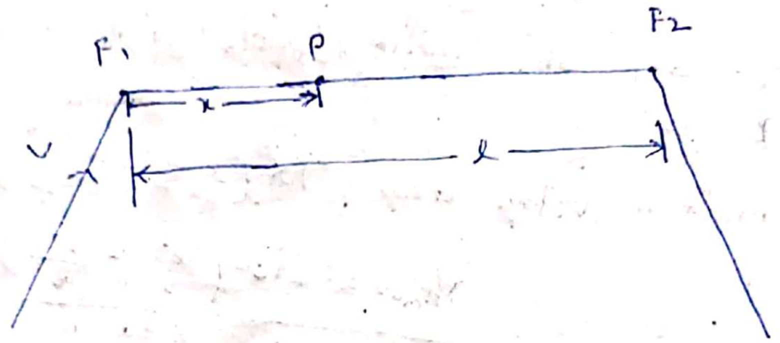
voltage at point Q is $V_Q = V_p - V_{PQ}$

$= 223.25 - (75 \times 0.05$

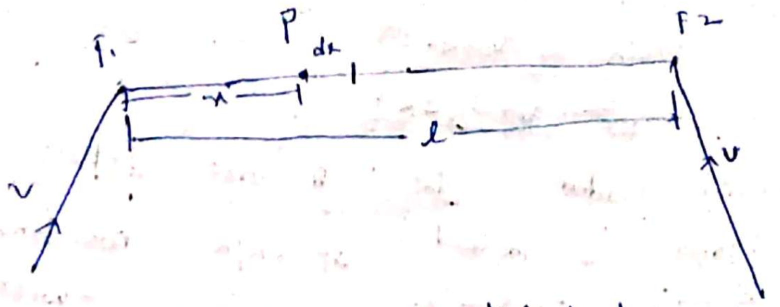
$\boxed{V_Q = 219.5\,V}$

~~voltage at~~

DC distributor fed at both ends with uniform load and same voltage:



when the voltage at both ends is same, the middle point becomes the point of ~~minimum~~ minimum potential. Thus the distributor can be image to be cut into two, at the middle point giving rise to two uniformly loaded distributor each fed at one end. The current applied to distributor = il



Consider a point P on distributor at distance of x from feeding point "F_1" as shown in above fig.

$\therefore$ current at P = $i(l-x)$.

consider a small section dx from point P and voltage drop in small ~~d~~ section dx = dv

$dv = i(l-x)r\,dx$

Voltage drop at any point at x from feeding end F, is

$$V_{Fx} = \int_0^x dv$$

$$V_{Fx} = \int_0^x i(l-x)r\,dx$$

$$= ir\int_0^x (l-x)\,dx$$

$$= ir\left[\int_0^x l\,dx - \int_0^x x\,dx\right]$$

$$\boxed{V_{Fx} = ir\left(lx - \frac{x^2}{2}\right)}$$

The drop at middle point is maximum i.e at $x = l/2$

$$\text{maximum voltage drop} = ir\left(l\cdot\frac{l}{2} - \frac{(l/2)^2}{2}\right)$$

$$V_{Dmax} = ir\left(\frac{l^2}{2} - \frac{l^2}{8}\right)$$

$$\boxed{V_{Dmax} = ir\left(\frac{3l^2}{8}\right)}$$

$$\Rightarrow V_{Dmax} = \frac{3}{8}\,ir\,l^2$$

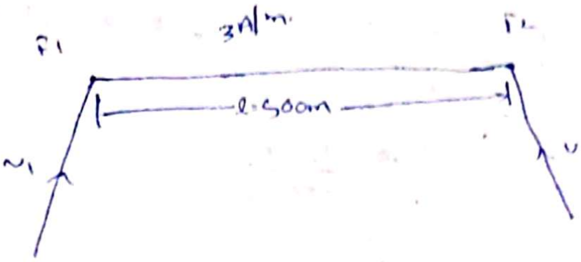
$$= \frac{3}{8}(i\cdot l)(r\cdot l)$$

$$\boxed{V_{Dmax} = \frac{3}{8}IR}$$

$$V_{min} = V - V_{Dmax}$$

$$\boxed{V_{min} = V - 3/8\,IR}$$

A uniformly loaded DC, 2 wire distributor of 500 m long is loaded at 3 A/m. Resistance of loop is 0.01 Ω/km. Determine maximum voltage drop if distributor fed at both ends with same voltage?



$i = 3\ A/m$

$R = 0.01\ \Omega/km$

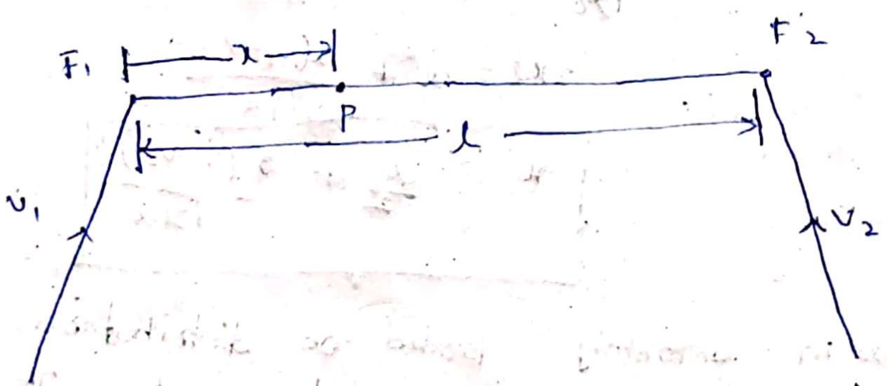
$R = \frac{0.01}{1000}\ \Omega/m$

$$V_{Dmax} = \frac{3}{8} i r l^2$$

$$= \frac{3}{8} \times 3 \times \frac{0.01}{1000} \times 500^2$$

$$\boxed{V_{Dmax} = 2.8125\ V}$$

DC distributor fed at both ends with uniform load and different voltages :-



let i be the current rating of distributor

r be the resistance in Ω of distributor

V_1 and V_2 are the voltages fed at points F_1 and F_2

Voltage drop in section F_1P = $V_{F_1P} = \frac{irl^2}{2}$

$= \frac{irx^2}{2}$

Voltage drop in section F_2P $V_{F_2P} = \frac{ir(l-x)^2}{2}$

Voltage at minimum potential point p from F_1 is

$$V_p = V_1 - V_{F_1P}$$

$$V_p = V_1 - \frac{irx^2}{2}$$

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voltage at minimum potential at point p from F_2 is

$$V_p = V_2 - V_{F_2P}$$
$$= V_2 - \frac{ir(l-x)^2}{2}$$

$$V_1 - V_{F_1P} = V_2 - V_{F_2P}$$

$$V_1 - \frac{irx^2}{2} = V_2 - \frac{ir(l-x)^2}{2}$$

$$V_1 - V_2 = \frac{irx^2}{2} - \frac{ir(l-x)^2}{2}$$

$$V_1 - V_2 = \frac{ir}{2}\left[\cancel{x^2} - l^2 - \cancel{x^2} + 2xl\right]$$

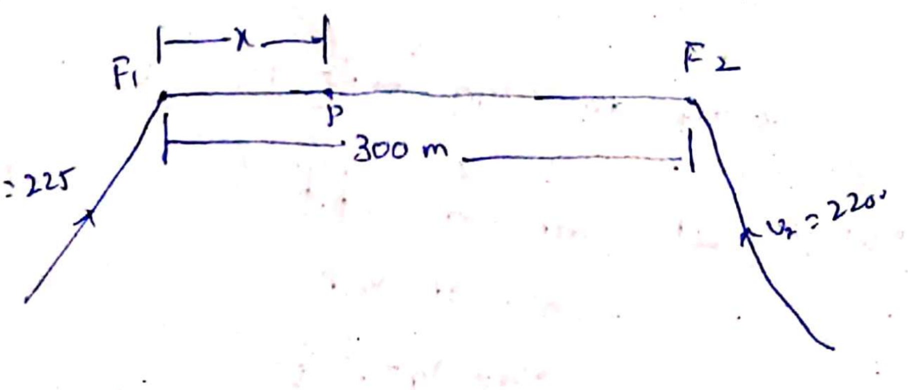
$$V_1 - V_2 = \frac{ir}{2}\left[2xl - l^2\right]$$

$$\frac{2(V_1 - V_2)}{ir} = 2xl - l^2$$

$$2xl = l^2 + \frac{2(V_1 - V_2)}{ir}$$

$$\boxed{x = \frac{l}{2} + \frac{(V_1 - V_2)}{irl}}$$

A 300 m uniformly loaded DC distributor is fed at both ends F_1 and F_2 at 2 A/m. The loop resistance is 0.2 Ω/km. Find distance b/w feeding end F_1 and minimum potential point. Also find voltage at minimum potential point if both feeding ends F_1 and F_2 are fed at 225 V and 220 V respectively. Determine current supplied from feeding end F_1 and F_2



$i = 2\ A/m$

$r = 0.2\ \Omega/km = 2\times 10^{-4}\ \Omega/m$

$l = 300$

minimum potential point is is at x distance.

$$x = l/2 + \frac{V_1 - V_2}{i r l}$$

$$x = \frac{300}{2} + \frac{225-200}{2\times 2\times 10^{-4}\times 300}$$

$$\boxed{x = 191.67\ m}$$

$$V_P = V_{F_1} - V_{F_1P}$$

$$= 225 - \frac{i r x^2}{2}$$

$$= 225 - \frac{2\times 2\times 10^{-4}\times (191.67)^2}{2}$$

$$V_P = \cancel{73}\ 225 - 7.34$$

$$\boxed{V_P = 217.65\ V}$$

current fed from F_1 is $ix = 2\times 191.67 = 383.34\ A$

current fed from F_2 is $i(l-x) = 2\times(300 - 191.67) = 216.66\ A$

Ring main distributor

A distributor which is arranged in the form of closed loop and can be fed at one (or) more number of feeding points is called as Ring main distributor (or) loop type distributor

-> For calculating the voltage distribution, a Ring main distributor fed at one point can be treated as equivalent to a straight line distributor fed at both ends at same voltage.

-> In Ring distributor any two load points are joined by means of a connector (or) interconnector.

-> The purpose of interconnector is to reduce the voltage drop in various section and the distributor is formed as Interconnected distributor.

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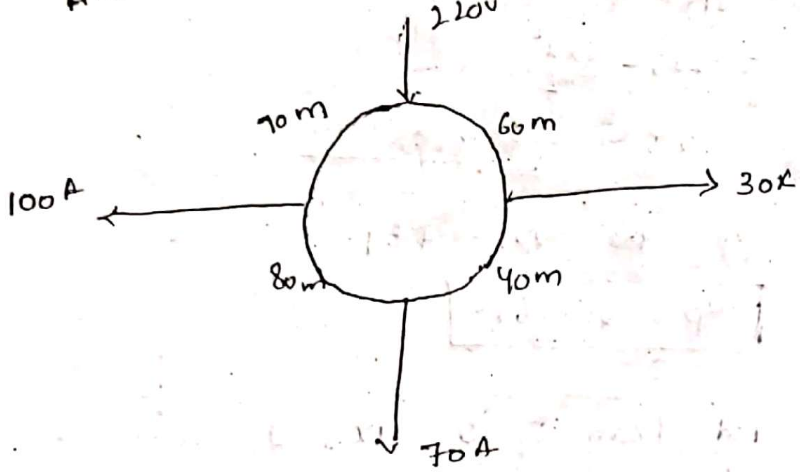
→ The current distribution can be obtaine[d] ... applying Thevinins theorem (or) Kirchoff laws

A 250 m Ring main distributor has loads as shown in the below fig. The resistance of distributor is $0.2\ \Omega/km$. If distributor fed at 220V at point P, then find the voltage at load point Q, R, S ?



Given:

$r = 0.2\ \Omega/km = 2\times10^{-4}\ \Omega/m$

let current in PQ = I

Applying KVL aroung the ring

Drop in PQ + Drop in QR + Drop in SP = 0

$(I\times2\times10^{-4}\times70) + (I-100\times2\times10^{-4}\times80) + (I-170\times2\times10^{-4}\times40)$

$+ (I-200\times2\times10^{-4}\times60) = 0$

$0.014I + 0.016I - 1.6 + 0.08I - 1.36 + 0.012I - 2.4 = 0$

$0.05I = 5.36$

$\boxed{I = 107.2A}$

current in section PQ is $I_{PQ} = I = 107.2A$

current in section QR is $I_{QR} = I - 100 = 7.2A$

current in section RS is $I_{RS} = I - 170 = -62.84$ i.e. $I_{SR} = 62.8$

current in section $I_{SP} = I - 200 = -92.8A$ i.e; $I_{PS} = 92.8A$

voltage at point Q is $V_Q = V_P - V_{PQ}$

$= 220 - (107.2 \times 2 \times 10^{-4} \times 70)$

$\boxed{V_Q = 218.492\,V}$

Voltage at point R is $V_R = V_Q - V_{QR}$

$= 218.49 - (\cancel{10}7.2 \times 2 \times 10^{-4} \times 80)$

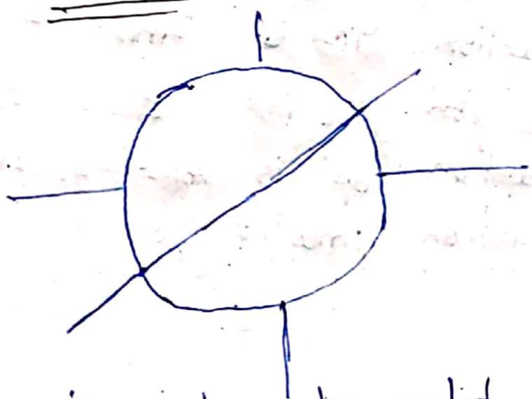
$\boxed{V_R = 218.38\,V}$

voltage at point S is $V_S = V_P - V_{PS}$

$= 220 - (92.8 \times 60 \times 2 \times 10^{-4})$

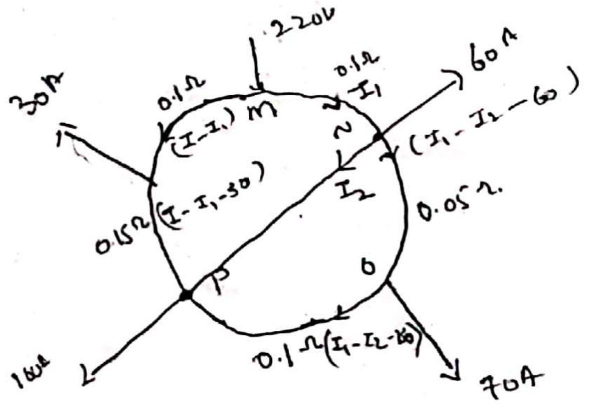
$\boxed{V_S = 218.8864\,V}$

Interconnected distributor



This is called Interconnected distributor

Find the current in various sections and voltage of various load points of Ring main distributor as shown in below Fig.



Let current in section MN be I_1 and in section NP be I_2

Total current fed at point M is $I = 60 + 70 + 100 + 30 = 260\,A$

Apply kvl to loop MNPQOM

$0.1 I_1 + 0.3 I_2 - 0.15(230 - I_1) - 0.1(260 - I_1) = 0$

$0.35 I_1 + 0.3 I_2 = 60.5 \rightarrow (1)$

Apply kvl to loop NOPN

$0.05(I_1 - I_2 - 60) + 0.1(I_1 - I_2 - 130) - 0.3 I_2 = 0$

$0.15 I_1 - 0.45 I_2 = 16 \rightarrow (2)$

$$\boxed{\begin{array}{l} I_1 = 158.14\ A \\ I_2 = 17.16\ A \end{array}}$$

current in section MN is $I_{mn} = I_1 = 158.14\ A$

current in section NO is $I_{NO} = I_1 - I_2 - 60 = 81.98\ A$

current in section OP is $I_{OP} = I_1 - I_2 - 130 = 10.98\ A$

current in section MQ is