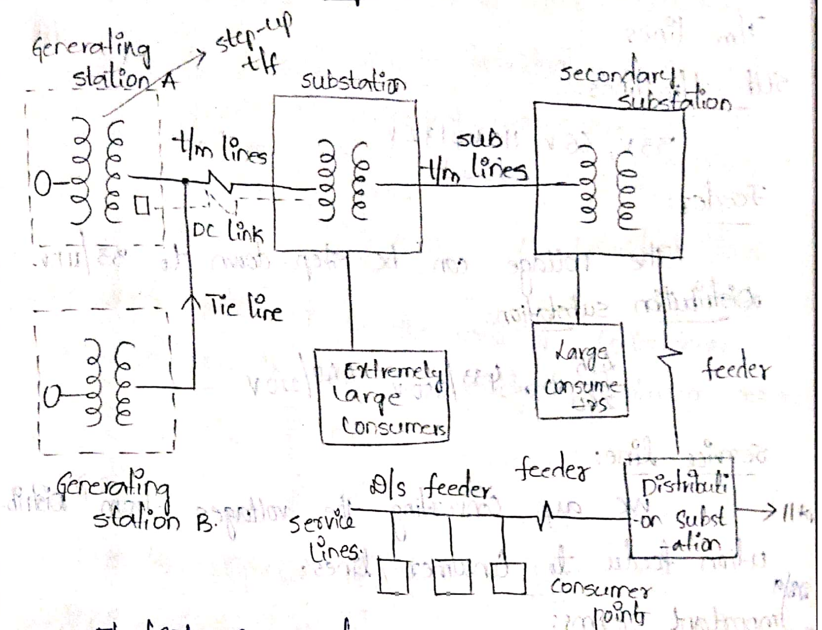
26-9-22

UNIT- 1

General Concepts



Electricity is modern society. most convient & useful form of energy. without energy the present socicty would not at all works. The increasing of consumption of electricity throughout the world reflects a growing standard of living of the people.

The above fig: shows the typical parts of electrical power s/m in a single line diagram.

Generation of AC:

By using hydro, thermal, nuclear, non-conventional Sources. we are generating 6.6 KV, 10.5 KV, 15.75 KV, 21 KV and 33 KV.

Tie line:

The interconnection of 2 Generating stations con

T/m lines :

200 KV, 400, 500, 750, 765, 800 KV are called as T/m lines.

sub - t/m lines:

33 V, 66 V, 110 V, 132 V.

Feeder:

The voltage can be step-down to 33/11 KV.

Distribution substation:

$\frac{415}{240}$ V, 433/250 V, 440/220 V.

Service line:

we are converting the voltages from distribution feeder to consumer lines.

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Important Terms:

* Demand: The average load at receiving terminal over a specified time.
* Demand Interval: It is the time period over the load is average.
* Connected load: It is the sum of all load points and outlets connected to the system.
* Maximum demand: The maximum power at the ckt drawn at any time is called max. demand.
* Demand factor: It is the ratio of maximum demand to the connected load.

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

* The Demand factor lies b/w 0.5 to 0.8

Diversity factor: It is the ratio of sum of individual demand to coincident max. demand.

$$\text{Diversity factor} = \frac{\text{sum of individual max. demand}}{\text{coincident max. demand of all consumers}}$$

$$= \frac{\sum_{i=1}^{n} D_i}{\sum_{i=1}^{n} C_i D_i}$$ C_i = Coincident factor

Co-incidence factor: It is the ratio of co-incidence max. demand to sum of individual maximum demand.

$$= \frac{\sum_{i=1}^{n} C_i D_i}{\sum_{i=1}^{n} D_i}$$ (or)

It is reciprocal of D.F. $= \frac{1}{DF}$

Contribution factor: It is per unit of individual max. demand to max. demand.

Load factor: It is the ratio of Average load to max. demand at a specified demand.

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

Average load: It is the ratio of no. of units generated to no. of hours at a certain time.

$$\text{Average Load} = \frac{\text{Number of units generated}}{\text{No. of hrs} \times \text{max. demand}}$$

Loss factor: It is the ratio of average power loss to peak load power loss (or) max. power loss.

Utilization factor: It is the ratio of max. load to rated capacity.

$$\text{Utilization factor} = \frac{\text{max. load}}{\text{rated capacity}}$$

Plant capacity factor (PCF): It is the ratio of average anual load to plant rated capacity.

$$\text{plant capacity factor} = \frac{\text{Avg. Annual load}}{\text{plant rated capacity}}$$

Plant use factor: It is the ratio of actual energy produced to multiplication to no. of hours at a certain time.

$$\text{plant use factor} = \frac{\text{Actual energy produced}}{\text{no. of hrs} \times \text{plant capacity}}$$

Problems:

Q. A residencial consumer has a connected load of 10A & max. demand of 100W. Find demand factor, load factor & No. of units generated 100W.

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

$$DF = \frac{100}{10} = 10$$

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

$$= \frac{0.041}{100} = 0.41 \times 10^{-4}$$

$$\text{Average load} = \frac{100}{\text{[illegible]}} = \frac{1}{24} = 0.041.$$

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Load curve:

The curve obtained by plotting the time in hrs on x-axis & load on y-axis is known as "load curve".

From the load curve we can know the following information:

1. The variation in load during different hrs. is advantageous.
2. The area under load curve represents the total no. of units generated in a day.
3. The min. & max. loads in a day.
4. The area under load curve is divided by area of rectangle is gives load factor.
5. The area under load curve divided by no. of hrs. gives the average load on the power station.

And also,

6. The load curve for sunday are holiday is different from the week days.
7. The load curve for summer & winter seasons will be different.
8. The load curve for rural & urban areas will be different.

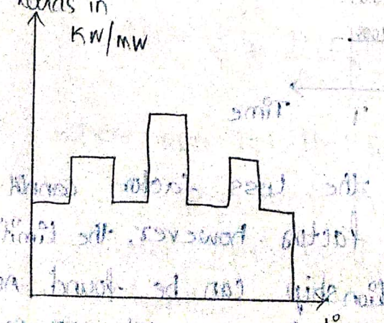


Fig: 1

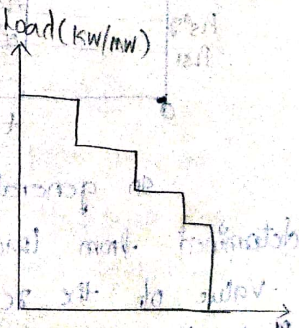


Fig: 2

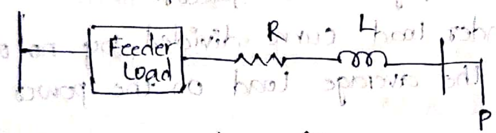
Load duration Curve:

This curve also gives the variations of the load:

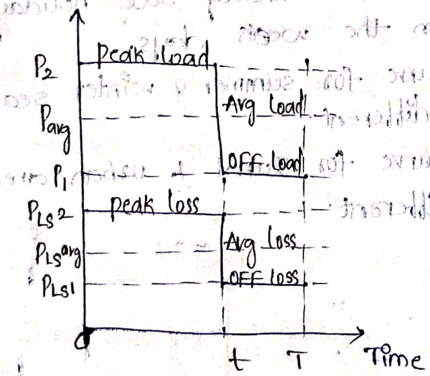
1. It is obtained from load curve.
2. This curve all the loads are arranged in descending order of magnitudes.
3. This is the greatest load on left & least load on the right side.

Fig (2)

Relationship b/w load factor & loss factor:



A Feeder with variable load.



In general the loss factor cannot be determined from load factor. however, the limiting value of the relationship can be found. Assume that the OFF peak loss is P_{LS1} at OFF peak load P_1. The peak loss is P_{LS2} at peak load P_2.

The load factor is

$$F_{LD} = \frac{P_{avg}}{P_{max}} = \frac{P_{avg}}{P_2} \rightarrow (1)$$

From load curve P_{avg} is

$$P_{avg} = \frac{P_2 \times t + P_1 \times (T-t)}{T} \rightarrow (2)$$

Substitute eqn (2) in eqn (1)

$$F_{LD} = \frac{P_2 \times t + P_1 \times (T-t)}{P_2 \times T}$$

$$F_{LD} = \frac{t}{T} \times \frac{P_1}{P_2} \times \frac{(T-t)}{T} \rightarrow (3)$$

The loss factor is

$$F_{LS} = \frac{P_{LS\,avg}}{P_{LS\,max}} = \frac{P_{LS\,avg}}{P_{LS2}} \rightarrow (4)$$

From the load curve,

$$P_{LS\,avg} = \frac{P_{LS2} \times t + P_{LS1} \times (T-t)}{T} \rightarrow (5)$$

Substitute eqn (5) in (4)

$$F_{LS} = \frac{P_{LS2} \times t + P_{LS1} \times (T-t)}{P_{LS2} \times T}$$

$$F_{LS} = \frac{t}{T} + \frac{P_{LS1}}{P_{LS2}} \times \frac{(T-t)}{T} \rightarrow (6)$$

where, P_{LS1} is the OFF peak loss at OFF peak load, T is the peak load duration, $(T-t)$ is the half peak load duration.

∴ ~~Max~~ OFF Peak load & peak loads can be expressed in

$$P_{LS1} = K \times P_1^2 \longrightarrow (i)$$

$$P_{LS2} = K \times P_2^n \longrightarrow (ii)$$

Where, K is constant.

Sub (i) & (ii) in eqn ⑥

$$F_{LS} = \frac{t}{T} + \frac{K \times P_1^n}{K \times P_2^n} \times \frac{T-t}{T}$$

$$F_{LS} = \frac{t}{T} + \left(\frac{P_1}{P_2}\right)^n \times \left(\frac{T-t}{T}\right) \longrightarrow ⑦$$

Case :1 OFF peak load is 0

$$P_{LS1} = P_1 = 0$$

$$\Rightarrow F_{LD} = F_{LS} = \frac{t}{T}$$

The load factor is equal to loss factor & they are $= \frac{t}{T}$ (constant)

Case :2 Very short, lasting peak.

$$t = 0$$

$$\Rightarrow F_{LS} = (F_{LD})^n$$

The value of loss factor approaches the value of load factor squared.

Case :3 Load steady

$$t = T$$

$$\Rightarrow F_{LS} = F_{LD}$$

The value of loss factor is equal to the value of load factor.

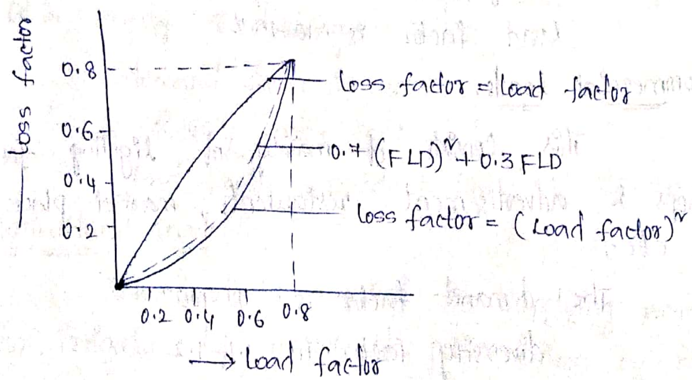
In general,

$F_{LD}^2 < F_{LS} < F_{LD}$

The loss factor cannot be determined directly from load factor.

Approximate formulae to relate the loss factor to load factor:

$$F_{LS} = 0.3 F_{LD} + 0.7 F_{LD}^2$$



loss factor curves as a fn of load factor.

*** Classification of Loads:

1. Domestic Loads
2. Commercial loads
3. Industrial loads
4. Municipal loads
5. Agricultural loads.
6. Other loads.

Domestic loads:

This Consists mainly of lights, fans, domestic application appliances such as heaters, refrigerators, air conditionars, mixers, ovens, heating ranges, small motors for pumping, various other small house holding appliances....etc;

demand factor is 70-100%

diversity factor is 1.2-1.3

Load factor is 10-15%

Commercial loads:

This Consists of mainly of lighting for shops & advertisement restaurents, market places.... etc.;

The demand factor is 90-100%

diversity factor is 1.1-1.2

Load factor is 25-30%

Industrial loads:

These loads may be following power ranges

Cottage industries < 5 KW

Small scale industries 5-25 KW

Medium Scale industries 25-100 KW

Large scale industries 100-500 KW.

Heavy industries above 500 KW.

For large scale & heavy industries need power over large period & which remains uniform throughout day.

For large industries,

demand factor 70-80%

Load factor 60-65%

For heavy industries,

demand factor 35-90%

Load factor 70-80%

Municipal Loads:

This load is for street lighting & remains practically constant throughout night.

The other type of municipal load is for water supply & drainage.

demand factor is 100%.

diversity factor is 1.

load factor for street light is 25-30%.

Agricultural Loads:

This load is required for supplying water for irrigation by means of pump driven by motor.

Load factor is 20-25%.

diversity factor is 1-1.5%.

demand factor is 90-100%.

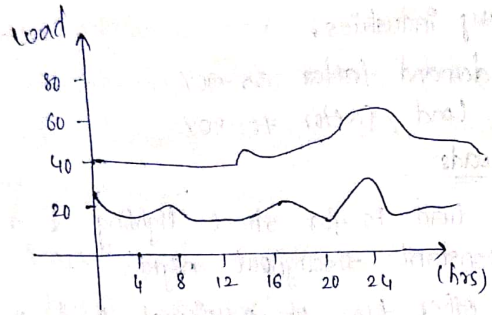
Other loads:

The other load such as bulk supplies, special industries such as paper, textile... etc,

Government loads have their own characteristics.

Characteristics of loads:

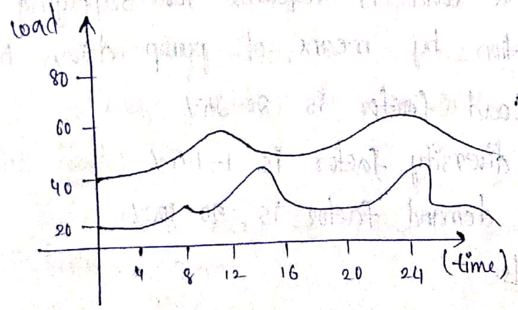
Domestic loads:



From figure during morning hrs load requirement is very less.

During evening hours, load requirement is very high & max. during 6pm to 10pm.

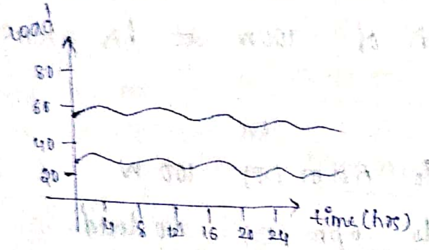
Commercial loads:



During morning hours load requirement is high and maximum during 6 to 10 pm.

During night, load requirement is less.

Industrial loads:



From graph, for industrial loads, the load requires throughout the day.

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Q. A daily load on a station is given below:

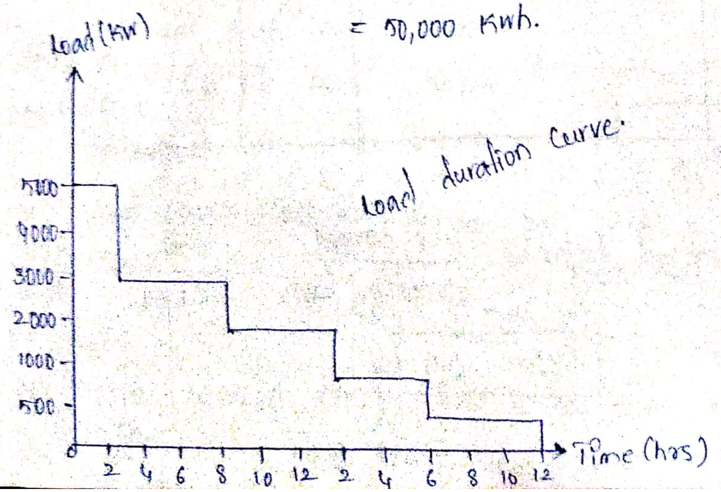
Load, kW	1000	5000	500	3000	2000
Time, Hrs	4	3	6	6	5

It is desired to draw a load duration curve & determine energy units consumed in a day.

Total energy consumed = $1000 \times 4 + 5000 \times 3 + 500 \times 6 + 3000 \times 6 + 2000 \times 5$

$= 4000 + 15000 + 3000 + 18000 + 10000$

$= 50,000$ Kwh.



Q. A residential consumer has a connected load of 10 lamps each of 100W at his premises & his demand:

From	midnight (12 Am)	to	5am (5)	hrs	100 W
From	5 am	to	6pm (13)		No load
From	6pm	to	7pm (1)		800W
From	7pm	to	9pm (2)		900 W
From	9pm	to	midnight (3) 12 pm		400W

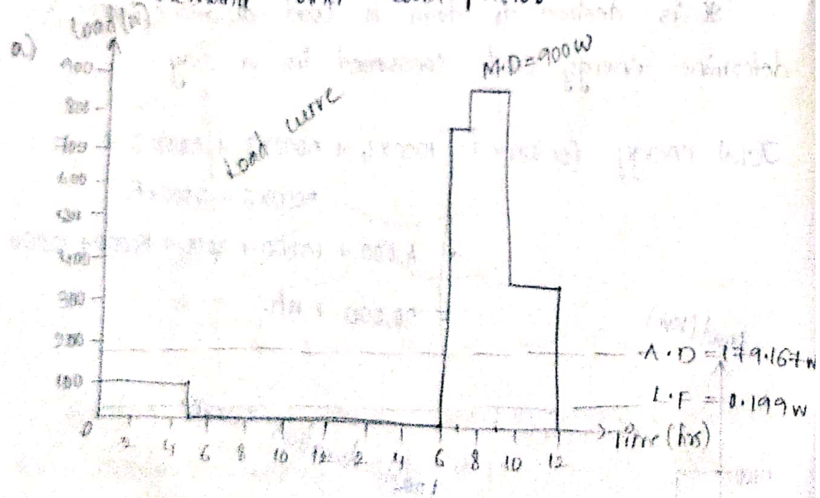
a) plot the load curve &

b) Determine Demand Factor, Avg. demand, max. demand and load factor.

C.L = 10 × 100 = 1000 W

no. of units = 100×5+...

a)



b) Demand factor = $\frac{\text{Max. demand}}{\text{connected load}} = \frac{900}{10 \times 100} = \frac{900}{1000}$

D.F = 0.9 /W

Average demand = $\frac{\text{No of units generated}}{\text{No. of hrs}}$

$= \frac{100\times5 + 0\times13 + 800\times1 + 900\times2 + 400\times3}{24}$

$= \frac{500 + 0 + 800 + 1800 + 1200}{24}$

$A.D = \frac{4300}{24}$

$\boxed{A.D = 179.167}$ W

max. demand = 900 W

Load Factor = $\frac{\text{Avg load}}{\text{max. demand}} = \frac{179.16}{900} = 0.199$ W

Q. Assume that annual peak load of 1° feeder is 2000 KW, at which the power loss i.e., total copper (or) I^2R loss is 80 KW. per 3-ϕ. Assume annual loss factor is 0.15. Determine

1. Avg. power loss
2. The total annual energy loss due to copper loss of the feeder ckt.

Given,

Annual peak load = 2000 KW

Cu/I^2R loss = 80 KW

Annual loss factor = 0.15

a) Avg. power loss = ? Annual loss factor × peak load power loss

$A.p.L = 0.15 \times 80 = \underline{12\ KW}$.

b) Total annual energy loss = Avg. power loss × no. of hours $\Rightarrow 12 \times 8760 = 105120$ kWh.

Assignment - 1

1. Derive the relationship b/w load factor & loss factor?
2. Explain load curve & load duration curve?
3. Classification of loads with their characteristics?

Assignment - 2

1. Explain connection schemes of Distribution s/m's?
2. Derive V.D when d/r connected at both ends with equal & un-equal voltages with C.L?
3. Derive V.D for d/r fed at both ends with equal & un-equal voltages with U.L?

Assignment - 3

1. Explain primary feeder voltage levels & its factors?
2. Factors affecting primary feeder loading?
3. Explain voltage drop calculations:
   i) when the p.f loads refers to receiving end voltage?
   ii) p.f loads reffered to respective load voltages?
4. Define TAF?

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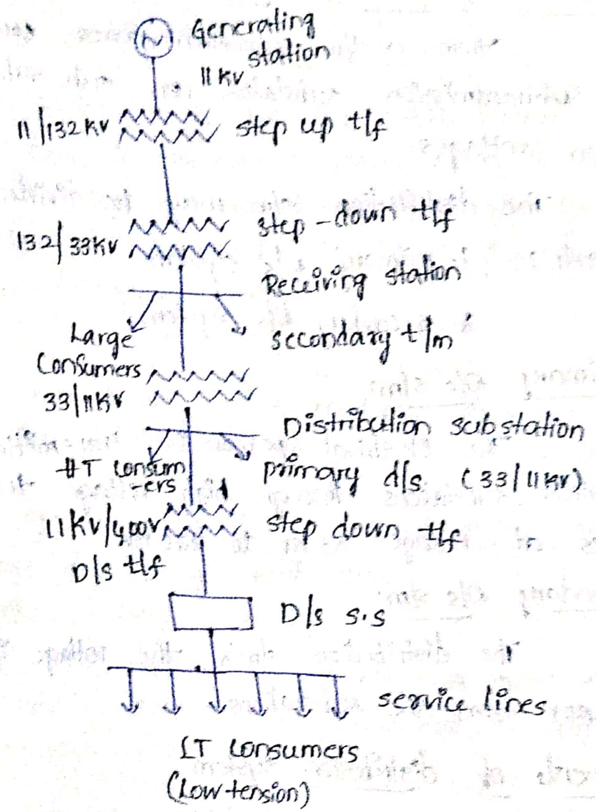
UNIT-2

DC DISTRIBUTION SYSTEMS



The electrical power s/m has 3 important components:

1. Generating s/m
2. Transmitting s/m
3. Distribution s/m

The electrical energy produced at G.S is conveyed to consumers through the t/m & Distribution s/m's.

It is difficult to draw the lines b/w t/m & D/s s/m's of large power system, so we have used single line diagram for representing the D/s s/m.

Transmission & Distribution systems:

From a T/m substation power could be taken to subtransmission substation (or) sub substations at Low voltages.

The distribution s/m may be divided into two parts : 1. primary D/s system
2. secondary D/s system.

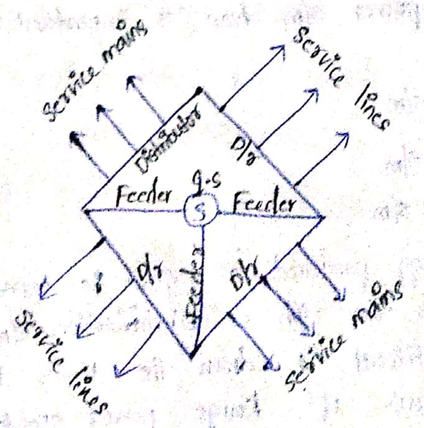
primary D/s s/m:

The Electrical power is transmitted to various substations through high voltage transmission lines at voltage 33 KV to 220 KV.

secondary D/s s/m:

The distribution s/m's, the voltage is step down to 400V from the substations.

Elements of distribution system



The distribution s/m can be subdivided into

1. Feeders
2. service mains
3. Distributors

Feeder: A feeder is a conductor which connects the substation (G.S) to the area where power is distributed.

* There is no tappings are taken from the feeder.
* The design of feeder is considered depends on current carrying capacity.

Distributor:

A Distributor is a conductor from which tappings are taken from the supply to the consumers.

* The design of D/r is considered depends on voltage drop along with length.

service mains:

A service mains is generally a small cable/conductor which connects the distributor to consumer terminals.

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Development of distribution plan:

The distribution plan for a particular area, the following main points should be considered:

1. service conditions:
   i) Load to be served
   ii) density of customers
   iii) Length of lines &
   iv) points of supply.

2. Electrical design:

i) voltage of supply

ii) ~~den~~ voltage regulation at the consumers

iii) transformers and accessories

iv) protection of electrical systems and

v) operation of the system.

3. mechanical design:

i) poles and spans

ii) hardware and guying

iii) wires and clearences and

iv) instalation of t/f and substation.

4. cost:

per kilometer of distribution lines and cost per consumer.

Requirements of a distribution system:

The following are the requirements of a good distribution system:

1. proper voltage

2. Availability of power on demand

3. Reliability

1. proper voltage:

One of the primary requirement of a d/s system is that the voltage variations at a the consumers terminals should be as low [as possible. while low voltage causes revenue loss, inefficient lighting and possible burning out of motors] the high voltage causes permanent burning out of the lamps and may also cause failure of other appliances.

2. Availability of power on demand:

A good D/s s/m must make available the consumers the required amount of power efficiently. This necessitates that operating staff must continuously study load patterns.

3. Reliability:

Another important requirement of a good d/s s/m is its reliability. Although cent percent reliability is not possible, yet the reliability can be improved to a considerable extent by:

i) Interconnected s/m
ii) Reliable automatic c.s
iii) providing additional reserve facilities.

Classification of D/s systems:

1. According to "Nature of current":
i) D.C distribution s/m
ii) A.C distribution s/m

2. According to "Type of construction":
a) overhead s/m
b) underground s/m

3. According to "scheme of connection":
a) Radial s/m
b) Ring main s/m
c) Interconnected s/m

4. According to "Number of wires":

a) Two-wire s/m

b) Three-wire s/m

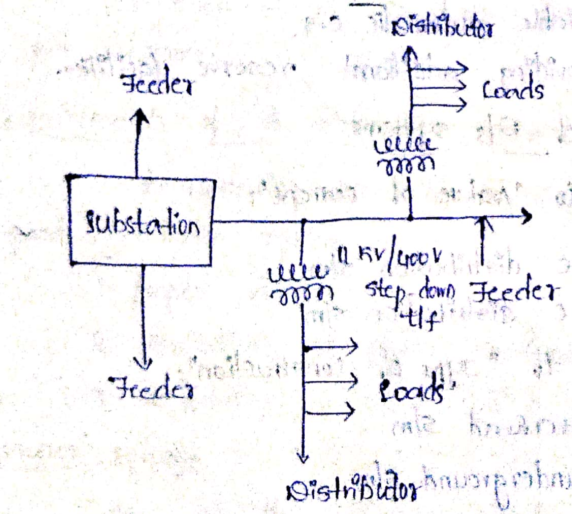
c) Four-wire s/m

Connection schemes of distribution s/m:

According of scheme of connections, the d/s s/m is classified into 3 parts:

1. Radial d/s s/m.
2. Ring main d/s s/m
3. Interconnected d/s s/m.

1. Radial distribution s/m:

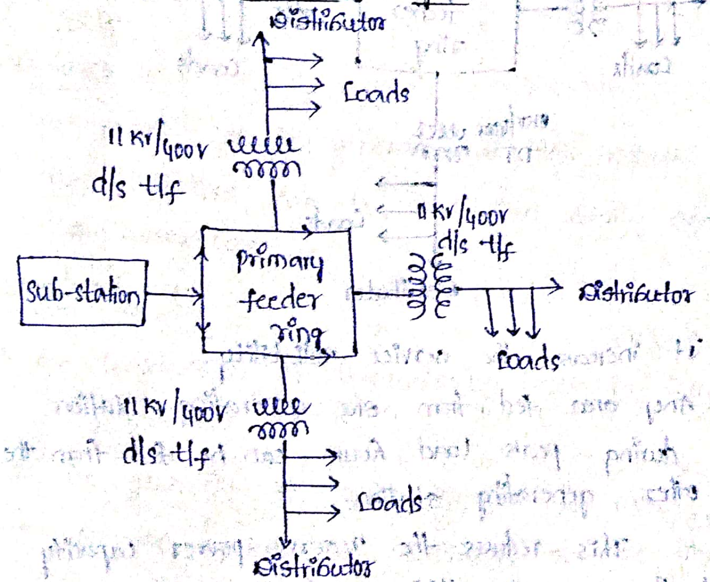


1. The end portion of the distributor nearest to the feeding point will be heavily loaded.
2. The consumers are dependent on a single feeder and single distributor. Therefore, any fault on the feeder (or) distributor cuts off supply to the.

consumers who are on the other side of fault away from the sub-station.

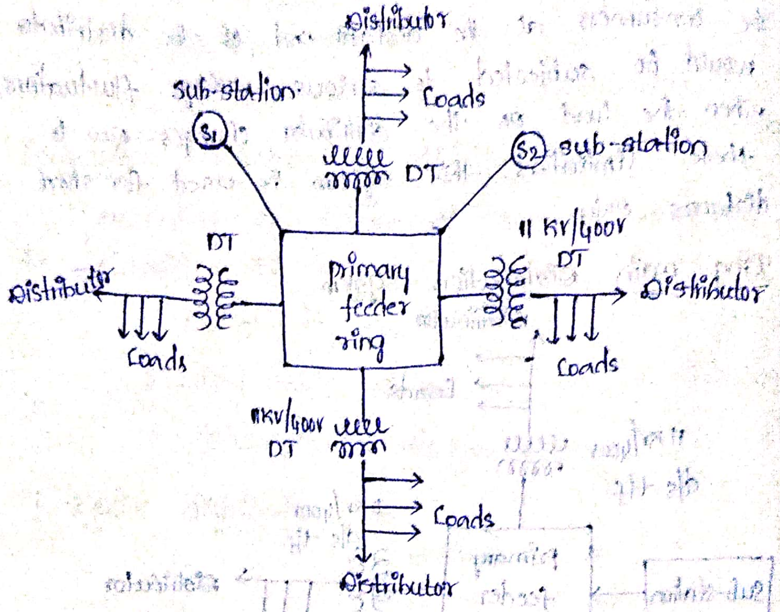
3. The consumers at the distant end of the distributor would be subjected to serious voltage fluctuations when the load on the distributor changes. Due to these limitations, this system is used for short distances only.

2. Ring main Distribution system:



1. There are less voltage fluctuations at consumer's terminals.
2. The s/m is very reliable, as each distributor is fed via both the sides of the feeder.
3. Less copper is required for the conductors as, each part of the ring carries less current than that in radial systems.

3. Interconnected Distribution system:



1. It increases the service reliability.
2. Any area fed from one generating station during peak load hours can be fed from the other generating station.

This reduces the reserve power capacity and increases the efficiency of the system.

Comparison b/w DC & AC systems of transmission and Distribution:

DC system:

Advantages:

1. There is greater power per conductor and simple line construction.
2. Ground return is possible

DC	AC
→ Con S.	→ C diff.
→ C.S.	→ not pos
→ insul less	→ insul high
→ converter req	→ can not req
→ distur ↑	→ d ↓
→ 1-ϕ supply	→ 1-ϕ, 3-ϕ
→ losses ↓	→ losses ↑
→ damage ↓	→ ↑

3. No stability problems & synchronizing difficulties.
4. Since, the potential stress on the insulation in case of D.C system is $1/\sqrt{2}$ times that in AC.

Dis advantages:

1. Converters require considerable reactive power
2. Harmonics are generated which require filters.
3. Converters do not have overload capability.

AC system:

Advantages

1. The power can be generated at high voltages
2. The substations can be maintained easily and at a lesser cost

Dis-advantages:

1. The construction of transmission lines is comparatively difficult
2. The quantity of copper required is more.
3. In AC system, the resistance of the line is increased due to skin effect

Comparision between overhead lines and underground cables:

1. The large charging current on very high voltage cable limits the use of underground cable for long length t/m, where a long distance t/m is required, overhead t/m lines are used.

2. The insulation cost is more in case of cables than the overhead lines.

3. The erection cost of an overhead line is much less than the underground cable.

There are certain situations, they are:

1. For power stations and substation, connection (or) a link in overhead lines.

2. For submarine crossings.

Over head → High V t/m, → At, in X loss ↓, → cost ↓, → fault easy rectify, → cons. in ✓, → Hars ✓, → cons. easy

Under → Low V t/m, → Cx, → insulation/loss, → cost ↑, → diff, → Rn diff, → C.S. ↓ X, → Har X, → Main ↑, → cons. diff

Over head lines.

Adv:

1. T/m & D/s by overhead lines is much cheaper than the underground cables.

2. The capacity of t/m line can be increased easily by only replacing the conductor, by now one of larger cross-sectional area.

Dis-adv:

1. The overhead lines are subjected to supply interruptions due to lightning, short circuit, the breakage of line conductors, bird-faults etc.

2. Maintenance cost is higher

3. Interference with communication ckt's.

under-ground cables:

Adv:

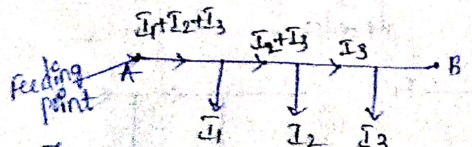
1. Elimination of accidents to public
2. Freedom from interruption of service and damage due to the thunderstorms, lightning and falling objects.
3. No disturbance to communication ckt's.

Dis-adv:

1. underground cable s/m is more costly than the overhead system.
2. Faults cannot be easily detected by inspection
3. Repairs and extension is not as easy as in overhead s/m.

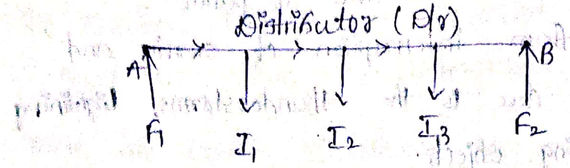
Types of DC distributors:

1. Distributor fed at one end:



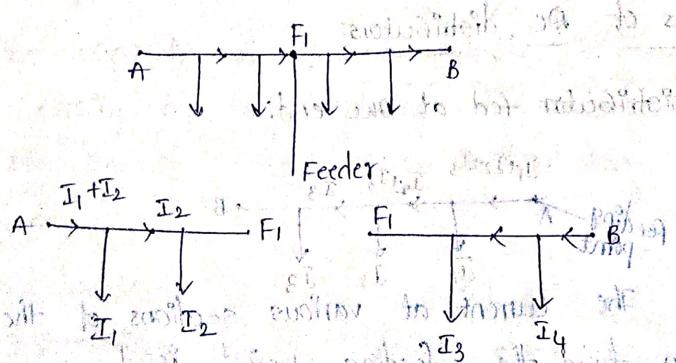
* The current at various sections of the d/r away from the feeding point is ↓.
* The fault occurs in any section of the feeder the whole d/r will have disconnected from the supply mains. Therefore, the continuity of supply is interrupted.

2. Distributor fed at Both ends:



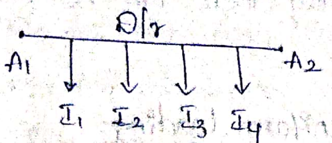
* The fault occurs on any feeder point of the D/r, the continuity of supply mainted from other feeding point.
* The area of cross-section of conductor required for Doubley-Fed D/r is less than single fed d/r.

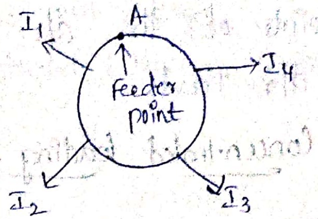
3. Distributor fed at centre:



* The d/r is equivalent to two-single fed d/r's, each d/r having common feeding point and length equal to half-off the total length.

4. Ring main Distributor :



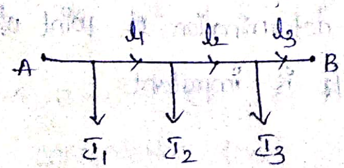


* It is equivalent to straight d/r fed at both ends with equal voltages, the two ends combined together to form a closed ring.

Types of loadings:

1. Concentrated loading
2. uniform loading
3. Concentrated loading in addition with uniform loading.

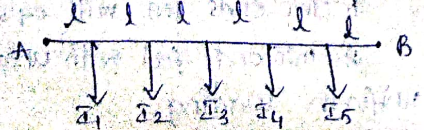
* Concentrated loading:

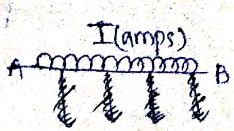


$l_1 = 2m$
$l_2 = 3m$
$l_3 = 4m$

The concentrated loads act on a particular point of the d/r. The magnitude of loads & length of sections of d/r may be unequal.

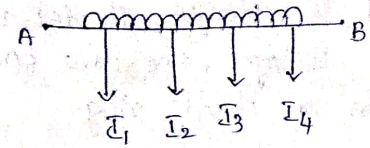
* uniform loading:





The d/r loads are uniformly loaded on all points of the d/r. Ideally there are no uniform d/r loads.

3. Concentrated loading + uniform loading:



The above diagram shows the combination of concentrated loading & uniform loading.

15/10/22

Calculation of voltage drops in DC distributor:

The main requirement of d/r is to supply power to consumers at the rated voltage within the permissible voltage variation. Hence, the D/s calculations the determination of point of minimum potential on the d/r is important.

1. DC D/r:

a) D/r fed at one end

i) concentrated loading

ii) uniform loading

b) D/r fed at both ends

i) concentrated loading

1. Two ends fed with equal voltages

2. Two ends fed with unequal voltages

ii) uniform loading.

1. Two ends fed with equal voltages
2. Two ends fed with unequal voltages.

c) D/r fed with both concentrated & uniform loading

d) D/r fed at centre.

e) Ring main D/r.

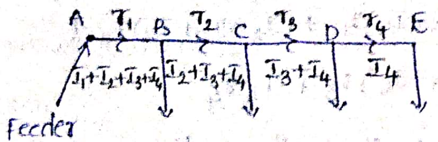
2. AC D/r:

a) concentrated loading
   i) 1-ϕ AC supply using 2-wire s/m
   ii) 3-ϕ AC supply using 3-wire s/m
   iii) 3-ϕ & neutral using 4-wire s/m

1-10-22

Derivations:

DC Distributor fed at one end - concentrated loading:



A 2-wire DC D/r AE fed at one end having a concentrated loads $I_1, I_2, I_3,$ and I_4 tapped of at point B, C, D, E.

currents

current in section AB = $I_1+I_2+I_3+I_4$

current in section BC = $I_2+I_3+I_4$

current in section CD = I_3+I_4

current in section DE = I_4

Voltage of Resistances

$V = IR$

Resistance in section AB = r_1

Resistance in section BC = r_2

Resistance in section CD = r_3

Resistance in section DE = r_4

Voltage drop

Voltage drop in section AB = $(I_1+I_2+I_3+I_4)r_1$

Voltage drop in section BC = $(I_2+I_3+I_4)r_2$

Voltage drop in section CD = $(I_3+I_4)r_3$

Voltage drop in section DE = $I_4 r_4$

Total voltage drop = (V.D in AB) + (V.D in BC) + (V.D in CD) + (V.D in DE)

$$T.V.D = (I_1+I_2+I_3+I_4)r_1 + (I_2+I_3+I_4)r_2 + (I_3+I_4)r_3 + I_4 r_4$$

= Σ(current flowing in section + Resistance in section)

T.V.D = Σ (V.D in individual section).

In a 2-wire DC D/r system the 2-wires (go & return wire) are present.

Hence, the actual V.D will be equal to V.D in both wires. The min. potential will occur at point E, which is far from the feeding point A.

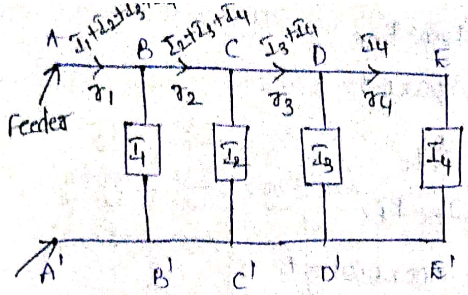
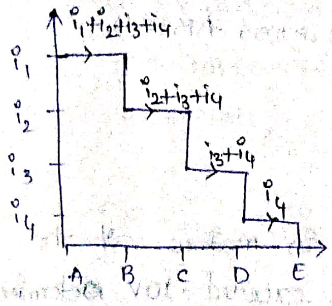
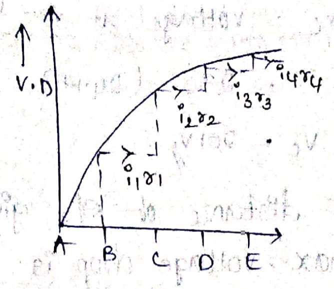


Fig: DC D/r fed at one end with 2-wire.



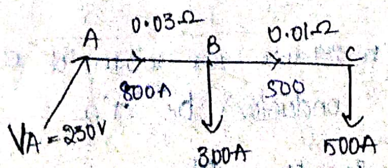
Various currents



Various voltage drops.

problem:

1. A 2-wire DC D/r shown in fig: If the voltage at feeding point A is 230V, calculate the voltage at point B & C?



Given, $V_A = 230V$

$I_1 = 300A$, $I_2 = 500A$

$r_1 = 0.03\Omega$, $r_2 = 0.01\Omega$

V.D across AB = $I_{AB} R_{AB}$

= 800 × 0.03

AB = 24

V.D across BC = $I_{BC} R_{BC}$

BC = 500 × 0.01 = 5

V_B = voltage at A − (V.D across AB)

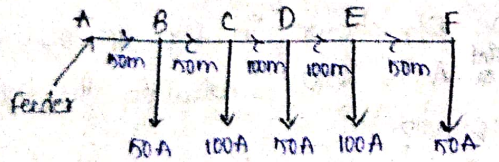
= 230 − 24 = 206 V

V_C = voltage at A − (V.D across AB+BC)

= 230 − (24+5)

V_C = 201 V

2. The distance of o/r given in meters, if the max. voltage drop is not exceeded 10V. Determine the cross-sectional area of the o/r. Take $\rho = 1.78 \times 10^{-8}$ Ωm.



Let us assume, resistance for 100m of o/r length (Both return & go conductor) be 'r' Ω

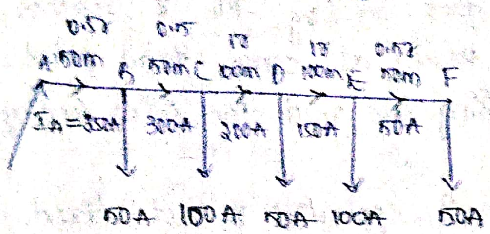
Resistance across sec AB = $\frac{50}{100} \times r = 0.5r\,\Omega$

BC = $\frac{50}{100} \times r = 0.5r\,\Omega$

CD = $\frac{100}{100} \times r = 1r\,\Omega$

$$DE = \frac{100}{100} \times r = 1 r \Omega$$

$$EF = \frac{50}{100} \times r = 0.5 r \Omega$$



175
175
200
150
25
700

T. V.D = V.D across section AB + V.D BC + CD + DE + EF

$= 350 \times 0.5r + 300 \times 0.5r + 200 \times 1r + 150 \times 1r + 50 \times 0.5r$

$V = 700 r$

$$r = \frac{V}{700} = \frac{10}{700} = 0.01428 \, \Omega$$

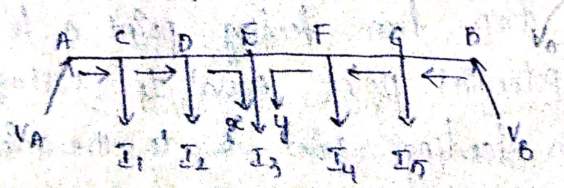
$$R = \frac{\rho l}{A} \Rightarrow a = \frac{\rho l}{R} = \frac{1.78 \times 10^{-8} \times (2 \times 100)}{0.01428} = 2.492 \times 10^{-4} \, m^2$$

$$= 2.493 \, cm^2$$

20/10/22

Distributor Fed at both ends – Concentrated Loading:

a) Equal voltages:



Consider, a dlr AB fed at both ends with equal voltages V (volts) and having concentrated loads I_1, I_2, I_3, I_4 and I_5 at points C, D, E, F, G respectively.

1. As we move away from the feeding point A the potential goes on ↓ing till it reaches the minimum value at some load point, & then starts rising we reach the other feeding point B.

The point of min. potential is not fixed it is always shift with variation of load points.

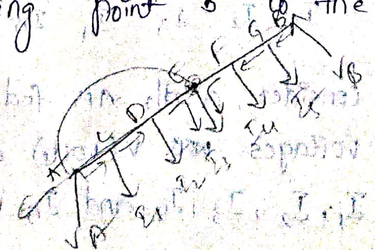
2. All the currents tapped OFF b/n point A & E will be supplied from feeding point A. while tapped OFF b/n point E & B will be supplied from point B.

3. The current tapped at min. point of potential is supplied by both f. point A & feeding point B.

4. The sum of currents fed from feeding point A & B equal to the total load current tapped off from the D/r.

$$I_A + I_B = I_1 + I_2 + I_3 + I_4 + I_5$$

5. voltage drop from feeding point A to the min. potential point equal to voltage drop from feeding point B to the min. potential point.



section	I in section (A)	R of section (Ω)	V.D in section (volts)
AC	I_A	R_{AC}	$I_A \cdot R_{AC}$
CD	$I_A - I_1$	R_{CD}	$I_A - I_1 \cdot R_{CD}$
DE	$I_A - (I_1+I_2)$	R_{DE}	$I_A - (I_1+I_2) \cdot R_{DE}$
EF	$I_A - (I_1+I_2+I_3)$	R_{EF}	$I_A - (I_1+I_2+I_3) \cdot R_{EF}$
FG	$I_A - (I_1+I_2+I_3+I_4)$	R_{FG}	$I_A - (I_1+I_2+I_3+I_4) \cdot R_{FG}$
GB	$I_A - (I_1+I_2+I_3+I_4+I_5)$	R_{GB}	$I_A - (I_1+I_2+I_3+I_4+I_5) \cdot R_{GB}$

Voltage drop from F.P A upto point B,

$$V_A - V_B = I_A \cdot R_{AC} + (I_A - I_1) R_{CD} + I_A - (I_1+I_2) \cdot R_{DE} + I_A - (I_1+I_2+I_3) \cdot R_{EF} + I_A - (I_1+I_2+I_3+I_4) R_{FG} + I_A - (I_1+I_2+I_3+I_4+I_5) \cdot R_{GB} \longrightarrow (1)$$

⇒ As the 2 ends are fed with equal voltages

$V_A = V_B$ i.e; $V_A - V_B = 0$

From the above expression the value of unknown current I_A can be determined when the other quantities being known values.

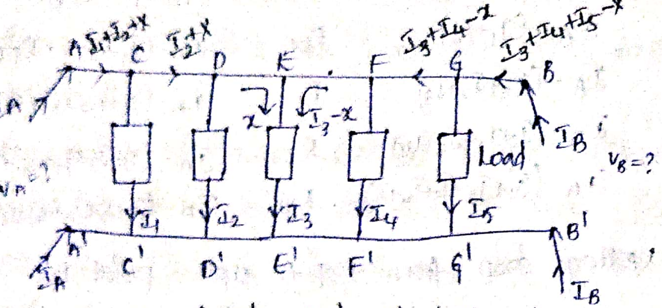
6) un-equal voltages:

The magnitude of voltages at 2 ends are subtracted in eqn (1)

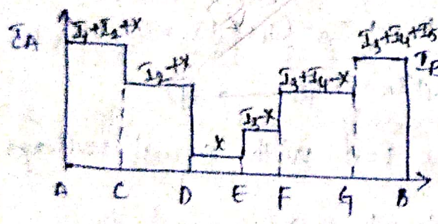
The value of unknown current I_A can be determined the point of min. potential will be determined in the same manner as that for two ends fed with equal voltages.

* voltage drop b/n feeding point A & B is equal to voltage drop over d/r AB con

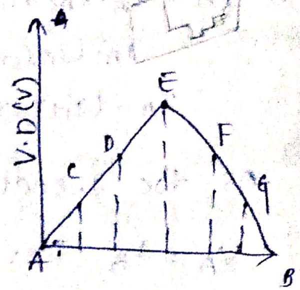
* $V_A - V_B$ = voltage drop over d/r AB.



a) D/r Fed at both end



a) Current d/r at various sections.

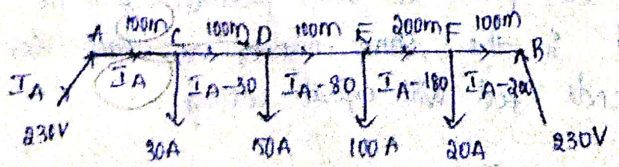


b) V.D in various sections.

21/10/22

Q. A DC 2-wire D/r AB, 600m long tapped at distance of 100 m, 200m, 300m, & 500m from the end A respectively. If the area of cross-section of d/r conductor is 1.0 cm² . Find the min. consumer voltage take $\varrho = 1.7 \times 10^{-6}$ cm.

Sol:



Let the current supplied from feeding end (point) A $= I_A$ (A)

The resistance of 1m length of D/r (Both go & return conductors): $r = \frac{\rho l}{A} = \frac{1.7\times10^{-6}\times1.0}{1.0}\times 2$

$r = \frac{\rho l}{a}$

$r = 3.4\times10^{-4}$

Resistance at sec AC: R_{AC}

$= (3.4\times10^{-4})\times 100 = 0.034\,\Omega$

CD: $R_{CD} = (3.4\times10^{-4})\times 100 = 0.034\,\Omega$

$R_{DE} = (3.4\times10^{-4})\times 100 = 0.034\,\Omega$

$R_{EF} = (3.4\times10^{-4})\times 200 = 0.068\,\Omega$

$R_{FB} = (3.4\times10^{-4})\times 100 = 0.034\,\Omega$

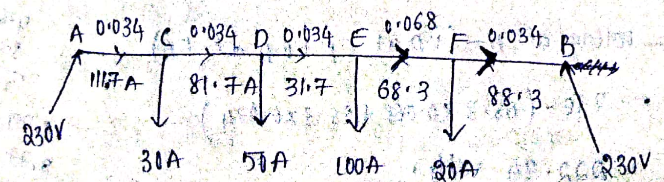
voltage at A − voltage at B = V.D over AB

$V_A - V_B = I_A \times R_{AC} + (I_A-30)R_{CD} + (I_A-80)R_{DE} + (I_A-180)R_{EF} + (I_A-200)R_{FB}$

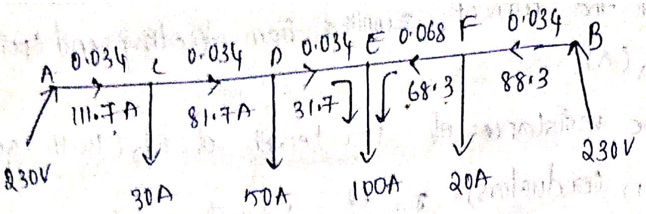
$230-230 = I_A\times0.034 + (I_A-30)0.034 + (I_A-80)0.034 + (I_A-180)0.068 + (I_A-200)0.034$

$0 = 0.204\,I_A - 22.78$

$I_A = 111.7\,A$



The point 'E' is the minimum value.



The actual current distributions of various sections of a D/r as shown in figure.

It is clear that the current are coming to load point E from both sides i.e; from point D to point F.
Hence, E is the min. point of potential.

The d/r fed at both ends AB under given load conditions. can be treated as individual equal to d/r fed at one end.

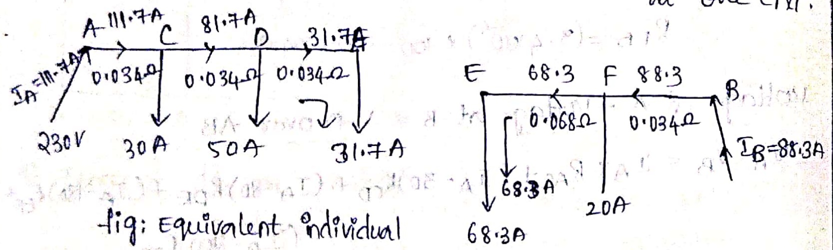


fig: Equivalent individual d/r fed at one end.

Min. consumer voltage:

From A

V_E = voltage at point A − (V·D at AC + V·D at CD + V·D at DE)

= 230 − (111·7 × 0·034 + 81·7 × 0·034 + 31·7 × 0·034)

V_E = 230 − 7·654 = 222·346 volts.

From B

V_E = voltage at B − (V·D at EF + V·D at FB)

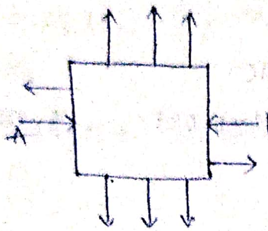
= 230 − (68·3 × 0·068 + 88·3 × 0·034)

= 222·34 volts.

4·64
3·002
7·642

3·79
2·77
1·07
7·654

DC Ring main D/r:



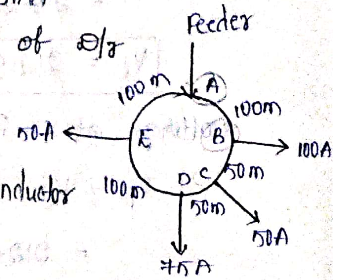
A ring d/r is arranged to form a closed loop & fed at one (or more points) is called Ring d/r.

A d/r starts from one point makes a loop through the area to be served & returns to the original point.

Ex-1: A 2-wire ring d/r is 400 m long & it is fed at 230V at point A. The various loads are connected shown in figure. Find

i) current in each section of D/r
ii) voltage at load points
iii) min. potential point

resistance for 100m of single conductor is 0.01 Ω.



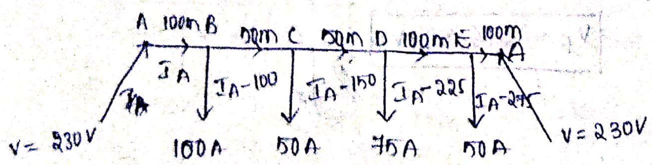


fig: D/r fed at both ends with equal voltages

Resistance of single conductor = 0.01 Ω /100m length

The total resistance for both (go & return) conductors

$r = 2 \times 0.01 = 0.02/100m = $ ____

Let 'x' be the current in section AB. The resistance & current in various sections.

Section	Current	Resistance	Length
AB	x	0.02	100
BC	x−100	0.01	50
CD	x−150	0.01	50
DE	x−225	0.02	100
EA	x−275	0.02	100

Voltage drop in the closed loop ABCDEA = 0

$T.V.D = x \times 0.02 + (x-100)0.01 + (x-150)0.01 + (x-225)0.02 + (x-275)0.02$

$= 0.08x + (-1 - 1.5 - 4.5 - 5.5)$

$0 = 0.08x - 12.5$

$0.08x = 12.5$

$\boxed{x = 156.25 A}$

100
50
75
50
275

The current fed in section AB = 156.25 A

I_{AE} = Total load − I_{AB}

$= (100+50+75+50) - 156.25$

$\boxed{I_{AE} = 118.75 A}$

(1)

⇒ current in each section

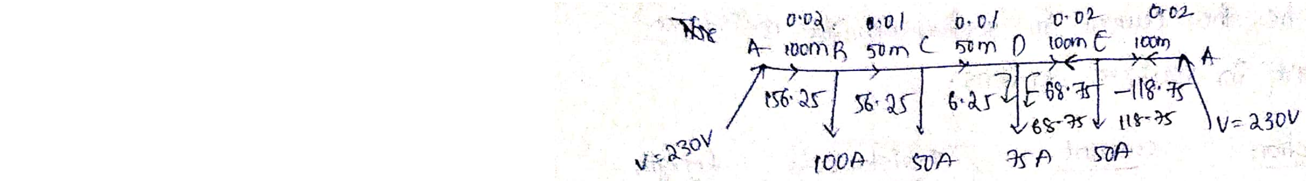
AB ⇒ $I_A = 156.25 A$

BC ⇒ $I_A - 100 = 56.25 A$

CD ⇒ $I_A - 150 = 6.25 A$

DE ⇒ $I_A - 225 = -68.75 A$

EA ⇒ $I_A - 275 = -118.75 A$



(3) ⇒ The currents are coming to load point D from both sides so, D is the point of minimum potential.

Hence, the currents in ring d/r,

$I_{AB} = 156{\cdot}25A$	$I_{DE} = 68{\cdot}75A$
$I_{BC} = 56{\cdot}25\ A$	$I_{EA} = 118{\cdot}75$
$I_{CD} = 6{\cdot}25A$	

(2) ⇒ Voltage at point A = 230V

V_B = (Voltage at A − V·D at AB)

= 230 − (0·02 × 156·25)

= 230 − 3·125

V_B = 226·875 V

$V_C = 230 - (156{\cdot}25 + 56{\cdot}25)\ 0{\cdot}01 \times 0{\cdot}02$ (AB + BC)

= 226·31 V

V_D = V. at A − (V·D at AB+BC+CD)

= 226·247 V

V_E = V_A − V·D a/c AE   230 − (406·25)

= 227·625 V

156·25 × 0·02
56·25 × 0·01
6·25 × 0·01
68·75 × 0·02
118·75 × 0·02

3·125
0·5625
0·0625
1·375
2·375
(7·5)

Ex-2

A two-wire DC d/r AB 600m long is loaded as

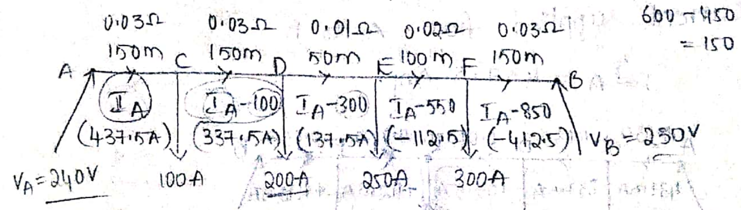
Distance from A	150 m	300m	350 m	450m
Loads in Amps	100	200	250	300

A feeding point A is maintained at 240V & feeding point B at 230V if each conductor has a resistance of 0.01Ω/100m. calculate

i) The current supplied from A & B

ii) The min. voltage & the point at which it occurs

iii) voltage at each load point.



$V_A = 240V$, $V_B = 230V$

The total resistance for both (go & return) conductors

$r = 2 \times 0.01\Omega/100m = 2\times10^{-4}\Omega/m$

Resistance at section AC is

$r \times 150$

I_{AC} $R_{AC} = 2\times10^{-4}\times150 = 0.03\Omega$ ✓

I_{CD} $R_{CD} = 2\times10^{-4}\times150 = 0.03\Omega$ ✓

$R_{DE} = 2\times10^{-4}\times50 = 0.01\Omega$ ✓

$R_{EF} = 2\times10^{-4}\times100 = 0.02\Omega$

$R_{FB} = 2\times10^{-4}\times150 = 0.03\Omega$

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V.D over AB = voltage at A − voltage at B

$V_A - V_B = I_A \cdot R_{AC} + (I_A - 100) R_{CD} + (I_A - 300) R_{DE} + (I_A - 550) R_{EF} + (I_A - 850) R_{FB}$

$240 - 230 = I_A \times 0.03 + (I_A - 100) 0.03 + (I_A - 300) 0.01 + (I_A - 550) 0.02 + (I_A - 850) 0.03$

$240 - 230 = 0.03 I_A + 0.03 I_A - 3 + 0.01 I_A - 3 + 0.02 I_A - 11 + 0.03 I_A - 25.5$

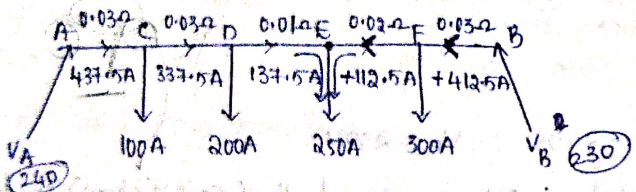
$0 = 0.12 I_A - 52.5$

$0.12\, I_A = 52.5$

$I_A = 437.5$ Amps

i) Current supplied from A to B

$I_A = 437.5$ Amp.



ii) Voltage at point A = 240V

ii) Minimum voltage

$V_A - V_E = 437.5 \times 0.03 + 337.5 \times 0.03 + 137.5 \times 0.0$

13.125
10.125
1.375
24.625

$V_E = 240 - (24.625)$

$V_E = 215.375$ volts. & E is the min. potential.

iii) Voltage at point A = 240V

voltage at C is

$V_C = V_A - I_{AC} R_{AC}$

$= 240 - (437.5 \times 0.03)$ 13.125

$V_C = 226.875V$

$V_D = V_C - I_{CD} R_{CD}$

$= 226.87 - (337.5 \times 0.03)$

$V_D = 216.745V$

$V_E = V_D - I_{DE} R_{DE}$

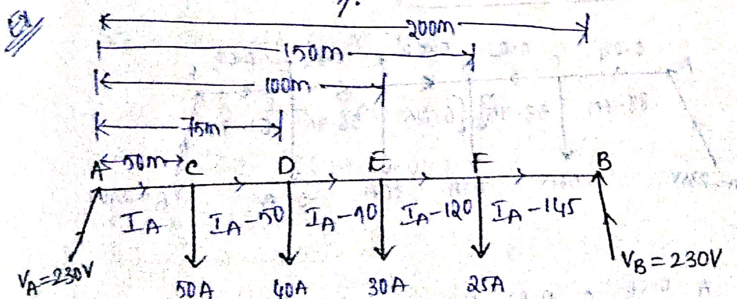
$= 216.74 - (137.5 \times 0.01)$

$V_E = 215.365V$

$V_F = V_E - I_{EF} R_{EF}$

$= 215.365 - (-112.5 \times 0.02)$

$V_F = 217.61V$



Let the current supplied from feeding point A is I_A Amp.

Resistance of conductor (both go & return)

$= 0.8\,\Omega/km = 0.8 \times 10^{-3}\,\Omega/m$

The resistances of sections & currents flowing are:

section	Length	Resistance	current
AC	50	0.04 Ω	I_A
CD	25	0.02 Ω	$I_A - 50$
DE	25	0.02 Ω	$I_A - 90$
EF	50	0.04 Ω	$I_A - 120$
FB	50	0.04 Ω	$I_A - 145$

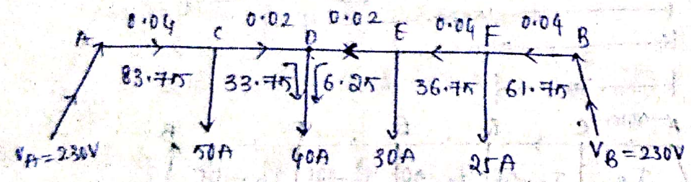
Voltage drop across AB = Voltage at A − voltage at B

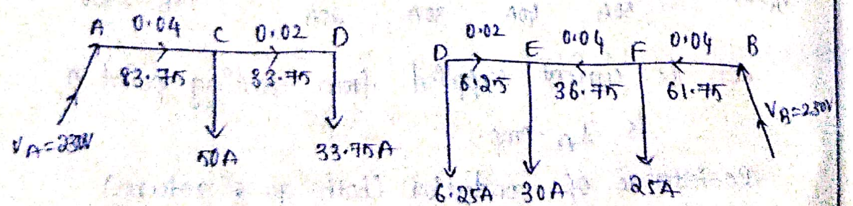
$$V_A - V_B = I_A \times 0.04 + (I_A - 50)0.02 + (I_A - 90)0.02 + (I_A - 120)0.04 + (I_A - 145)0.04$$

$$0 = 0.16 I_A - (1.0 + 1.8 + 4.8 + 5.8)$$

$$0.16 I_A = 13.4$$

$$\boxed{I_A = 83.75 \text{ Amp}}$$





The currents are coming to the load point D from both sides i.e; from point C & point E & Hence 'D' is the point of minimum potential.

From A Minimum consumer voltage;

$V_D = V_A - (V.D \text{ at } AC + V.D \text{ at } CD)$

$= 230 - (I_{AC} \cdot R_{AC} + I_{CD} \cdot R_{CD})$

$= 230 - (83.75 \times 0.04 + 33.75 \times 0.02)$

$= 230 - (3.35 + 0.675)$

$V_D = 225.98 V$

From B $V_D = V_B - (I_{BF} \cdot R_{BF} + I_{FE} \cdot R_{EF} + I_{ED} \cdot R_{ED})$

$= 230 - (61.75 \times 0.04 + 36.75 \times 0.04 + 6.25 \times 0.02)$

$= 230 - (2.47 + 1.47 + 0.125)$

$V_D = 225.94 V$

Voltage at point C,

$V_C = V_A - [V.D \text{ at } AC]$

$= V_A - I_{AC} \cdot R_{AC}$

$= 230 - (83.75 \times 0.04)$

$V_C = 226.65 V$

$V_F = V_B - [V.D \text{ at } BF]$

$= V_B - I_{BF} \cdot R_{BF}$

$= 230 - (61.75 \times 0.04)$

$V_F = 227.53 V$

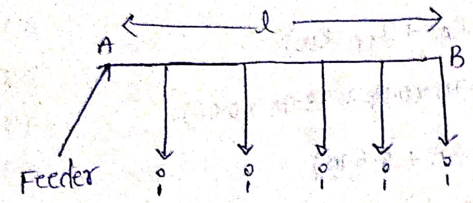
$V_E = V_B - (\text{Voltage drop at } BE)$

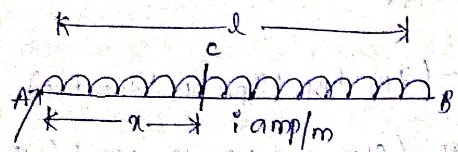
$= V_B - [I_{BF} \cdot R_{BF} + I_{FE} \cdot R_{EF}] \Rightarrow V_E = 226.06 V$

$= 230 - (61.75 \times 0.04 + 36.75 \times 0.04)$

27-10-2...

D/r fed at one end with uniform loading:





Let us consider, a 2-wire dc d/r AB fed at one end 'A' and uniformly loaded with 'i' amp/m length. It means that at every one metre length of d/r the load tapped is 'i' amp

Let, length of d/r = 'l' meters

Resistance of d/r = 'r' Ω/m run (Both go & return conductors)

Consider, a point 'c' on the d/r at a distance 'x' m from feeding point 'A' then, current flowing at point c = Load current supplied over remaining length of d/r CB.

$i_c = i(l-x)$ amperes

Now, consider a small length 'dx' near point c. It's resistance is '$r.dx$' Ω & the voltage drop over the length 'dx' is

$V = i(l-x)r$

$dv = i(l-x)r.dx$

$dv = ir(l-x)dx$

Total voltage drop in the d/r from feeding point A upto point 'C'.

$$V.D \text{ across } AB = \int_0^x dv$$

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

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

$$V.D \text{ a/c } AB = ir\,lx - \frac{x^2}{2} ir$$

The V.D upto point 'B' can be obtained by letting $x = l$ in above equation.

voltage drop over the d/r AB,

$$AB = irl^2 - \frac{x^2}{2} ir$$

$$AB = \frac{1}{2} irl^2$$

$$= \frac{1}{2}(rl) \cdot (li)$$

$$= \frac{1}{2} R \times I$$

$$AB = \frac{1}{2} IR = V$$

where,

$rl = R$, the total resistance of the d/r

$il = I$, the total current entering at point A.

power loss in element 'dx' at distance

$$'x' = [i(l-x)]^2 r$$

$$\text{Total power loss in d/r} = \int_0^l [i(l-x)]^2 r\,dx$$

$$\boxed{AB = i^2 r l^3/3}$$

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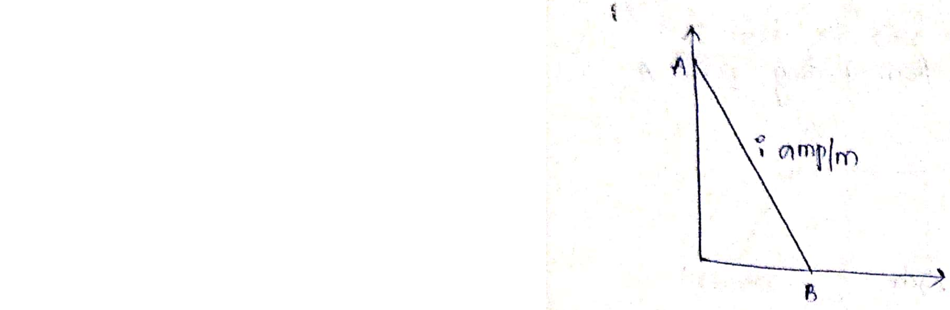
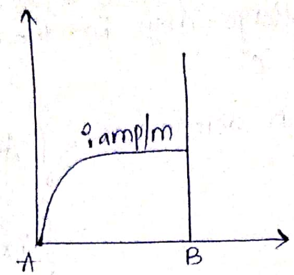


current in various sections



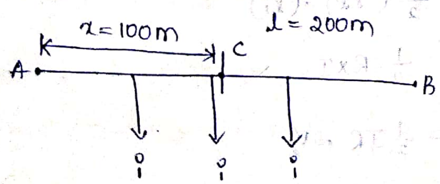
voltage drop in various sections.

Q. A 2-wire DC d/r 200m long is uniformly loaded with 2 amp/m, Resistance of single wire is 0.2 Ω/km, if the d/r fed at one end. calculate : 1. The voltage drop upto a distance of 100 m from the feeding point.

2. The max. voltage drop.

AC = 12

AB = 16



Resistance $R = 0.2\ \Omega/km$

Both (Go & return) $= r = 0.2 \times 2$

$r = 0.4 \times 10^{-3}\ \Omega/m$

$i = 2\ A/m$

i) voltage drop across AC is $ir(lx - \frac{x^2}{2})$

$= ir(lx - \frac{x^2}{2})$

$= 2 \times 0.4 \times 10^{-3} \left(200(100) - \frac{(100)^2}{2}\right)$

$= 8\times10^{-4}\left(20{,}000-\frac{(100)^2}{2}\right)$

$= 8\times10^{-4}\left(20{,}000-\frac{100\times100}{2}\right)$

AC = 1.2 12 V   15000

ii) Total current entering the d/r

$I = i\times l = 2\times200 = 400A$

$R = r\times l = 0.0004\times200 = 0.08\Omega$

Total drop over the d/r $= \frac{1}{2}IR$

$= \frac{1}{2}\times400\times0.08$

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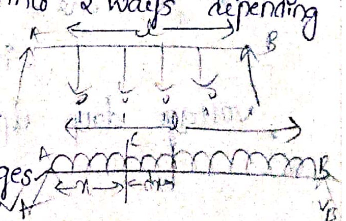
$= 16V$

D/r fed at Both ~~sides~~ ends with uniform loading:

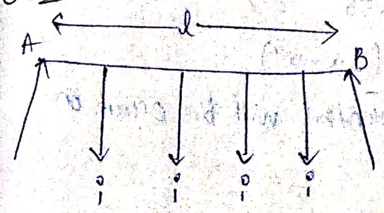
The d/r is classified into 2 ways depending on feeder points:

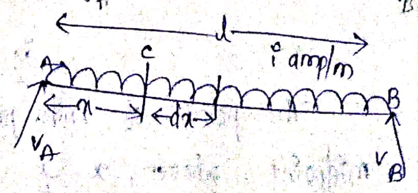
1. with equal voltages

2. with un-equal voltages



① Equal





consider, a d/r AB of length 'l' meters, having resistances ~~are~~ 'r' Ω/m run (both go & return conductors).

with uniform loading of 'i' amp/m run.

Let the d/r fed at feeding point A & B at equal voltages with 'V' volts.

Total current supplied to d/r $\Rightarrow il = I$

As end voltages are equal the current supplied from each feeding point $= \frac{il}{2}$.

Consider, a point 'C' at the distance 'x' m from feeding point A.

The current flowing at point C $= \frac{il}{2} - ix$

$$I_C = i\left(\frac{l}{2} - x\right)$$

Now, consider small length 'dx' from point 'C' its resistance is 'r.dx'. voltage drop over the length 'dx' is $dv = i(l/2 - x)r.dx$

$$= ir\left(\frac{l}{2} - x\right)dx$$

, voltage drop upto point 'C' = $AC = \int_0^x ir\left(\frac{l}{2} - x\right)dx$

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

$$= \frac{ir}{2}(lx - x^2)$$

The point of min. potential will be occurs on midpoint where, $x = \frac{l}{2}$

Sub. $x = \frac{l}{2}$ in above eqn.

V.D at $AB = \frac{ir}{2}\left(l.\frac{l}{2} - \left(\frac{l}{2}\right)^2\right)$

$$= \frac{ir}{2}\left(\frac{l^2}{2} - \frac{l^2}{4}\right)$$

$$= \frac{ir}{2}\left(\frac{l^2}{4}\right) = \frac{irl^2}{8} = \frac{1}{8}(il)(rl) = \frac{1}{8}IR$$

V.D at $AB = \frac{1}{8} IR$

where, $il = I$, The total current fed to d/r from both ends.

$rl = R$, The total resistance of the d/r.

The min. voltage $= V - \frac{IR}{8}$

power loss in a element,

$$dx = I^2 R$$

$$= \left[i\left(\frac{l}{2} - x\right)\right]^2 r \cdot dx$$

Total power loss in a d/r,

$$P = \int_0^l dp$$

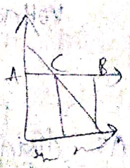
$$= \int_0^l \left[i\left(\frac{l}{2} - x\right)\right]^2 r\, dx$$

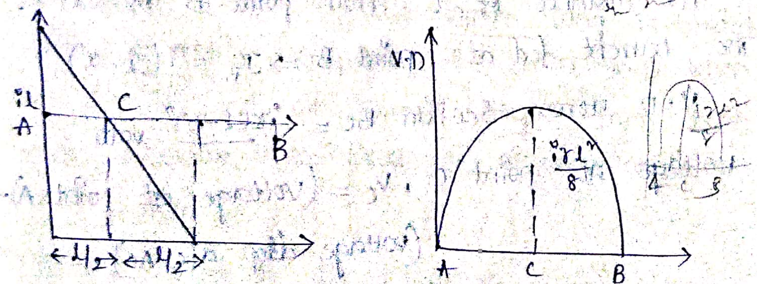
$$\boxed{P = \frac{1}{12} i^2 r l^3}$$

element $dx = I^2 R = \left(i\left(\frac{l}{2} - x\right)\right)^2 r\, dx$

T.P.L $p = \int_0^l dp$

$P = \frac{1}{12} i^2 r l^3$

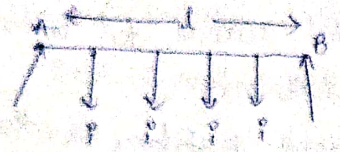


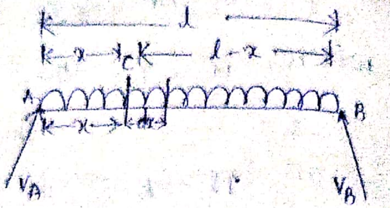


Current in various sections.

Voltage drop in various sections.

② Unequal





Consider, a d/s AB of length 'l' m having resistance of 'r' Ω/m run (Both go & return conductors) with uniform loading of 'i' amp/m run.

Let the d/s fed from A & B at V_A & V_B respectively.

Suppose the point of min. potential 'C' situated (located) at the distance of 'x' m from point A.

The current supplied by Feeding point, $I_A = i.x$

voltage drop at section AC,

$$AC = \frac{irx^2}{2} \text{ volts}$$

As distance of 'C' from point 'B' is "l-x".

The current fed at point B ⟹ $I_B = i(l-x)$

V.D across Section $BC = \frac{ir(l-x)^2}{2}$ volts

voltage at point C, V_C = (voltage at point A) − (voltage drop a/c AC)

$$V_C = V_A - \frac{irx^2}{2} \rightarrow ①$$

voltage at point C, V_C = (V. at B − V. a/c BC)

$$V_C = V_B - \frac{ir(l-x)^2}{2} \rightarrow ②$$

from ① & ②

$$V_A - \frac{irx^2}{2} = V_B - \frac{ir(l-x)^2}{2}$$

$$V_A - V_B = \frac{irx^2}{2} - \frac{ir(l-x)^2}{2}$$

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

$$= \frac{ir}{2}\left[x^2 - (l^2 + x^2 - 2lx)\right]$$

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

$$= \frac{irl}{2}\left[-2x - l\right]$$

$$x = \frac{V_A - V_B}{irl} + \frac{l}{2}$$

All the quantities V_A, V_B, i, r, l are the known quantities.

∴ The point on the d/r where, min. potential occurs can be calculated by using 'x' formulae.

29/10

Q: A uniform 2-wire d.c d/r 200m long is loaded with 2 amp/m. calculate the max. V.D when the d/r is fed at equal voltages from both ends. Assume resistance of single wire is 0.5 Ω/km

Given, length of d/r $l = 200\,m$

current $i = 2\,amp/m$

$r = 0.5 \times 2\ \Omega/km$

$r = 1 \times 10^{-3}\ \Omega/m$

$0.001\ \Omega/m$

The max. V.D at AB $= \frac{1}{8} IR$

$= \frac{1}{8}(il)(rl)$

$= \frac{1}{8}(2 \times 200)(1 \times 10^{-3} \times 200)$

V.D at AB = 10 volts //.

HW Q2. A 600m d/r fed from both ends A & B is loaded uniformly at the rate of 1 amp/m run, the resistance of each conductor being 0.05 Ω/Km. The d/r is fed at both ends A & B at 235V & 230V respectively.

Determine: 1. The min. voltage & the point where it occurs.

2. The current supplied from feeding point A & B.

Sol. Given, $V_A = 235V$

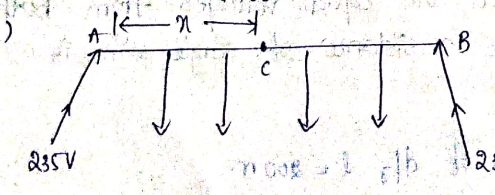
$V_B = 230V$

$l = 600m$

$i = 1 amp/m$

$r = \frac{0.05 \times 2}{1000} = 1 \times 10^{-4} = 0.0001 \Omega/m$

i)



Let, the min. potential occur at point C distant 'x' m from the f. point A.

$$x = \frac{V_A - V_B}{irl} + \frac{l}{2}$$

$$= \frac{235-230}{1 \times 0.0001 \times 600} + \frac{600}{2}$$

$$= 83.3 + 300$$

$$\boxed{x = 383\ m}$$

i.e; minimum potential occurs at 383 m from point A.

min. voltage, $V_C = V_A - \frac{irx^2}{2}$

$$= 235 - \frac{1 \times 0.0001 \times (383)^2}{2}$$ 146689

$$= 235 - 7.3$$

$$V_C = 227.7V \simeq 228V$$

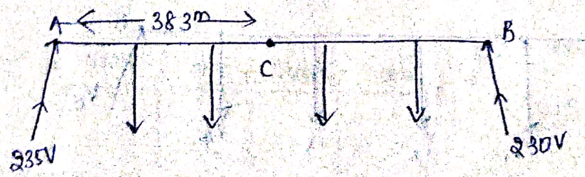
ii) current supplied from A

$= ix = 1 \times 383 = 383\ A$

current supplied from B

$= i(l-x) = 1 \times (600-383)$

$= 217\ A$



31/10/22

D.C d/r with both C.L & U.L:-

1 concentrated loading &

2. uniform loading

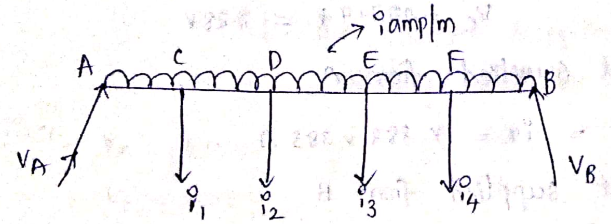
D/r is fed with

1. At one end
2. At Both ends
   a) with equal voltages
   b) with un-equal voltages.

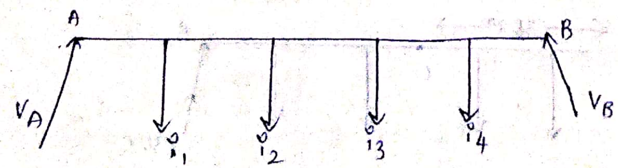
Procedure : 1

The given C.L & U.L on d.c d/r are independently & the voltage drops b/n Feeding point A & B are calculated seperately.

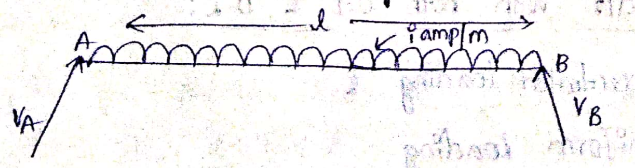
Resultant V.D due to both C.L & U.L is equal to V.D due to C.L + V.D due to U.L



a) D.C d/r fed both C.L & U.L



b) D/r fed at only C.L



c) D/r fed at only U.L

procedure: 2

DC d/r fed at one - end with C.L & U.L.

consider, a d/r having length 'l' m and let us consider, a point 'c' from distance of 'x' m & current flowing through the d/r is 'i' amp/m

V.D from point $x = \int_0^x [I - ix] r \cdot dx$

$$= \left[Ix - \frac{ix^2}{2}\right] r$$

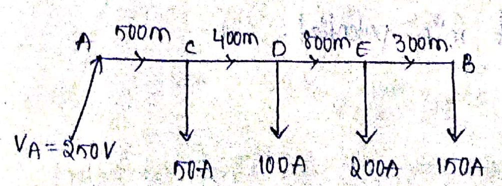
$$= \left[I - \frac{ix}{2}\right] x \cdot r$$

$\boxed{x = l}$

V.D in length $l = \left(I - \frac{il}{2}\right) l \cdot r$ //.

Q. A 2-wire dc d/r is supplying loads are 50A, 100A, 200A, & 150A located at 500m, 900m, 1700m & 2000m respectively from f.p A.

The resistance of each conductor is 0.01 Ω/km the potential diff. at f.p is 250V. Find the p.D at each load point.



$250 = 0.04 I_A + 4.9$

$\frac{254.9}{0.04} = I_A$

$-0.4 - 2.4 - 2.1$

$r = 0.01 \Omega / Km = \frac{0.01}{1000} \times 2$ (Both go & return)

$r = 2 \times 10^{-5} \Omega / m$

$$V_A - V_B = I_A \times 0.01 + (I_A - 50) \times 0.008 + (I_A - 150) \times 0.016 + (I_A - 350)\, 0.006$$

$$250 = 0.01 I_A + 0.008 I_A - 50 \times 0.008 + 0.016 I_A - 150 \times 0.016 + 0.006 I_A - 350 \times 0.006$$

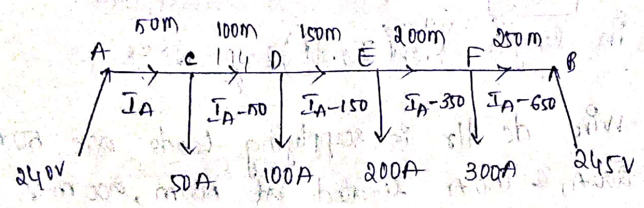
$$250 = 0.04 I_A + (-0.4 - 2.4 - 2.1)$$

$$250 = 0.04 I_A - 4.9$$

$$254.9 = 0.04 I_A$$

$$\boxed{I_A = 122.5 A}$$

Q. slip test



r = for single conductor = $0.5\ \Omega/km$

i) V.D at d/r ✓

ii) I at each loads ✓

iii) voltage at each load ✓

iv) point of min. potential ✓ E

$V_A = 240V$, $V_B = 245V$

$r = 0.5\ \Omega/km$ (for single conductor)

for both (go & return) $r = 0.5 \times 10^{-3}\ \Omega/m \Rightarrow 1 \times 10^{-3}$

⇒ Resistance at section AC is

$$R_{AC} = 1 \times 10^{-3} \times 50 = 0.05\ \Omega$$

$$R_{CD} = 1 \times 10^{-3} \times 100 = 0.1\ \Omega$$

$R_{DE} = 1 \times 10^{-3} \times 150 = 0.15\,\Omega$

$R_{EF} = 1 \times 10^{-3} \times 200 = 0.2\,\Omega$

$R_{FB} = 1 \times 10^{-3} \times 250 = 0.25\,\Omega$

V.D over AB = V.A − V.B

$$V_A - V_B = I_A \cdot R_{AC} + (I_A - 50)R_{CD} + (I_A - 150)R_{DE} + (I_A - 350)R_{EF} + (I_A - 650)R_{FB}$$

$$240 - 245 = I_A \cdot 0.05 + (I_A - 50)0.1 + (I_A - 150)0.15 + (I_A - 350)0.2 + (I_A - 650)0.25$$

$$= 0.05I_A + 0.1I_A - 5 + 0.15I_A - 22.5 + 0.2I_A - 70 + 0.25I_A - 162.5$$

$$-5 = 0.75\,I_A - 260$$

$$255 = 0.75\,I_A$$

$$\boxed{I_A = 340\ A}$$

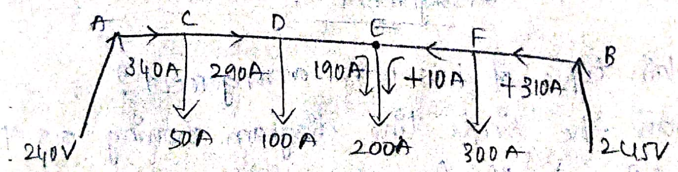
ii) $I_A = 340\ A$

$I_A - 50 = 290\ A$

$I_A - 150 = 190\ A$

$I_A - 350 = -10\ A$

$I_A - 650 = -310\ A$



∴ E is the minimum point of potential.

iii) Voltage at A = 240 V

voltage at C is

$$V_C = V_A - I_{AC}R_{AC}$$

$$= 240 - 340(0.05)$$

$$\boxed{V_c = 223\,V}$$

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$V_D = V_C - I_{CD} R_{CD}$

$= 223 - 290(0.1)$

$\boxed{V_D = 194 \text{ V}}$

$V_E = V_D - I_{DE} R_{DE}$

$= 194 - 190(0.15)$

$\boxed{V_E = 165.5 \text{ V}}$

$V_F = V_E - I_{EF} R_{EF}$

$= 165.5 - (-10)(0.2)$

$\boxed{V_F = 167.5 \text{ V}}$

i) V.D at d/r AB $= V_A + V_B + V_C + V_D + V_E + V_F$

$= 240 + 245 + 223 + 194 + 165.5 + 167.5$

$= 1235 \text{ V}$

Assignment - 4

1. Explain types of bus-bars arrangement?
2. Draw the single line diagram showing s.s apparatus
3. Explain classification of s.s depends on service requirement & constructional features?

Assign - 5

1. Improving methods of p.f?
2. Derive Most Economical p.f?
3. Methods of voltage Control?

UNIT-3

AC DISTRIBUTION SYSTEMS

Generating station:

In generating station electric power is produced by 3-ϕ alternators operating in parallel. Normally, the generation voltage is 11KV (33/66 KV in some cases).

primary transmission:

The electric power at 132 KV is supplied to other s/m by 3-ϕ, 3 wire over head s/m. The 11KV voltage is stepped up upto 132 KV, 66KV, 220KV (or) 400 KV.

secondary transmission:

The primary t/m line terminates the receiving station where, the voltage is reduced to 33KV by step down transformers.

primary distribution:

The secondary t/m line terminates at substation where voltage is reduced from 33KV to 11KV.

secondary distribution:

The electric power available at 11KV from primary d/s line is delivered to d/s substations which step down the voltages to 400V (or) 230V.

* The secondary d/s s/m consists of feeders, d/s's, and service mains.

Feeder:

These are line conductors, which connects the substation to d/r lines.

Distributors:

These are the conductors from which various tappings for the supply to the consumers are taken.

Service Mains:

These are the conductors which connects the consumer terminals to the d/r's.

Requirements and design features of primary feeder:

a) Factors affecting selection of primary feeder rating:

There are various and yet interrelated factors affecting the selection of a primary - feeder rating.

Examples are :

1. The nature of the load connected.
2. The load density of the area served.
3. The growth rate of the load.
4. The need for providing spare capacity for emergency operations.
5. The type and cost of circuit construction employed.
6. The design and capacity of the substation involved.
7. The type of regulating equipment used.

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8. The quality of service required.
9. The continuity of service required.

b) Improvement in voltage conditions on primary feeders:

By using shunt capacitors we are improving the voltage of primary feeders.

Radial - Type primary Feeder:

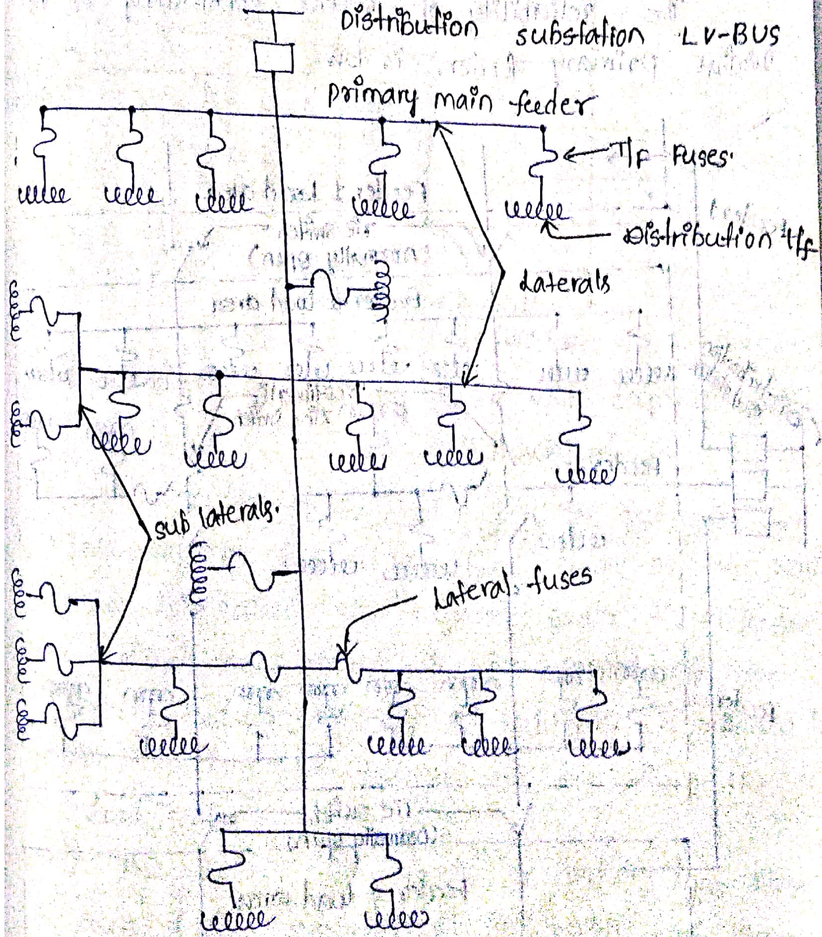


Fig: Radial-type primary feeder.

The main primary feeder branches into various primary laterals, which in turn seperates into several sublaterals to serve all the d/s transformers.

In general, the main feeder & subfeeders are 3-ϕ, three (or) 4-wire ckt's & the laterals are 3 or 1-ϕ. The current magnitude is the greatest in the ckt conductors that leave the substation.

The reliability of service continuity of the radial primary feeders is low.

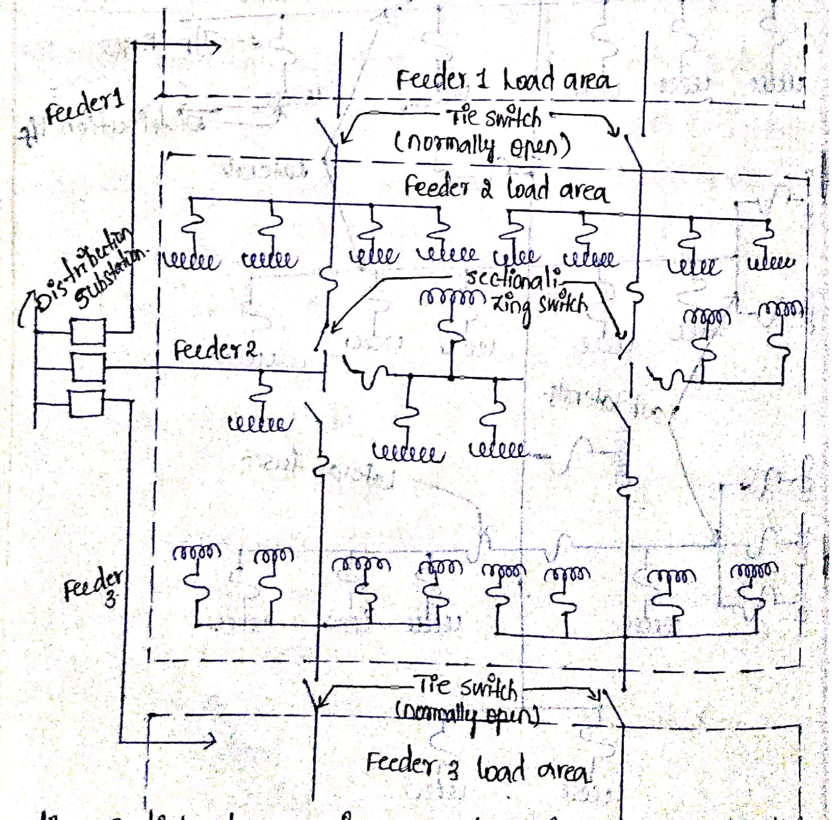


fig: Radial-type primary feeder with tie & sectionalizing switches

⇒ To provide fast restoration of service to customers by switching unfaulted sections of the feeder to an adjacent primary feeder on feeders. The fault can be isolated by opening the associated disconnecting devices on each side of the faulted section.

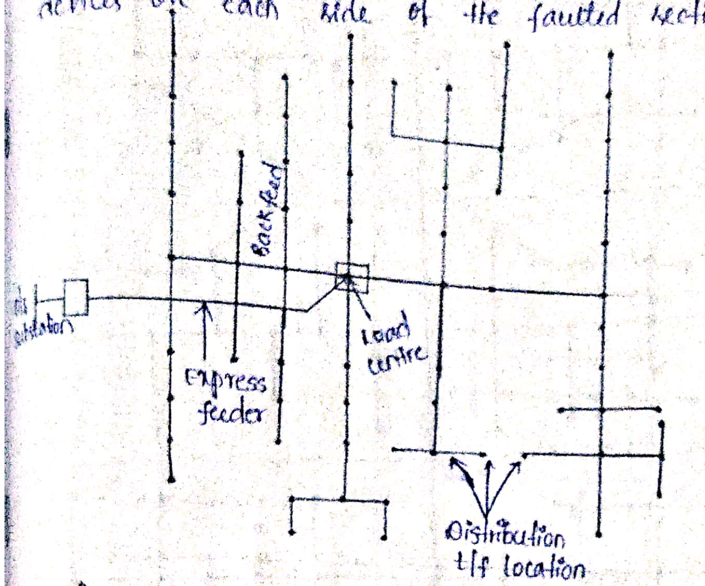
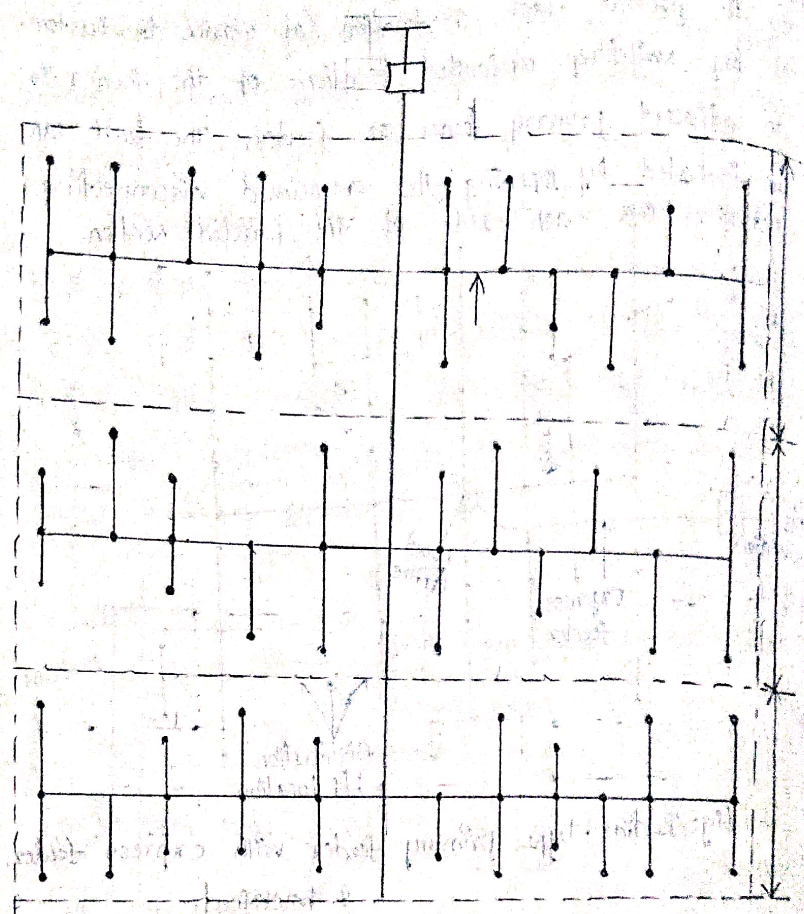


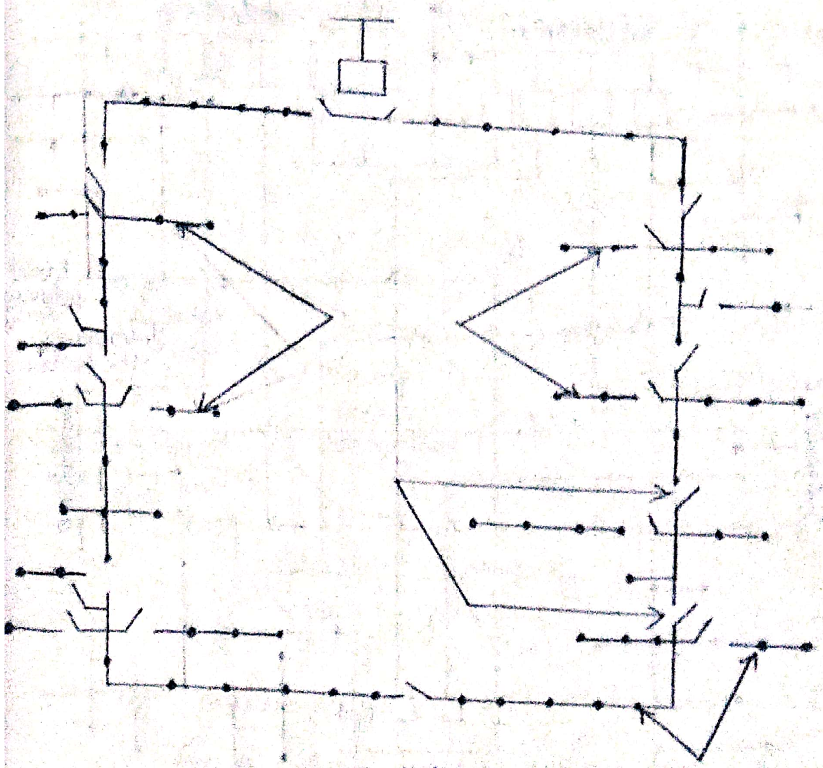
fig: Radial-type primary feeder with express feeder & backfeed.

⇒ The section of the feeder b/n the substation low-voltage bus & the load centre of the service are is called as express feeder. No subfeeders (or) laterals are allowed to be tapped off the 'express feeder'. However, a subfeeder is allowed to provide a back feed toward the s.s from the load center.

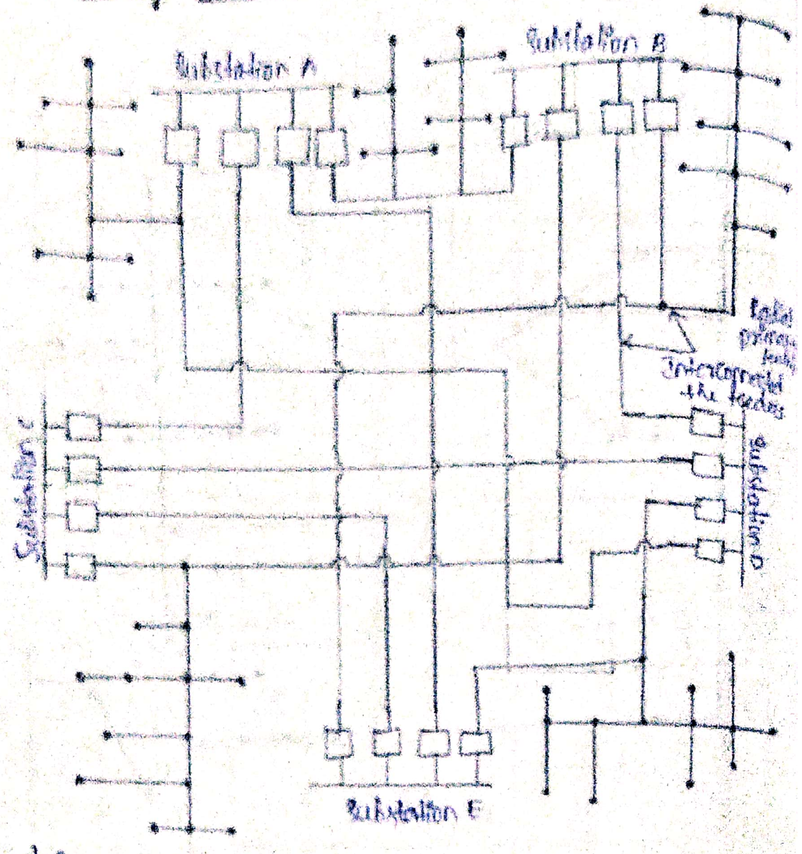
⇒ The below fig. shows a radial-type phase area feeder arrangement in which each phase of the 3-ϕ feeder serves its own service area.



Loop-Type Primary feeder



primary network:



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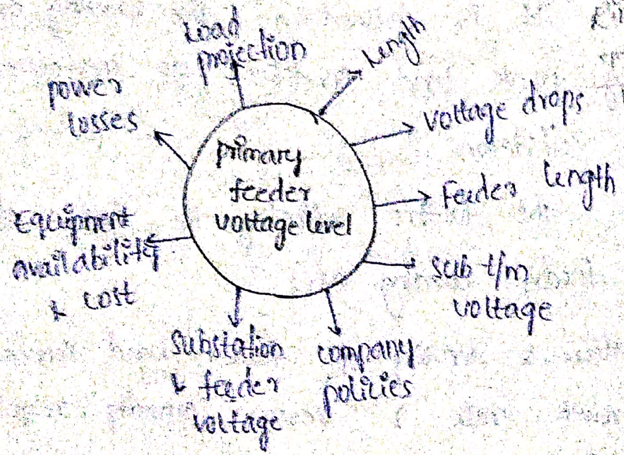
primary feeder voltage level:

Choice of primary feeder voltage level:

1. Length & loading of primary feeder.
2. No of locations & ratings of d/s substation
3. No of sub t/m lines & d/s lines that fed the given area.
4. Root plan, no of poles & t/m wave clearence.

5. No. of customers & their importance.

6. The additional factors for primary feeder voltage level are



voltage square rule:

For a given percent voltage drop the feeder length & loading are direct fn's of feeder voltage level.

voltage - square factor rule:

$$V.S\ Factor = \left(\frac{V_{L-N}\ New}{V_{L-N}\ old}\right)^2$$

$$\text{Feeder distance ratio} = \frac{\text{Feeder New distance}}{\text{Feeder old distance}}$$

$$\text{Feeder load ratio} = \frac{\text{Feeder New Loading}}{\text{Feeder old Loading}}$$

Feeder service area coverage principle:

$$\text{Feeder service area} \propto \left[\left(\frac{V_{L-N}\ New}{V_{L-N}\ old}\right)^{2}\right]^{2/3}$$

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Primary feeder Loading:

It is defined as the loading of feeder during peak load conditions as measured at the substation.

The factors affecting the design of primary feeder loading are:

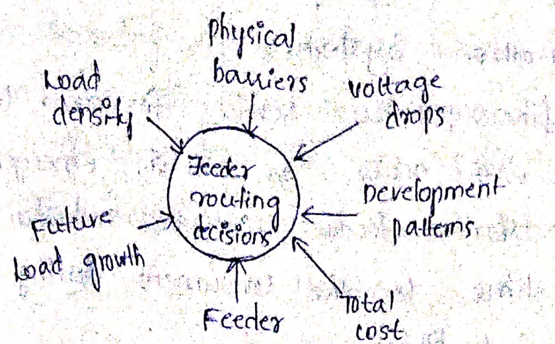
1. Nature & density of feeder Load connected.
2. Growth rate & reserve capacity, requirement for emergency.
3. Continuity, realiability (the efficiency of values) & quality of service.
4. primary feeder voltage level & regulation requirements. (based on specifications)
5. location & capacity of the d/s substation
6. Type of cost of construction & operating cost.
7. Alternate supply provisions made.

Additional factors affecting design of feeder:

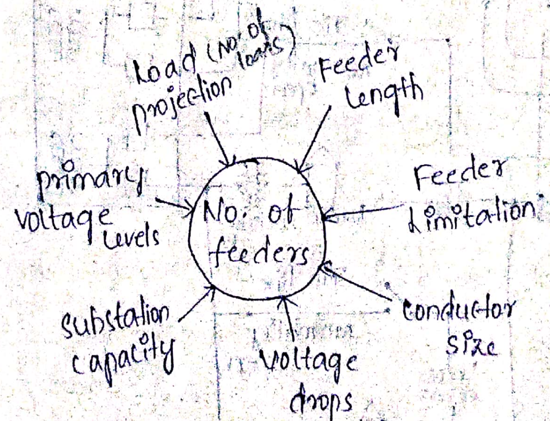
1. Feeder routing decisions.
2. No. of feeders

3. conductor size selection.

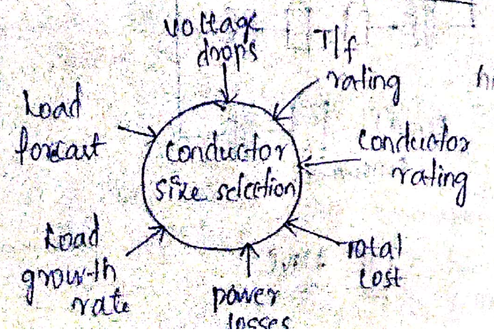
Factors affecting feeder routing decisions:



Factors affecting No. of feeders:



Factors affecting conductor size selection:

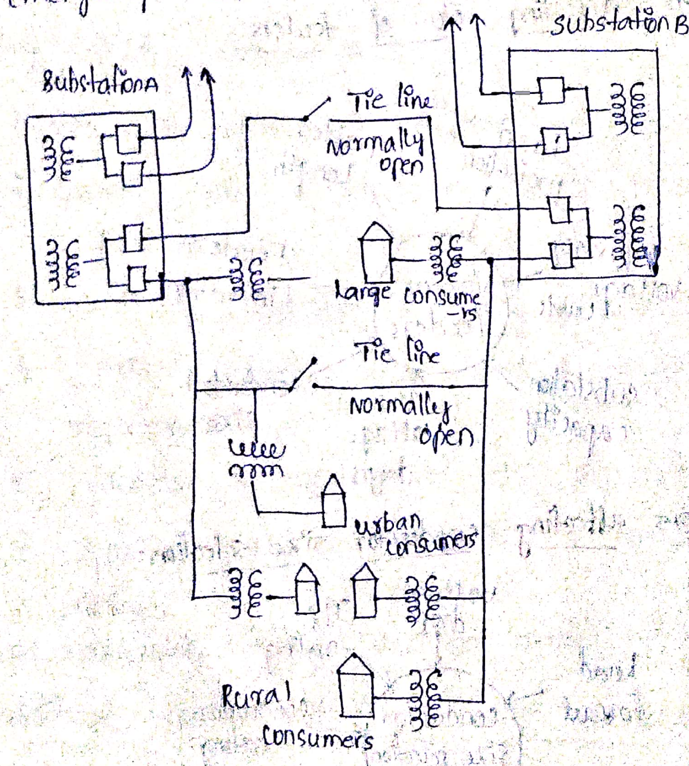


con. size is high low voltage

Tie Line:

It is a line that connects 2 supply s/m to provides Emergency Service two one sys from another System.

* A tie line provides service for area loads along with routes as well as emergency service for a feeder for the reduction of outage time to the consumers during emergency conditions.



TIE LINES

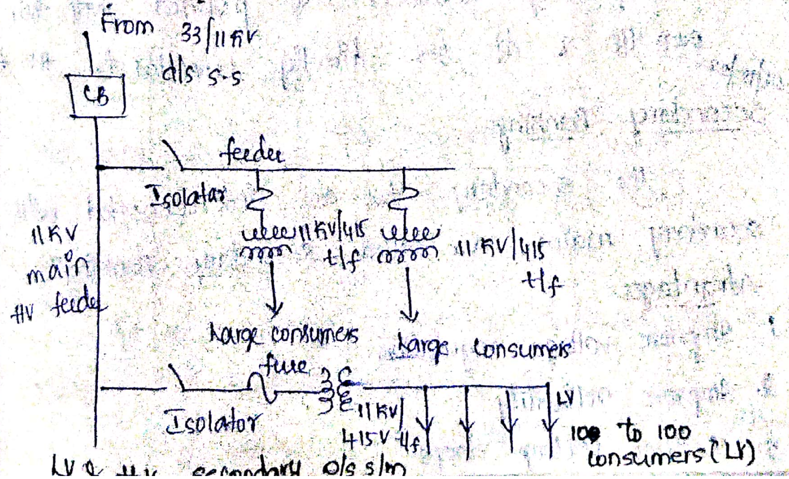
Secondary d/s system:

Which is connected b/w the primary system & consumer is called secondary d/s system. The secondary d/s feeds the electrical energy to consumers depending on no. of consumers and area, load requirements.

This includes: 1. step down d/s t/f's.
2. consumer services (service mains).
3. secondary ckt's
4. Energy meters to measure consumer energy conversion.

Secondary d/s s/m voltage levels:

1. High voltage d/s s/m (11 KV, 33 KV, 66 KV)
2. Low voltage d/s s/m (400 - 450 V, 3-ϕ, 230 - 240, 1-ϕ s/m).



LV & HV secondary d/s s/m

Requirements of Secondary distribution system:

1. Most economic size & combination of line network d/s t/f's and service mains.
2. Min. ckt length, voltage drop & power losses
3. Easy route location & maintainance.
4. To provide possibility of easy t/f management

Design practices of secondary d/s s/m:

1. Individual consumers is provided seperate service connection.
2. A group consumers [like domestic supply, commercial load, small industries] are supplied from a t/f s.s
3. Large consumers with loads of 25 KVA (or more (Flats in cities, residential building, hospitals medium size commercial buildings) provided with their own t/f.
4. Heavy large consumers also provided with their own t/f & d/s s.s directly connected to HV d/

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Secondary Banking:

The secondary n/w are interconnected with secondary mains are called "secondary Banking".

Advantages:

1. Improve voltage regulation.
2. Improve reliability
3. Reduce voltage drops.

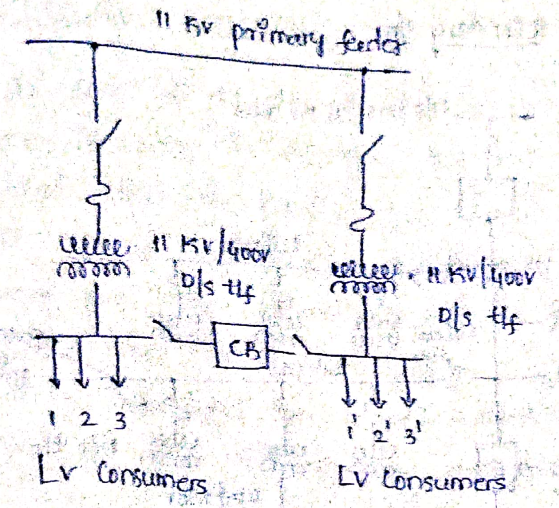


fig: D/s s/m with secondary banking

1. Improve service continuity

Dis-advantages:

1. over - Loading of one t/f in case other t/f goes out of service.
2. co-ordination of protecting devices (fuses, CB's) is difficult.
3. Restoration of service consumers takes more time.

T/f application factor:

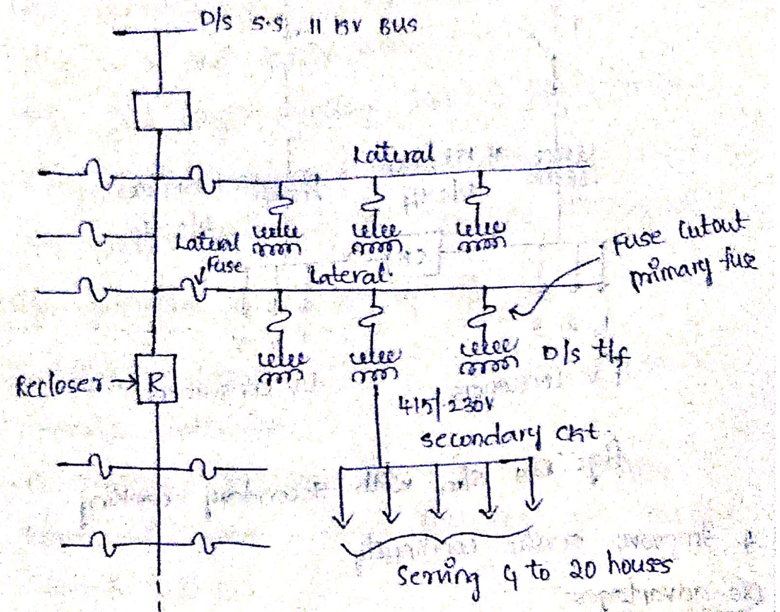
$$T/f \text{ app. factor} = \frac{\text{Total capacity of n/w t/f}}{\text{Total Secondary N/W load}}$$

Secondary Network:

The secondary N/w can be classified into 2 s/m's.

1. Radial secondary s/m
2. mesh / grid type / Loop type of secondary s/m

Radial secondary s/m:



Grid type:

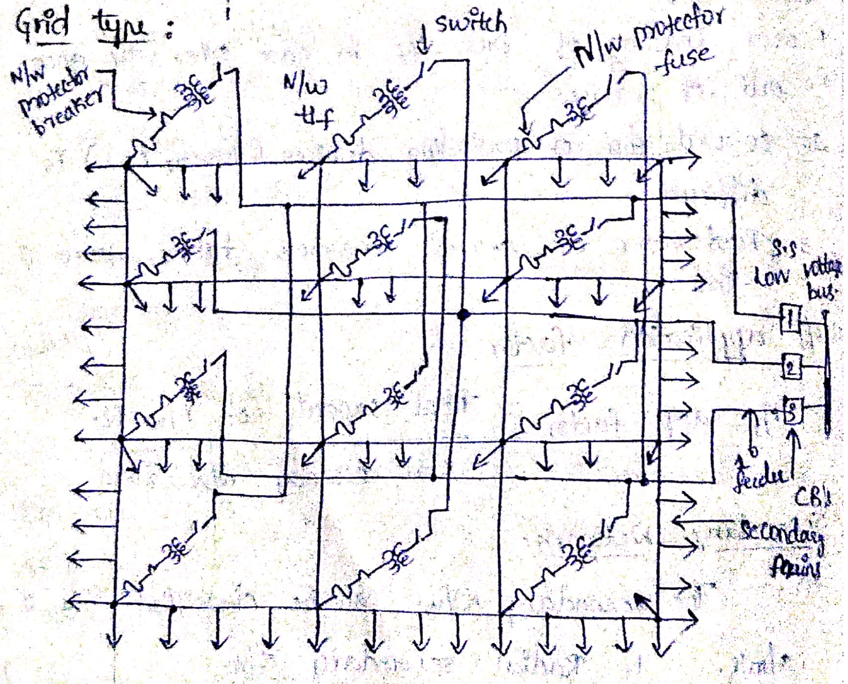


fig: One-line diagram of a small segment of a 2° N/w s/m

AC distribution calculations:

1. In case of dc s/m the V.D is due to resistance alone. However, in AC s/m the V.D are due to combined effect of R, L, C.

2. In dc s/m additions or subtractions of currents or voltages are done arithmetically but in case of AC s/m operations are done vectorically.

3. In AC s/m P.F has to be taken, loads are tapped of from the d/r are generally different P.F's.

4. There are 2 types of power factors:

a) It may be reffered to supply (or) Receiving End voltage, which is regarded as the reference vector.

b) It may be reffered to voltage at load point itself.

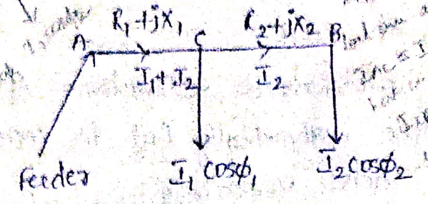
1-ϕ AC distribution s/m:

In AC d/s calculations P.F of various (vectors) load currents have to be considered since the currents in diff sections of d/r will be vector sum of Load currents and not the arithmetic sum, the P.F Load currents can be given by:

1 with respect to receiving End voltage

2. w.r.to Load voltage itself.

power factor loads referred to receiving End voltages:



AC D/r fed at one end

Consider, AC d/r with conc. loads of I_1 & I_2 tapped of at point C & B take a receiving end voltage V_r as the reference voltage.

Let the p.f of load points C & B, be the $\cos\phi_1$ & $\cos\phi_2$ lagging (w.r to V_B).

Let R_1, X_1 & $R_2 X_2$ be the resistance & reactance of sections AC & CB of d/r.

Impedence of section AC, $Z_{AC} \Rightarrow$

$$Z_{AC} = R_1 + jX_1$$

Impedence of section CB,

$$Z_{CB} = R_2 + jX_2$$

Load current at point C, $I_{AC} = I_1 \angle -\phi$

$$I_{AC} = I_1 \angle -\phi_1 = I_1 (\cos\phi_1 - j\sin\phi_1)$$

Load current at point B,

$$I_{CB} = I_2 \angle -\phi_2 = I_2 (\cos\phi_2 - j\sin\phi_2)$$

current in section CB,

$$I_{CB} = I_2 = I_2 (\cos\phi_2 - j\sin\phi_2)$$

current in section AC.

$I_{AC} = I_1 + I_2$

$= I_1((\cos\phi_1 - j\sin\phi_1)) + I_2(\cos\phi_2 - j\sin\phi_2)$

V.D in section CB,

$V_{CB} = I_{CB} \times Z_{CB}$

$= I_2(\cos\phi_2 - j\sin\phi_2) \times R_2 + jX_2$

V.D in section AC,

$V_A = V_B + V_{AC} + V_{CB}$ ↓ reference voltage

$V_{AC} = Z_{AC} \times I_{AC}$ $I_{AC} = I_1 + I_2$

$= I_1(\cos\phi_1 - j\sin\phi_1)(R_1 + jX_1)$.

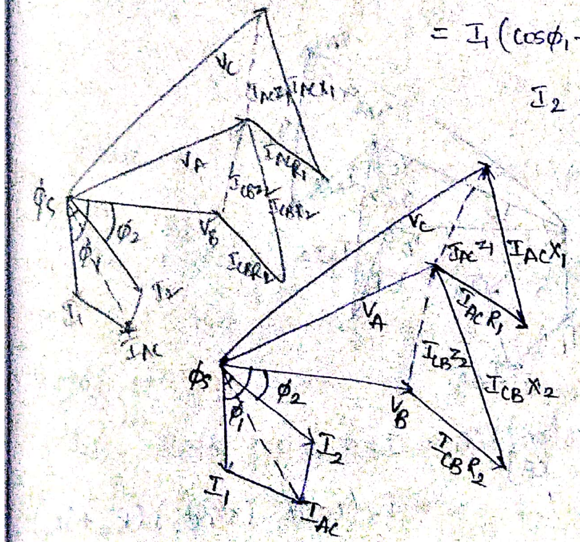
The Sending end voltage $V_A = V_B + V_{AC} + V_{CB}$

where, V_B – Reference voltage & sone

⇒ sending end current $I_{AC} = I_1 + I_2$

$= I_1(\cos\phi_1 - j\sin\phi_1) +$

$I_2(\cos\phi_2 - j\sin\phi_2)$



Hence, the p.f of loads are given the reference voltage w.r.to V_B & I_1, I_2 lag behind V_B with $\cos\phi_1$ & $\cos\phi_2$ respectively.

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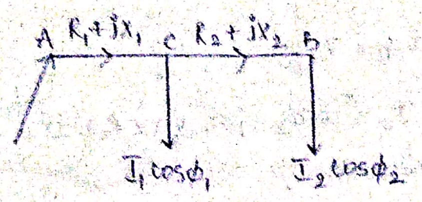
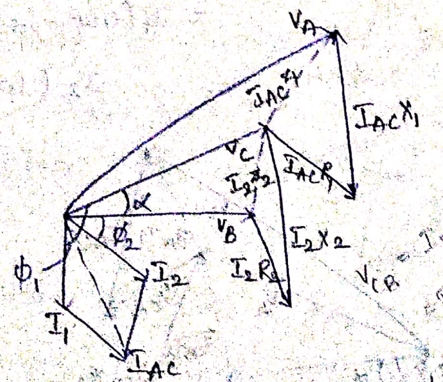
power factor loads reffered to respective load voltage:



Consider, a d/s AB with conc. loading of I_1 & I_2 tapped of at point C & B. suppose the P.F of loads are reffered to their respective load voltages then ϕ_1 is the phase-angle b/n V_C & I_1 and ϕ_2 is the phase-angle b/n V_B & I_1



$V_{CB} = I_2 Z_{CB}$

$= I_2(\cos\phi_2 - j\sin\phi_2)(R_2+jX_2)$

$V_C = V_B + V.D$ in V_{CB}

V.D in section CB } $V_{CB} = I_2 Z_{CB}$

$= I_2(\cos\phi_2 - j\sin\phi_2)(R_2+jX_2)$

Voltage at point C,

V_C = voltage at B + V.D in section CB

= V_B + V.D in CB

= $V_C \angle \alpha$

$I_1 = I_1 \angle -\phi_1$ w.r.to V_C

$I_1 = I_1 \angle -\phi_1 - \alpha$ w.r.to V_B

$I_1 = I_1 [\cos(\phi_1 - \alpha) - j\sin(\phi_1 - \alpha)]$

current in section AC,

$I_{AC} = I_1 + I_2$

$= I_1 [\cos(\phi_1 - \alpha) - j\sin(\phi_1 - \alpha)] + I_2 (\cos\phi_2 - j\sin\phi_2)$

voltage drop in section AC,

$V_{AC} = I_A \cdot Z_{AC}$

$= I_1 [\cos(\phi_1 - \alpha) - j\sin(\phi_1 - \alpha)] (R_1 + jX_1) + I_2 (\cos\phi_2 - j\sin\phi_2)$

Finally, voltage at point A,

$V_A = V_B$ + V.D in CB + V.D in AC

where, V_B is the reference voltage

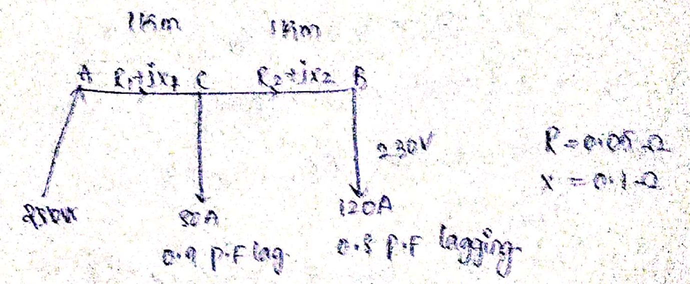
problem:

Q1. A 1-ϕ d/r 2km long supplies a load of 120A at 0.8 PF lagging at its far end and a load of 80A at 0.9 PF lagging at its mid point. Both p.F's are reffered to the voltage at far end. The resistance & reactance per km (Both go & return) are 0.05 Ω & 0.1 Ω respectively. If the voltage at far end is maintained at 230V. calculate :

i) voltage at sending end.

ii) phase-angle b/n voltages at two ends.

Given,



Impedance of d/s $Z = (0.05 + j0.1)\,\Omega$

Impedance of section AC,

$$Z_{AC} = R_1 + jX_1 = (0.05 + j0.1)\,\Omega$$

$$Z_{CB} = (0.05 + j0.1)\,\Omega$$

Reference vector $V_B = 230V\angle 0^\circ = 230 + j0$

current at point B. $I_2 = I_2(\cos\phi_2 - j\sin\phi_2)$

$$= 120(0.8 - j0.6)$$

$$= 96 - j72$$

current at point C,

$$I_1 = I_1(\cos\phi_1 - j\sin\phi_1)$$

$$= 80(0.9 - j0.43) = 72 - j34.4$$

$\Rightarrow I_{AC} = I_1 + I_2$

$$= 168 - j106.4$$

V.D a/c AC = $I_{AC} \cdot Z_{AC}$ = $168 - j106.44 \, (0.05 + j0.1)$

$= 19.04 + j11.48$

V.D a/c CB = $I_{CB} \cdot Z_{CB}$ = $96 - j72 \, (0.05 + j0.1)$

$= 12 + j6.$

V_A = V.D AC + V.D BC + V_B

$= 19.04 + j11.48 + 12 + j6 + 230 + j0$

$= 261.04 + j17.48$

R = 261.04, X = 17.48

magnitude = $\sqrt{(261.04)^2 + (17.48)^2}$

$= 261.62$

$\phi = \tan^{-1}\left(\frac{X}{R}\right)$

$\phi = \tan^{-1}\left(\frac{17.48}{261.04}\right)$

$= 3°83'$

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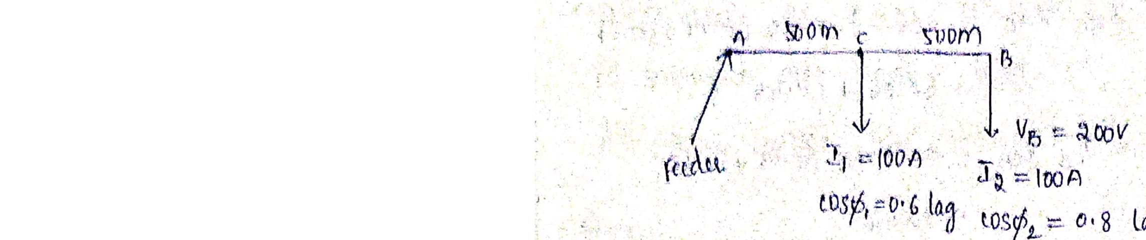
2. A 1-ϕ d/r AB 1 Km long has a resistance & reactance / conductor of 0.1 Ω & 0.15 Ω respectively at the far end B, the voltage $V_B = 200$V & the current tapped is 100 A at a power factor of 0.8 lagging. At the midpoint C of the d/r a current of 100A is tapped at p.f of 0.6 lagging with reference to the voltage V_C at the midpoint. Calculate : i) voltage at mid point

ii) sending End voltage

iii) phase angle b/n V_A & V_B.



Total Impedance of the conductor (Both go & return)

AB $\Rightarrow Z_{AB} = 2(0.1 + j0.15) = 0.2 + j0.3$

$Z_{AC} = 0.1 + j0.15\ \Omega$

$Z_{CB} = 0.1 + j0.15\ \Omega$

current a/c section AC,

$I_{AC} = I_1 + I_2$ 0.594

current a/c section BC, 0.783

$\Rightarrow I_{BC} = I_2$

$= 100(0.8 - j0.6)$

$I_2 = 80 - j60$

Voltage a/c CB $= I_{CB} Z_{CB}$

$= (80 - j60)(0.1 + j0.15)$

$= (17 + j6)$

i) Voltage point C $= V_B + V.D$ a/c BC

$= (200 + j0) + (17 + j6)$

$= 217 + j6$

$V_B = 200\angle 0° = 200 + j0$

magnitude

$\Rightarrow V_C = \sqrt{(217)^2 + 6^2} = 217.1\ V$

phase angle b/n V_C & V_B

$$\alpha = \tan^{-1}\left(\frac{6}{217}\right) = 1^\circ 58'$$

ii) The load current I_1 has a lagging p.F of 0.6 w.r.to V_C it lags behind V_C by an angle $\phi_1 = \cos^{-1}(0.6) = 53^\circ 13'$

phase angle b/n I_1 & V_B,

$$\phi_1 = \phi_1 - \alpha = 53^\circ 13' - 1^\circ 58'$$ 3.064

$$= 51^\circ 55'$$

$$I_1 = I_1 [\cos\phi_1 - j\sin\phi_1]$$

$$= 100(\cos 51^\circ 55' - j \sin 51^\circ 55')$$

$$= 62.18 - j78.3$$

$$I_{AC} = I_1 + I_2$$ 80-60j, 100

$$= (62.18 - j78.3) + (80 - j60)$$

$$= (142.18 - j138.3)\,A$$

V.D a/c AC,

$$V_{AC} = I_{AC} \cdot Z_{AC}$$

$$= (142.18 - j138.3)(0.1 + j0.15)$$

$$= (34.96 + j7.49)V$$

sending End voltage $V_A = V_B + V.D\ a/c\ AC + V.D\ a/c\ BC$

$$= (200 + j0)(34.96 + j7.49) + (17 + j6)$$

$$= (251.96 + j13.49)V$$

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$|V_A| = \sqrt{(251.96)^2 + (13.49)^2}$

$= 252.32V$

iii) The phase diff b/n V_A & V_B

$\theta = \tan^{-1}\left(\frac{13.49}{251.96}\right)$

$= 3^\circ 64^\circ$

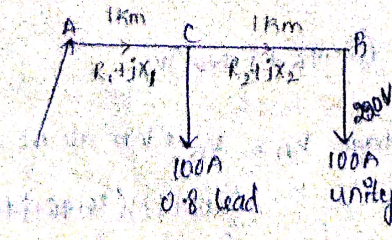
Hence, the supply voltage,

$V_A = 252.32$ Load is by $3^\circ 64^\circ$.

A.W 5/12/ A 1-ø line having R & X (Both Go & return) conductor having 0.06 & 0.1Ω/Km the length of section AB & BC are 1.0 Km each. The voltage at further end is 220V. Find the voltage at sending end and the phase angle difference b/n the voltage of 2 ends if

i) The P.F's of loads are reference to further end voltage.

ii) P.F's of loads are reference with to its load points (on load voltages.



$R = 0.06\Omega$

$X = 0.1 \times 10^{-3}\Omega$

Impedance of d/r $Z = (0.06 + j0.1) \times 10^{-3}\,\Omega$

current at point B,

$$I_B = 100\,(0.8 \mp j0.6)\,A$$

current at point C,

$$I_C = 100\,(1.0 \mp j0.0)\,A$$

Impedance of section BC,

$$Z_{BC} = (0.06 + j0.10)\,\Omega$$

Impedance of section AB,

$$Z_{AB} = 0.06 + j0.10$$

voltage drop in section BC

200.026 +0.0312 i

$$V_{BC} = I_C Z_{BC}$$

$$= 100\,(0.06 + j0.10)$$

$$= (6 + j10)\ \text{volt}$$

~~Reference vector~~ {potential at point B} $V_B = 220 + (6 + j10)$

$$= 226 + j10$$

$$= 226.22 \angle 2.53^\circ\ \text{volt}.$$

Ans

$$Z_{AB} = (0.06 + j0.1)$$

$V_A = V_B + V.D\ a/c\ AC + VDBC$

$= (200 + j0) + (0.016 - j0.0128) + (0.01 + j0.024)$

$= (200.026 + j\,0.031)\ V$

$= \sqrt{(200.026)^2 + (0.031)^2} = 200.026$

64°.
retcon)
length
the
the
diff
to
to
ages.
Ω
$10^{-3}\Omega$

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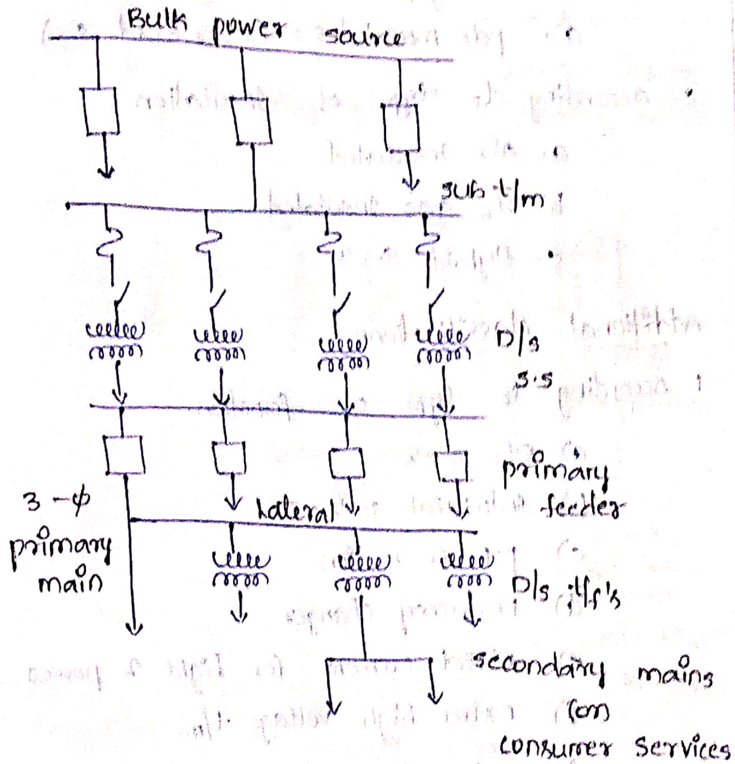
Unit 4

SUBSTATIONS

Typical layout of Distribution system :



The power s/m of electrical utility s/m connected b/n bulk power source & consumer terminals which includes sub. t/m s/m, D/s s.s's, primary feeders, D/s t/f's, secondary ckts and service mains.

Classification of substations:

1. According to service requirement
   a) static s/s.

b. converting s.s

2. According to constructional features

a. Indoor s.s

b. outdoor s.s

c. underground s.s

d. pole mounted s.s (over head s.s)

3. According to type of Insulation

a. Air Insulated

b. SF_6 gas Insulated

c. Hybrid s.s's

Additional classifications.

1. According to type of function.

a) E/s s.s's

b) Industrial s.s's

c) p.F correction

d) Frequency changer

e) direct current for light & power s.s's

f) Extra high voltage t/m.

2. According to type of operators required Apparatus

a) T/f

b) Rotary converter

c) Rectifier

d) motor Generator

e) Frequency changer

3. According to type of control

a) manual control

b) Automatic control

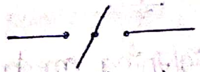
c) supervisary control

2/12/22

symbols for circuit Elements

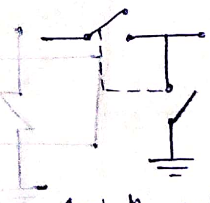
Bus-bar

single-break isolating switch

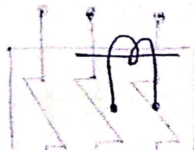


Double-break isolating switch

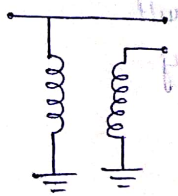
on-Load isolating switch



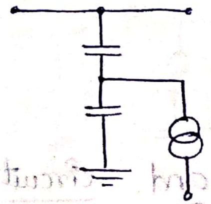
Isolating switch with earth blade



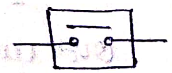
current transformer



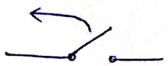
potential transformer



capacitive voltage transformer

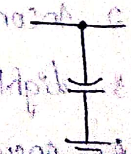


oil-circuit Breaker

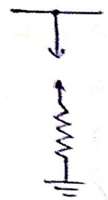


Air-circuit breaker with over current tripping device

Air blast circuit breaker

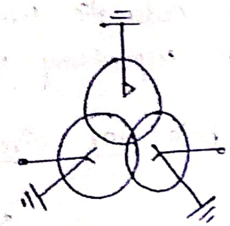


Lightning arrester (active gap)

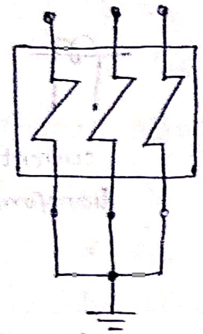


Lightning arrestor
(Valve type)

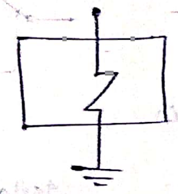
Arcing
horn



3-ϕ power
transformer



Over current
relay

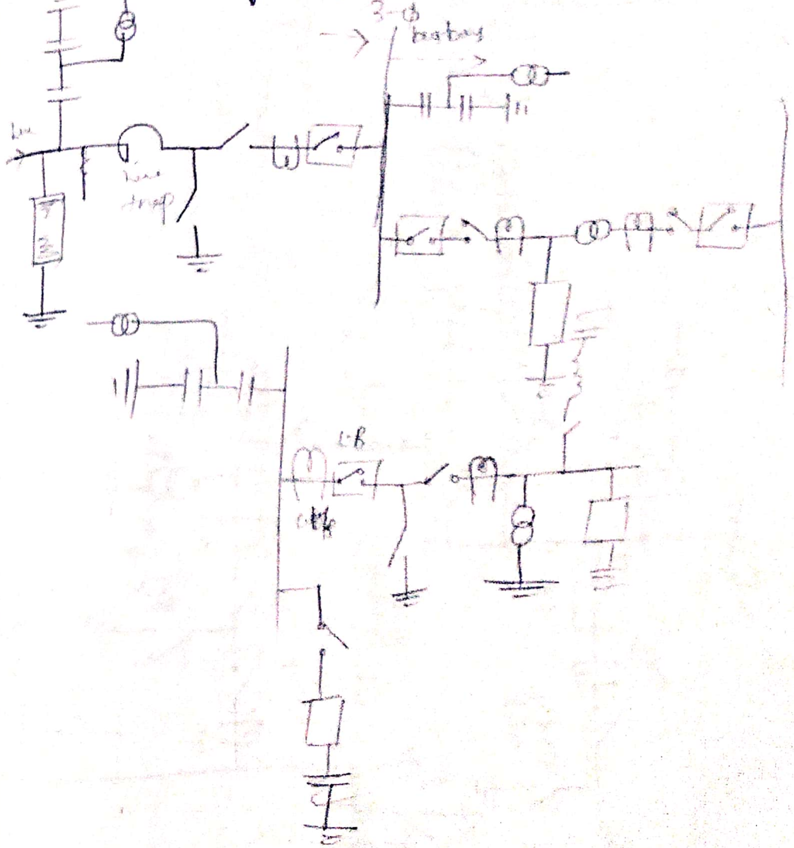


Earth fault
relay.

Equipments and circuit Elements of S.S:

1. Bus-bars
2. Incoming & outgoing lines
3. Lightning arrestors
4. Insulator
5. Isolators
6. CBs
7. Fuses
8. power transformers

9. Instrument t/f's (CT's & PT's)
10. metering & indicating instruments
11. protective relays
12. other equipment such as carrier current equipment, s.s, auxiliary power supply, earthing etc;



Equipments and circuit Elements of Substation

(1) Bus-bars
(2) Incoming and outgoing lines
(3) lightning arrestor
(4) Insulator
(5) Isolator (Isolating switches)
(6) circuit breakers
(7) fuses
(8) Power Transformer
(9) Instrument transformers (CT & PT)
(10) metering and indicating instrument
(11) Protective relays.
(12) other equipment such as carrier current equipments substation auxiliary Power supply, earthing etc.

The Busbar Arrangements

- Single Bus system
- main & transfer system
- Double Bus System
- Ring main Bus System
- Half & A-half Bus System.

Bus Bar:- It is a conductor, which distribute the Power to a equipments in a S-S or grid station

Bus coupler:- It is a device, which is used to connect 2 or more Busbar. It transfer the load from one busbar to another busbar.

C.B:- It is a device, which Protects the electrical equipment from fault such as overload & S.C

O.C.B, SF_6 C.B, V.C.B, A.C.B ... etc.

Isolator:- It is a device which disconnect the ckt

- Electrical Isolator
- mechanical Isolator
- optical " ... etc.

Electrical Isolator:- It is a switch, which is used to isolate the equipment

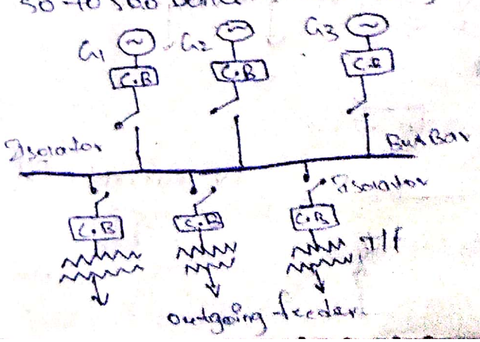
- Automatically operate
- manually operate

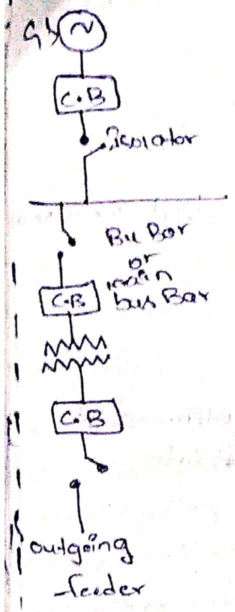
feeder:- It is a part of distribution system which transfer load from S.S to distribution point.

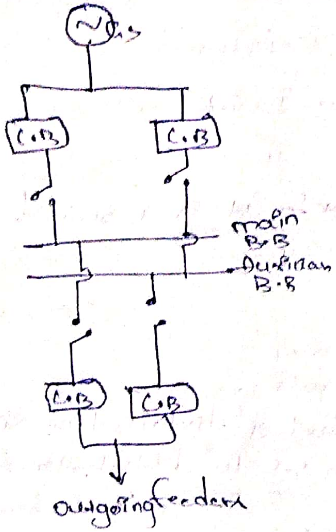
- Ring main feeder
- Parallel feeder
- Inter connected feeder etc.

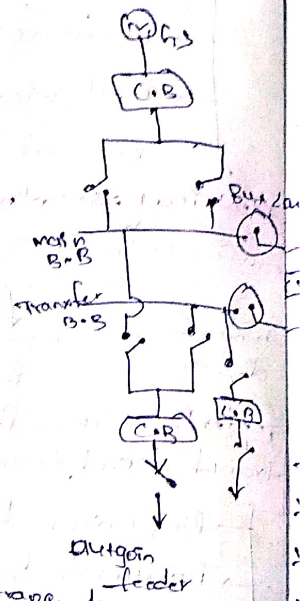
Single Bus Bar Arrangement

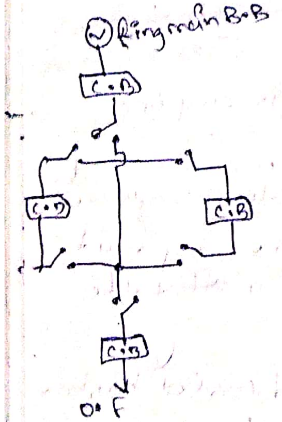
* In the name itself required busbar is only one.
* It is simple & cheapest
* where, all the device are connected to a single bus bar
* The drawback at this arrangement is any fault occur (OR) Any maintance required will affect the whole system
* It can operate easily & the around cost of busbar is 50 to 500 dollars depending upon the vlg level

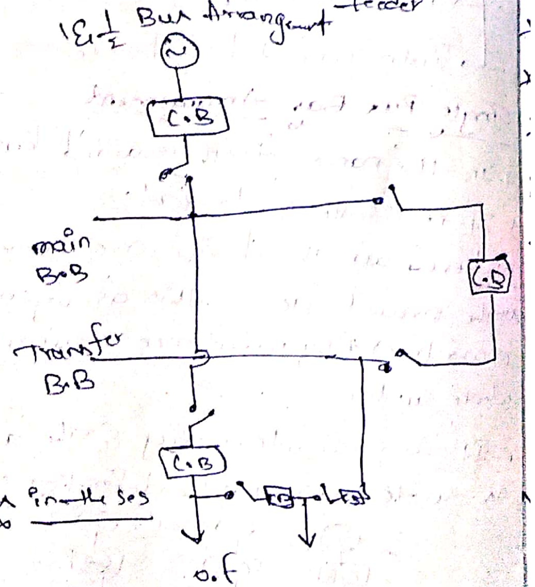












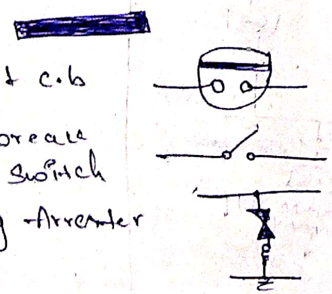
Symbol for equipments in the S/S

(i) Busbar

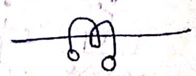
(ii) Air blast C.B

(iii) single break isolating switch

(iv) lighting Arrester



(v) Current. t/f



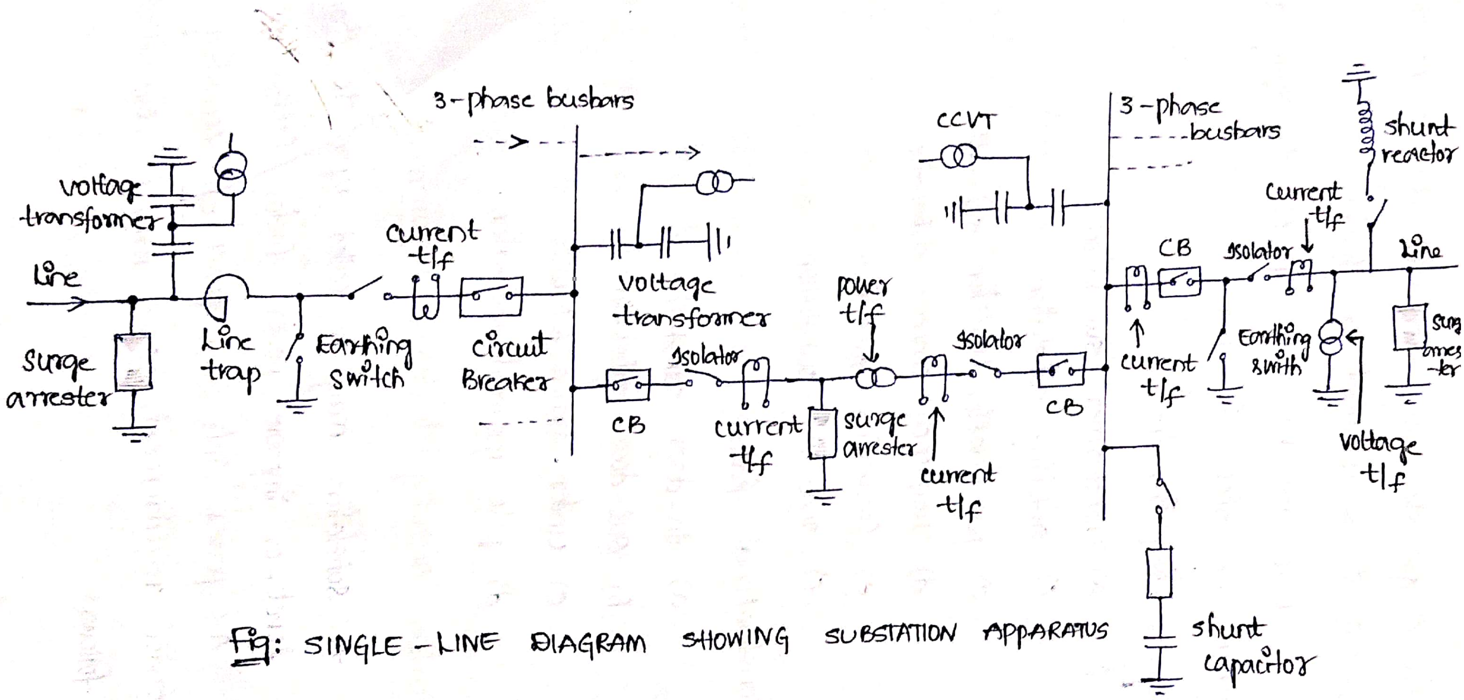


Fig: SINGLE-LINE DIAGRAM SHOWING SUBSTATION APPARATUS

1) Improvement of methods of powerfactor.

The problems pertaining to power factor improvement using static capacitors can be dealt with in the following two ways:

a) constant kw load assumption

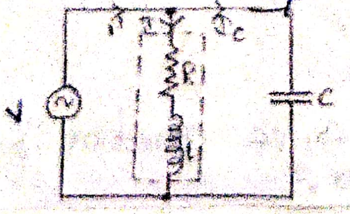
b) Constant kVA load assumption.

P.F Improvement for constant kw load

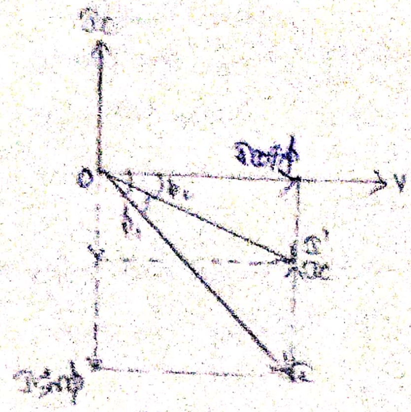
consider an inductive load taking a lagging current I at a power-factor $\cos\phi_1$. In order to improve the power factor of the circuit, the solution is to connect such an equipment in parallel with the load which takes a leading reactive component and thus partly cancels the lagging reactive component of the load current.

The capacitor takes a current I_c, which leads the supply voltage V by 90°. the current I_c partly cancels the lagging reactive component of the load current as shown in fig.

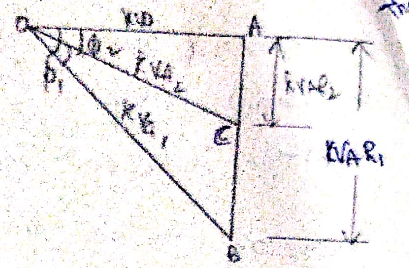
the resultant circuit current becomes 'I' & its angle of lag ϕ_2. It is clear that ϕ_2 is less than ϕ_1 so that new power factor $\cos\phi_2$ is more than previous power factor $\cos\phi_1$.



a) capacitor connected across load



b) vector diagram



c) Power triangle

Power factor correction, when kw demand is constant

a) From the vector diagram, it is clear that after P.f correction, the lagging reactive component of the load is reduced to $I' \sin\phi_2$

It may be seen

$I' \sin\phi_2 = I \cdot \sin\phi_1 - I_c$

or $I_c = I \sin\phi_1 - I' \sin\phi_2$

b) Calculation of capacitance and VAR rating

charge on capacitance $Q_c = V I_c$

$= V \omega C V$

$= \omega C V^2$

∴ capacitance of capacitor to improve P.f from $\cos\phi_1$ to $\cos\phi_2$

$$C = \frac{I_c}{\omega V} = \frac{Q_c}{\omega V^2}$$

the capacitance required for P.f correction is inversely proportional to V^2.

②

It may be seen that in this case, active power (OA) does not change with power factor improvement.

The lagging KVAR of the load is reduced by the power factor correction equipment, thus improving the power factor to $\cos\phi_2$

From the power triangle, it is clear that leading KVAR supplied by p.f correction equipment.

$$Q_C = BC = AB - AC$$

$$Q_C = KVAR_1 - KVAR_2$$

$$= OA(\tan\phi_1 - \tan\phi_2)$$

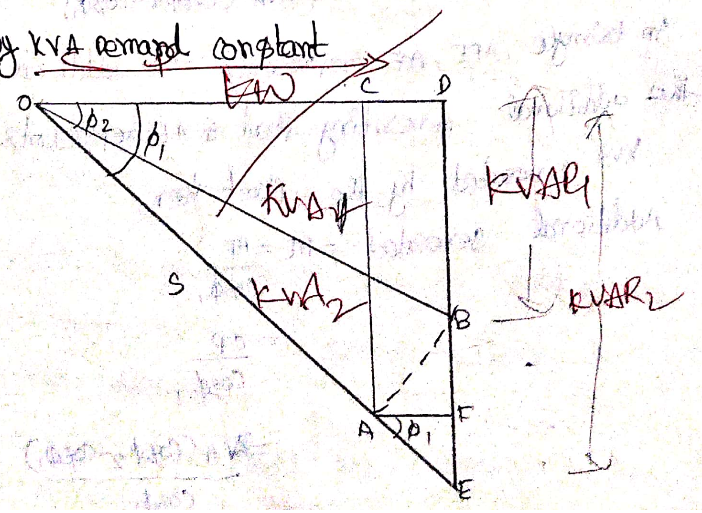
$$= KW(\tan\phi_1 - \tan\phi_2)$$

Active power, $P = KW = VI_1\cos\phi_1$

$$\therefore \phi_C = VI_1\cos\phi_1(\tan\phi_1 - \tan\phi_2) = VI_C$$

Knowing the leading KVAR supplied by the p.f correction equipment, the results can be obtained:

Improvement by KVA demand constant



Power triangles in P.f improvement when KVA demand constant.

Case I :- Additional kw and KVA required are supplied by installation of new generation.

let us first consider the case when the additional kw capacity is also met by the installation of new generating plant.

Referring to

OC = original kw output $= kw_1$

OD = the kw output after installation new plant $= kw_2$

OA = original KVA $= S$ KVA

OB = the final KVA $= S$ KVA

$\cos\phi_1$ = original p.f

$\cos\phi_2$ = the final p.f

Additional generated kw $= CD = OD - OC$

$= OB \cdot \cos\phi_2 - OA \cdot \cos\phi_1$

$= KVA(\cos\phi_2 - \cos\phi_1)$

In triangle, AFE, AF represents the additional kw supplied by the additional generating plant & AE represents the additional KVA generated by the plant. then,

Additional generated $= AE = \dfrac{AF}{\cos\phi_1}$

$= \dfrac{CD}{\cos\phi_1}$

$= \dfrac{KVA(\cos\phi_2 - \cos\phi_1)}{\cos\phi_1}$

Case II :- Addition Generated KVA can be kept down to the original KVA value by installation of a phase advancing plant. (3)

consider the case when generated KVA can be kept down to the original value by the installation of a phase advancing plant having KVAR rating equal to EB.

Additional KVAR rating of phase advancing plant $= EB = ED - BD$

$= OE \cdot \sin\phi_1 - OB \cdot \sin\phi_2$

$= \frac{OD}{\cos\phi_1} \cdot \sin\phi_1 - OB \cdot \sin\phi_2$

$= \frac{OB \cdot \cos\phi_2}{\cos\phi_1} \cdot \sin\phi_1 - OB \sin\phi_2$

$= \frac{KVA \cdot \cos\phi_2}{\cos\phi_1} \cdot \sin\phi_1 - KVA \cdot \sin\phi_2$

$= KVA (\tan\phi_1 \cdot \cos\phi_2 - \sin\phi_2)$.

3) Derive the most economical power factor.

If a consumer improves the power factor, there is reduction to this maximum KVA demand and hence there will be annual saving over the maximum demand charges.

The value to which the power factor should be improved so as to have maximum net annual saving is known as most economical power factor.

The most economical power factor for a customer can be found by the following two causes.

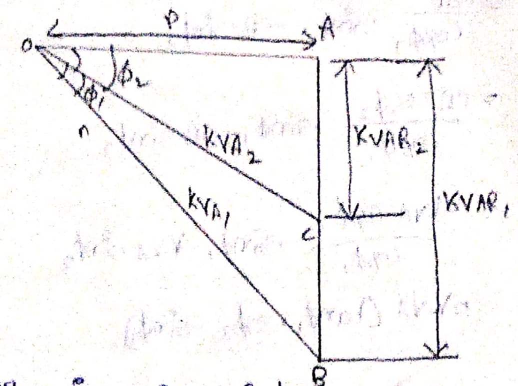
1) kw demand constant
2) KVA demand constant.

most economical p.f by 'kw' demand constant:

For a peak load P kw at a power factor $\cos\phi_1$, the power factor has to be improved to most economical power factor $\cos\phi_2$, It may be proved that the most economical power factor.

$$\cos\phi_2 = \sqrt{1-\left(\frac{y}{x}\right)^2}$$

Proof:



Power triangles in power factor improvement when kw demand constant.

consider a consumer taking a peak load P kw at a power factor.

KVA max. demand at $\cos\phi$

$$KVA_1 = \frac{P}{\cos\phi_1} = P.\sec\phi_1$$

KVA max. demand at $\cos\phi_2$

$$KVA_2 = \frac{P}{\cos\phi_2} = P.\sec\phi_2$$

∴ Annual saving in maximum demand charges.

$= Rs. X [KVA_1 - KVA_2]$

$= Rs. X [P\sec\phi_1 - P\sec\phi_2]$

$= Rs. X\ P(\sec\phi_1 - \sec\phi_2)$

Reactive power at $\cos\phi_1$

$KVAR_1 = P.\tan\phi_1$

Reactive power at $\cos\phi_2$

$KVAR_2 = P.\tan\phi_2$

using eqn

leading KVAR supplied by p.f correction equipment $= KVAR_1 - KVAR_2$

$= P(\tan\phi_1 - \tan\phi_2)$

∴ Annual expenditure incurred on p.f correction equipment.

$= Rs.\ Y P(\tan\phi_1 - \tan\phi_2)$

From eqn

Net annual saving

$S = Rs. XP[\sec\phi_1 - \sec\phi_2] - YP[\tan\phi_1 - \tan\phi_2]$

$\frac{d(S)}{d\phi_2} = 0$

$\therefore \frac{d}{d\phi_2}[XP(\sec\phi_1 - \sec\phi_2) - YP(\tan\phi_1 - \tan\phi_2)] = 0$

$\therefore \frac{d}{d\phi_2}(XP(\sec\phi_1)) - \frac{d}{d\phi_2}(X P\sec\phi_2) - \frac{d}{d\phi_2}(YP\tan\phi_1) + YP\frac{d}{d\phi_2}(\tan\phi_2) = 0$

$\therefore 0 - XP\sec\phi_2\tan\phi_2 - 0 + YP\sec^2\phi_2 = 0$

$\therefore -X\tan\phi_2 + Y\sec\phi_2 = 0$

$\therefore \tan\phi_2 = \frac{y}{x}\sec\phi_2$

$\therefore \sin\phi_2 = \frac{y}{x}$

∴ most economical power factor

$\cos\phi_2 = \sqrt{1-\sin^2\phi_2}$

$= \sqrt{1-\left(\frac{y}{x}\right)^2}$

3) methods of voltage control

the voltage at different buses of the power system vary with the changes in load.

the following methods are used for voltage control in a power systems:

1) Excitation control of generators
2) Tap-changing transformers
3) shunt reactors
4) synchronous phase modifiers
5) Induction regulators
6) shunt capacitors
7) series capacitors
8) static VAR systems (or) SVS

adjusting the system voltage by means of shunt reactive elements is known as shunt compensation.

Excitation control.

(5)

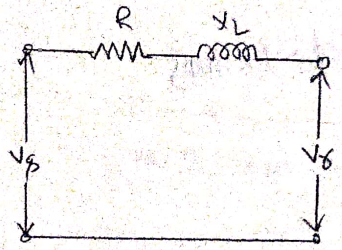
The voltage of the alternator can be kept constant by changing the field current of the alternator in accordance with the load. This is known as excitation control method.

There are two main types of automatic voltage regulators viz

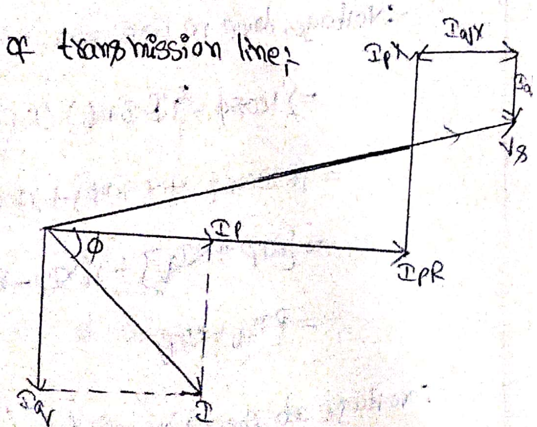
(i) Tirril regulator

(ii) Brown-Boveri regulator.

2) Principle of voltage control of transmission line:



(a) equivalent circuit.



Vector Diagram

Short transmission line.

R = Resistance of line

X = Reactance of line

$= X_L - X_C$

V_s = Sending end voltage per phase

V_r = Receiving end voltage per phase

I = Line current having power factor $\cos\phi$ at receiving end

$= I\cdot\cos\phi + jI\sin\phi$

$= I_p + jI_q$

where $I_p = I\cdot\cos\phi$

= In-phase component of line current I.

$I_q = I\cdot\sin\phi$

= quadrature component of line current I

∴ Voltage drop in line = I·Z

$= (I\cos\phi - jI\cdot\sin\phi)(R+jX)$

$= [R I\cos\phi + X\sin\phi] + j[XI\cos\phi - RI\sin\phi]$

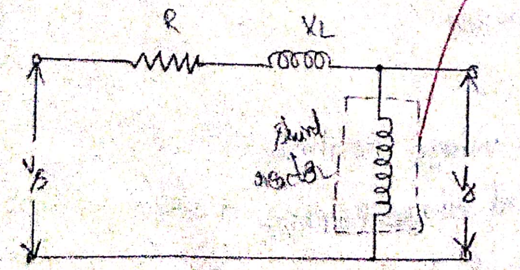
$= [RI_p + XI_q] + j[XI_p - RI_q]$

$= RI_q + XI_q$

∴ Voltage at receiving end = (Voltage at sending end) − (Voltage drop in line)

3) Use of shunt Reactors and shunt capacitors.

a) shunt Reactors :



use of shunt reactance of receiving end.

Reactive power absorbed by the Reactor

$$Q_L = -V \cdot I_L = \frac{-V^2}{X_L} = \frac{-V^2}{\omega L} \text{ VAR/ phase}$$

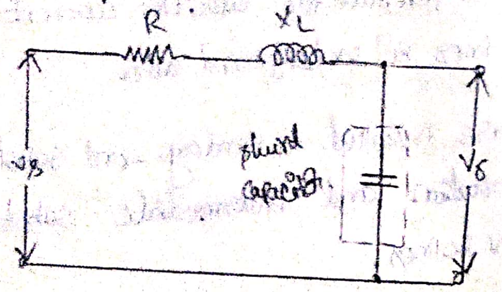
where

L = Inductance of reactor.

X_L = Reactance of reactor = ωL

V = phase voltage.

b) shunt capacitor:



use of shunt capacitor at receiving end.

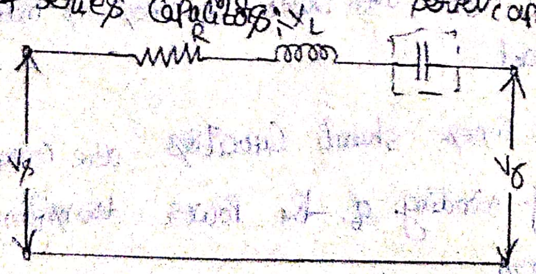
$$Q_C = V \cdot I_C = \frac{V^2}{X_C} = V^2 \omega C \text{ VAR/ phase}$$

where V = phase voltage

C = capacitance per phase

X_C = shunt capacitive reactance per phase.

4) use of series capacitors:



use of series.

the series capacitors may be located at the sending-end, receiving-end or at centre of the line

Rating of series capacitor

$Q_c = I^2 X_c \cdot VAR$

5) Shunt Reactors:

* shunt reactor is an inductive current element connected b/w line & neutral in compensate for capacitive current from transmission lines or underground cable.

* shunt reactors are installed in sending-end substations, receiving-end substation and intermediate substations of long EHV & UHV AC lines.

* It is difficult to switch off large shunt reactions as the switching overvoltages are of high magnitudes.

6) shunt Capacitors:

* Installed near the load terminals, in receiving-end substations, distribution substations & in switching substations.

* A series disadvantages with shunt capacitors is that at no load or light load.

* In transmission lines shunt capacitors are connected either to the tertiary winding of the power transformers or to the busbars.

i) series compensation

a) Increase in power transfer capability.

The power transfer over a line given by:

$$P_1 = \frac{V_s V_r}{X_L} \sin\delta$$

where P_1 = Power transferred per phase (w)

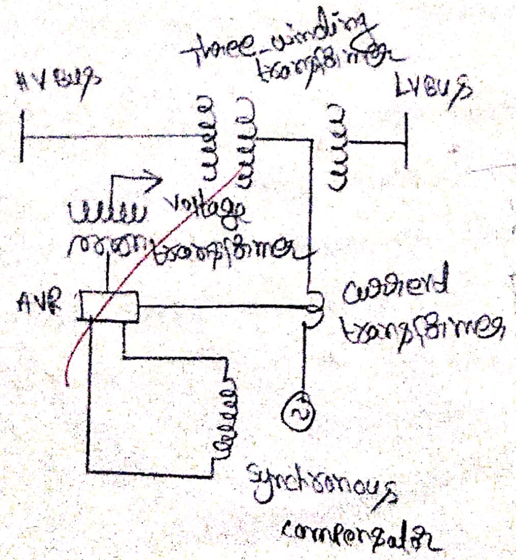
V_s = sending-end phase voltage (V)

V_r = receiving-end phase voltage (V)

X_L = series inductive reactance of the line per phase (Ω)

δ = phase angle b/w V_s & V_r

3) synchronous capacitors (synchronous condenser or synchronous phase modifiers).



connection of Synchronous phase modifier.

* A synchronous phase modifier is a synchronous motor running without a mechanical load.

* The other common names given to a synchronous phase modifier are 'synchronous condenser'.

* It is a very convenient device to keep the receiving-end voltage constant under and condition of load.