PERFORMANCE ANALYSIS OF OVERHEAD ELECTRICAL TRANSMISSION LINE

This Thesis submitted in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Electrical and Electronic Engineering

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Certification

This is to certify that this thesis entitled "**PERFORMANCE ANALYSIS OF OVERHEAD ELECTRICAL TRANSMISSION LINE"** is done by the following students under my direct supervision. This thesis work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering**. The presentation of the work was held on

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Dedicated to . . .

Our Beloved PARENTS

&

All of Our TEACHERS

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List of Abbreviations

AC - Alternative Current

DC - Direct Current

DG - Distributed Generation

DS - Distribution System

KCL - Kirchhoff's Current Law

KVL - Kirchhoff's Voltage Law

L-G - Line to Ground

L-L - Line to Line

L-L-G - Line to Line to Ground

PF - Power Factor

NL – No Load

FL – Full load

VR – Voltage Regulation

IOC – Instant Over Current

TOC – Time Over Current

UPS - Uninterruptible Power Provide

BIL – Basic Insulation Level

CT – Current Transformer

PT – Potential Transformer

VT – Voltage Transformer

List of Symbol

Π – Pi Constant

Δ – Delta

ϕ – Fi

≤ - Inequality

δ – Delta

≥ - Inequality

Ω – Ohm

‖ - Parallel

α- Alfha

β- Beta

∂ - Delta

η- Efficiency

ω- Angular Frequency

γ- Gamma

σ- Sigma

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ABSTRACT

Demanding electricity is gradually increasing day by day and we are facing boundaries to meet up the demands although. Now we want electricity in each and every sectors. As been being a development country our electricity demand has been raised at a higher rate for developing purposes. In this paper, short transmission line, medium transmission line and long transmission line performance has been developed using voltage regulation and efficiency between the power factor. And we compare between the short, medium and long transmission line for same nominal voltage and power. The line parameters and performance have been calculated by using several EXCEL.

Chapter 1

Introduction

1.1General Information:

Transmission lines area unit painted by constant model include acceptable circuit parameters on a per section ground. The outlaying voltages area unit exposed since one line to ground, this since one section and therefore, the 3 section system is attenuate to constant individual section system.

The purpose of this section, but isn't just to develop the pertinent equations; it conjointly provides a scope to grasp the results of the parameters of the road on bus voltages and therefore the stream of power. Including the trendy facility knowledge since everywhere the system area unit being fed unceasingly into one line computers for management functions and for data. Load stream studies performed by a laptop promptly offer answers to queries regarding the impact of shift lines into and out of the system or of changes in line parameters. Equations derived during this section stay vital, however, in growing and in whole considerate of what's fall out on a system and in calculative potency of transmission, damage, and borders of power stream upon a line for each steady state and transient situation.

The vital concerns including the style and activities of a cable area unit the realization of free fall, line damage and potency of transmission. These standard area unit commonly impact by the road constants R, L and C of the cable. As an example, the free fall including the line build upon the standard of higher than 3 line constants. Without change, the resistance of cable conductors is that the maximum significant explanation for power loss including the line and determines the transmission potency. During this section, we have a tendency to shall develop laws by that we are able to compute voltage regulation, line damage and potency of transmission lines. These laws area unit vital for two moral arguments. One of all, they supply a scope to grasp the results of the parameters of the road on bus voltages and therefore the stream of power. Secondly, they assist in growing and in whole considerate of what's fall out on electrical power system.

Power system square measure extraordinarily sophisticated electrical networks. Three portion networks all devices square measure put in all told 3-phases and every power circuit formations of 3 conductors. A whole emblematical design exhibition all the connections is extremely sophisticated and impractical. Three portion system square measure designed as balanced system and square measure generally managed as a balanced 3-phase system. One line designs square measure summary manner of communication the fundamental arrangement of facility portions. One line designs use one line to represent all 3-phases. One line designs are referred to as individual line design.

They exhibition the comparative electrical inter-connections of generators, transformers, transmission and distribution lines, loads, fuse etc. employed in aggregation the ability system. There's no universally accepted set of symbols practical for one line designs. A number of the symbols practical square measure exhibition below:

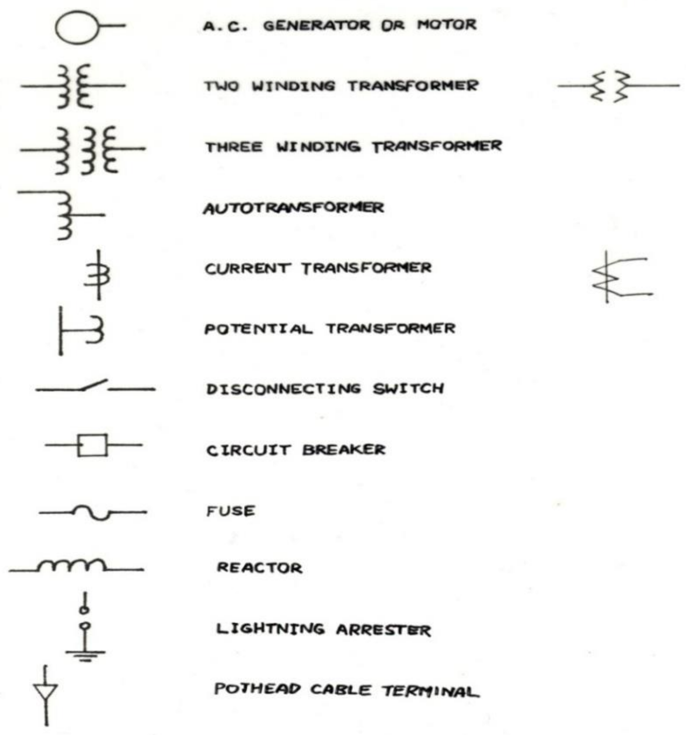


Fig.1.1: Apparatus symbols approved by the ASA

The purpose of the one line design is to provide in terse since the many info concerning the system. The consideration of various options of a system varies include the matter into consideration, and further the quantity of knowledge enclosed on the design build on the aim that the design is meant. For example, the situation of circuit breakers and relays is unimportant in creating a load study. Breakers and relays don't seem to be exhibition if the one perform of the design is to produce info for such a study. On the opposite hand, realization of the steadiness of a system beneath transient situation ensuing since a fault build on the speed include that relays gate breakers manage to isolate the faulted a portion of the system. Therefore, info concerning the circuit breakers is further of maximum consideration. Commonly one line design corpus info concerning the present and potential transformers that connect the relay to the system or that square measure put in for metering. The data found of a one line design should be expected to vary in step include the matter at hand and in step include practice of the actual company making ready the design.

The yank National Institute (ANSI) and further the Institute of Electrical and physical science Engineers have revealed a collection of ordinary symbols for electrical designs. Not all authors follow these symbols, particular in indicating transformers. Fig. 1.1 exhibitions a couple of symbols that square measure generally practical. The essential image for a machine or rotating coil may be a circle, however numerous diversifications of the essential image square measure listed that each piece of rotating electrical machinery in common use will be indicated. For anyone WHO isn't operating perpetually include one line designs, it's clearer to point a specific machine by the essential image followed by info on its sort and rating.

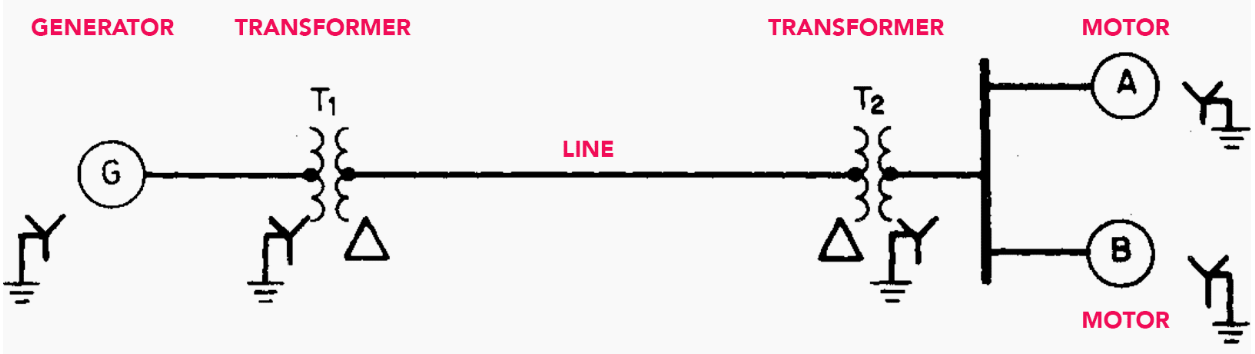


Fig.1.2: One line design of an electric system

Fig.1.2 is that the one line design of a awfully straight forward power grid. Two generators, one grounded by a reactor and one trough a electrical device, square measure linked to a bus and thus a intensify electrical device to a conductor. Another generator, grounded by a reactor, is linked to a bus and thru a electrical device to the alternative finish of the conductor. A load is linked to every bus. On the design info regarding the hundreds, the rating of the generators and transformers, and reactance of the various portions of the circuit is commonly given.

1.2 Electrical Power System:

Electricity is vital to ours everyday lives, however maximum of the society have very small considerate of the complicated method that fetch wattage to our houses, institutions, and workshops whenever we have a tendency to demand it. This appendix may be a tutorial on however the electrical grid works. We have a tendency to assume no previous data including the space and begin by providing an outline of the physical foundations of electricity. We have a tendency to next discuss the formation and portions of the electrical grid. We have a tendency to follow include an evidence of however the system is managed and the way whole sale electricity markets work. Including the final section, we offer a quick summary of system coming up. as a result of there square measure slight variations including the formation, activities, and coming up include of the electrical grid since country to country and region to region, we have a tendency to focus whole on elementary aspects that stay unchanged; but, wherever acceptable we offer U.S. centric details and highlight vital variations in follow.

The electric grid formations of manufacturing units where initial energy is regenerate into electric power, transmission and distribution networks that transport this power, and consumers' instrumentality (further said as "loads") where power is practical. Whereas originally generation, transport, and consumption of wattage were native to relatively small geographic regions, currently these regional method unit of measurement linked on by high-voltage transmission lines to form very interlinked and complicated method that span wide areas. This interconnection permits economies of scale, higher utilization of the utmost economical generators, enlarged responsiveness. Associate in Nursing improved relation of average load to top load as a result of load diversity, thus increasing capability utilization. Interconnection jointly ends up in virtue however, as any disturbance in one a section of (the method the method) can adversely impact the entire system. Figure 1.3 illustrates the essential formation of the electrical grid.

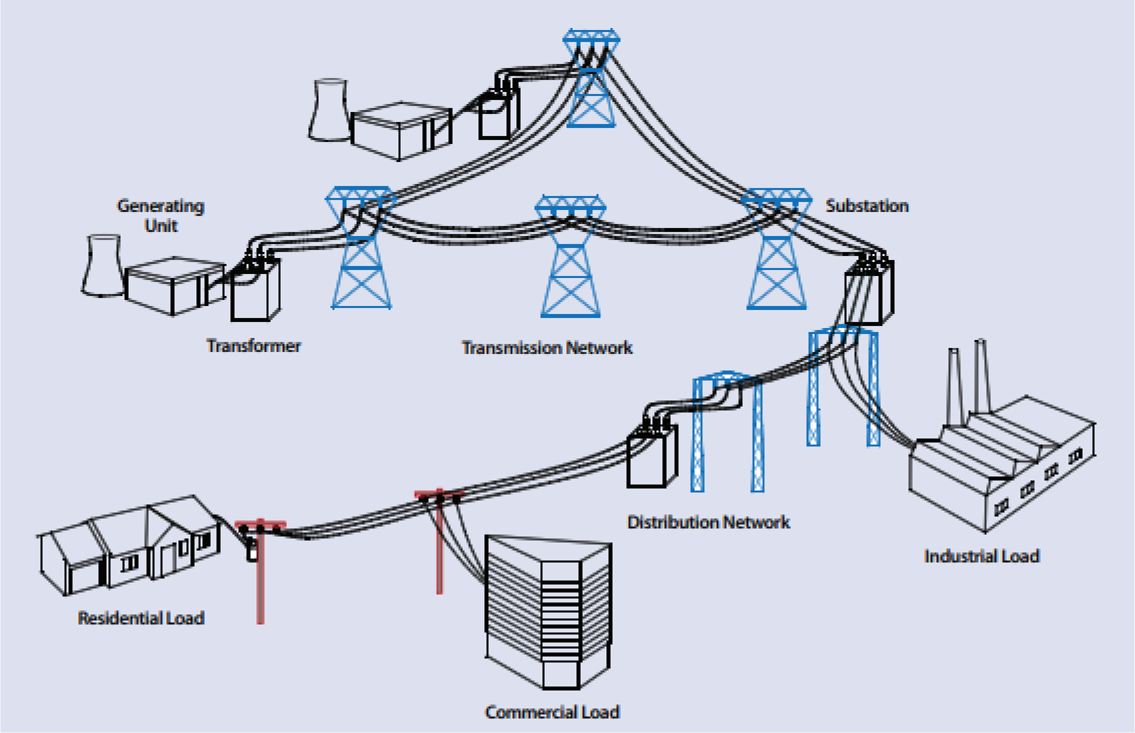


Fig1.3: Structure of the electric power system

1.3 Objective:

If we want to any power we must have a system, therefore electrical power we need electrical power system can be divided into three basic parts. Generation, transmission and the other one is distributions. After complete some task the electrical power reaches near the consumers. To complete the task generally we use generator, transformer, transmission line on cable, Pole and many other device. In generating station the primary energy converted into wattage and stepped up at a present of step up transformer, and send the wattage is stepped down and receive the substation with the presence of step down transformer. Now the low voltage electrical power can be easily distribute to the consumer.

1.4 Mechanism and Construction:

The main supporting unit of overhead line is transmission tower. Transmission towers have to be compelled to carry the numerous transmission conductor at a spare immune height since ground. In addition to it all towers have to be compelled to sustain every type of natural calamities. Therefore, transmission tower bobbing up embrace may be a very important engineering job where all three basic engineering ideas, civil, mechanical and engineering ideas unit equally applicable. An influence transmission tower formations of the subsequent components,

a. Top of transmission tower
b. Cross-arm of transmission tower
c. Boom of transmission tower
d. Cage of transmission tower
e. Transmission Tower Body
f. Leg of transmission tower

Top of Transmission Tower:

The segment higher than the highest cross limb is termed top of transmission tower. Emblematically ground defend wire linked to the tip of this top.

Cross-arm of Transmission Tower:

Cross limbs of transmission tower hold the transmission conductor. The dimension of cross limb build on the extent of transmission voltage, configuration and minimum forming angle for stress distribution.

Cage of Transmission Tower:

The segment among tower corpus and top is known as frame of transmission tower. This segment of the tower holds the cross limbs.

Transmission Tower Body:

The segment since bottom cross limbs up to the bottom equilibrium is named transmission tower corpus. This segment of the tower plays a significant role for maintaining needed ground cleanup of very cheap conductor of the conductor.

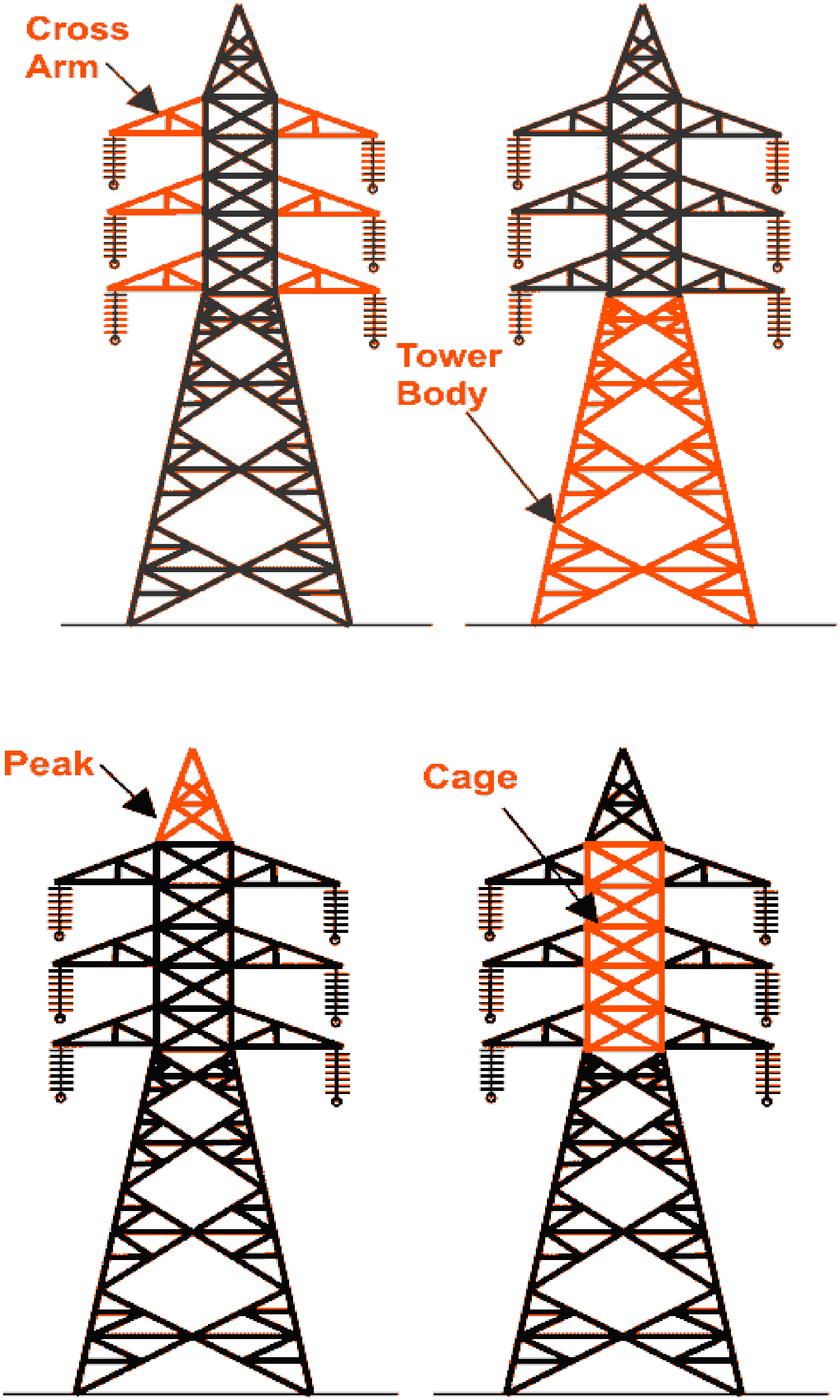


Fig.1.4: Various portion of transmission tower

Design of transmission tower:

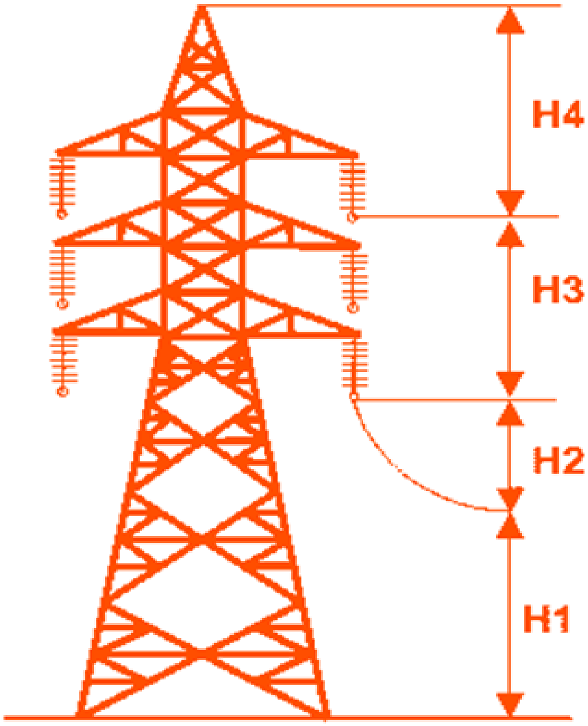


Fig.1.5 Design of transmission tower

During form of transmission tower the following points to be thought of in mind,

a) The minimum ground cleanup of very cheap conductor purpose on prime of very cheap equilibrium.

b) The spread of the fabric rope.

c) The minimum cleanup to be complied among conductors and among the conductor and tower.

d) The position of ground wire embrace relation to outer most conductors.

e) The center span cleanup required since problems with the progressive dealing of conductor and lightening protection of the road. To figure out the actual transmission tower height by considering the on prime of points, we've compound the whole height of tower in four elements,

a. Minimum permissible ground cleanup (H1)
b. most sag of the conductor (H2)
c. Vertical interval among prime and bottom conductors (H3)
d. Vertical cleanup among ground wire and prime conductor (H4)

Types of Transmission Tower

According to whole several concerns, there square measure differing types of transmission towers. The line goes as per out there corridors. Because of inconvenience of shortest distance straight passageway line should deviate since its straight manner once obstruction comes. In whole spread of an extended line there could further be many deviation points. In step with the angle of deviation there square measure four varieties of transmission tower-

1. A – sort tower – angle of deviation 00 to twenty.

2. B – sort tower – angle of deviation twenty to one hundred fifty.

3. C – sort tower – angle of deviation one hundred fifty to three hundred.

4. D – sort tower – angle of deviation three hundred to 600.

As per the force practical by the conductor on the cross limbs, the transmission towers may be classified in another way-

1. Tangent suspension tower and it's generally A - sort tower.

2. Angle tower or tension tower or few day it's known as section tower. All B, C and D varieties of transmission towers come back underneath this class.

A portion since the higher than built-to-order style of tower, the tower is intended to fulfill special usages listed below,

These are called special type tower,

I. River crossing tower
II. Railway/ Highway crossing tower
III. Transposition tower

Based on numbers of circuits carried by a transmission tower, it can be classified as-

a. Individual circuit tower
b. Double circuit tower
c. Multi circuit tower

Chapter 2

Transmission System

2.1 Introduction:

Generation, Transmission and Distribution system area unit the maximum portions of an electrical facility. Producing stations and distribution system area unit linked by line. Generally, transmission lines expose the majority transfer of power by high voltage links among main load centers. On the opposite hand, distribution system is especially to blame for the sale of this power to the shoppers by suggests that of lower voltage networks. Electrical power is generated including the vary of eleven kilovolt to twenty five kilovolt, that is enhanced by stepped up transformers to the maximum transmission voltage. At substations, the affiliation among numerous portions area unit created, for instance, lines and transformers and shift of those portions is dispensed. Transmission equilibrium voltages area unit being the vary of sixty six kilovolt to four hundred kilovolt (or higher). Giant amounts of power area unit transmitted since the producing stations to the load centers at two hundred twenty kilovolt or higher. In USA it's at three hundred forty five kilovolt, five hundred kilovolt and seven hundred sixty five kilovolt and United Kingdom of Great Britain and Northern Ireland, it's at two hundred sixty five kilovolt and four hundred kilovolt. The network fashioned by these terribly high voltage lines is generally referred to as because the super grid. This grid, in dice, feeds a sub-transmission network in activities at one hundred thirty two kilovolt or low. In our country, networks manage at one hundred thirty kilovolt, sixty six kilovolt, thirty three kilovolt, eleven kilovolt or six kilovolt and provide the ultimate shopper feeders at four hundred volt 3 portion, giving 230 V per portion.

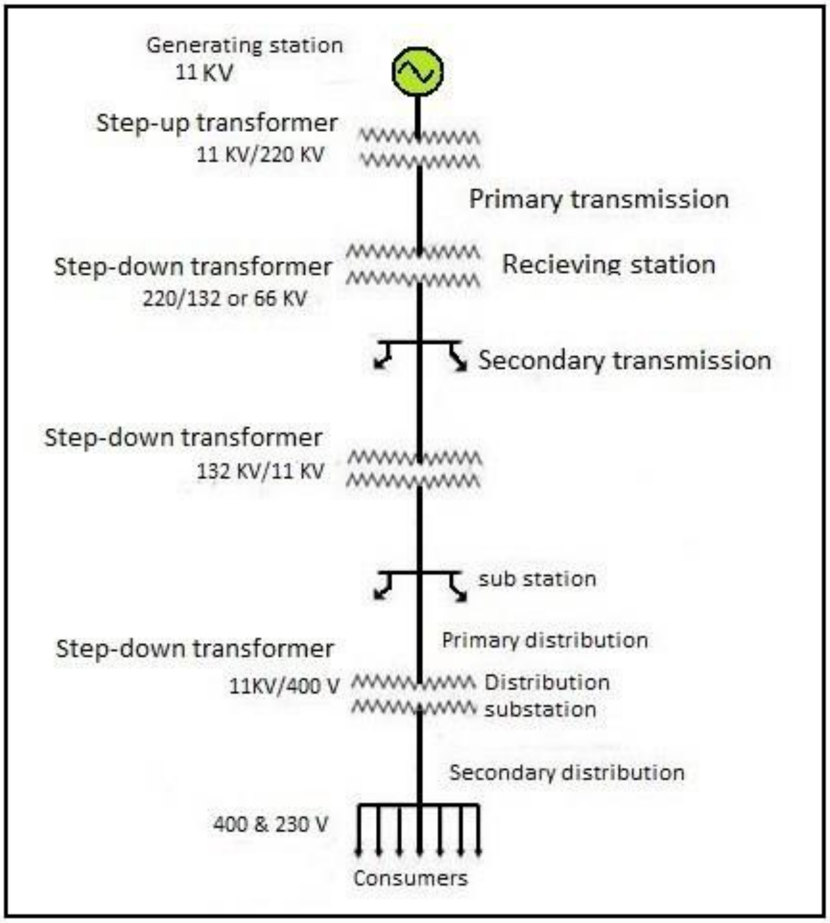


Fig.2.1: Schematic design of a power supply system

Figure 2.1exhibitions the design of an influence provide network. The facility provide network are often portioned into two elements, i.e., transmission and distribution system. The gear mechanism could further be portioned into initial and secondary (sub-transmission) gear mechanism. Distribution system are often portioned into initial and secondary distribution system. Maximum of the distribution networks manage radial for fewer short circuit current and higher protecting adjustment.

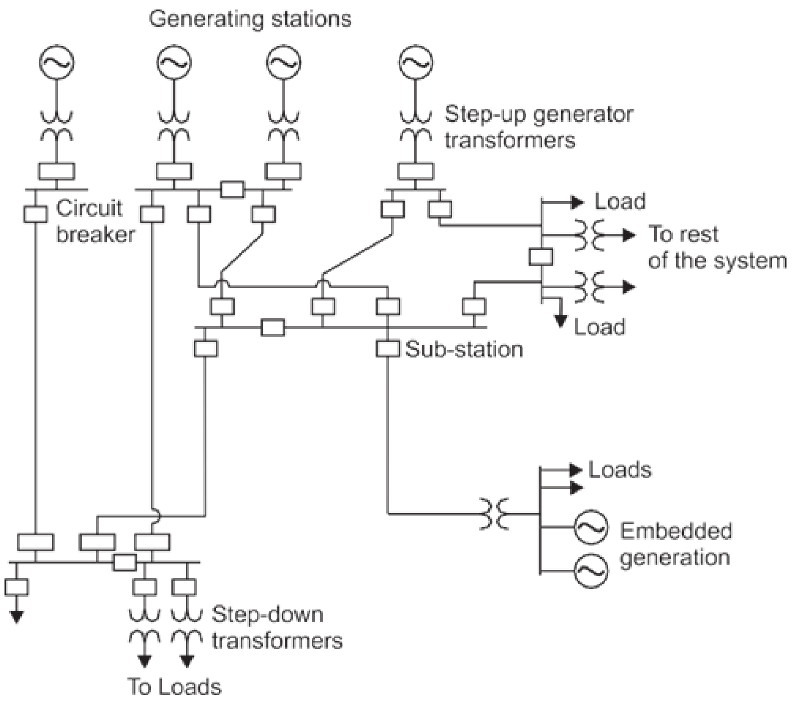


Fig.2.2: Portion of power system

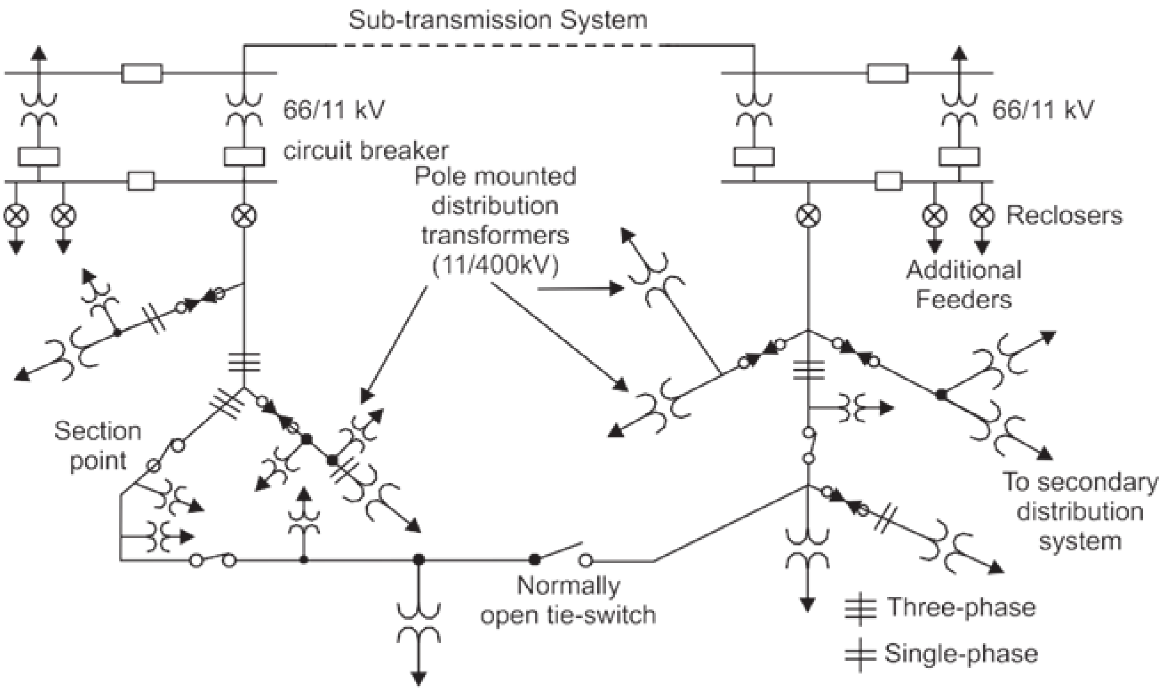


Fig.2.3: Typical distribution system

Distribution networks area unit completely several than transmission networks in few ways, perfectly except voltage magnificence. The final formation or topology of the distribution system is completely several and therefore the variety of affiliate and sources is far higher. A emblematical distribution system formations of a transformer (e.g., 132/11 kV or 66/11 kV or 33/11 kV) at a quantity offer purpose rearing variety of lines include varied spread since a couple of 100 meters to many kilometers. many 3-phase change of magnificence transformers, e.g., 11 kV/400 V area unit spaced on the feeders and since these, three-phase four-wire networks of customers area unit provided that offer 230 V individual-phase offer to houses and resembling hundreds. Figure 1.5 exhibitions a emblematical distribution system. Figure 1.4 exhibitions a portion of a emblematical power grid.

2.2 Objective:

After generation the voltage in stepped up from 11 kv to 132 kv by using step up transformer at primary transmission, then the voltage 132 kv is stepped down into 33 kv by using step down transformer. The receiving station receive the voltage. After receiving the voltage 33 kv again stepped down into 11 kv at secondary transmission and send it to substation.

2.3 Construction:

Towers for support of the lines are built since wood (as-grown or laminated), steel or aluminum (either lattice formations or hollow poles), concrete, and infrequently strengthened plastics. The vacant wire conductors on the road are typically built since aluminum (either plain or strengthened embody steel, or composite materials like carbon and glass fiber), though few copper wires are utilized in medium-voltage distribution and low-tension connections to client premises. a serious goal of upon head power cable style is to take care of adequate cleanup among energized conductors and further the ground thus on forestall dangerous contact embody the road, and to produce reliable support for the conductors, resilience to storms, ice loads, ground quakes and alternative potential harm causes these days upon head lines are habitually managed at voltages exceptional 765,000 volts among conductors, embody even higher voltages potential in few cases.

2.4 Protection:

Power-system protection may well be a locality of power engineering that volume embrace the protection of power method since faults by the isolation of faulted portions since the rest of the electrical network. The target of a protection theme is to be the power method stable by uninflected only the elements that unit below fault, whereas exploit the utmost quantity of the network as potential still activities. Thus, protection intention ought to imbed a awfully pragmatic and hope low obtainment to clearing method defects. The devices that unit won't to defend the power method since faults unit said as it.

Component:

Protection system emblematically comprise 5 components:

a. Current and voltage device to step down the high voltages and currents of the ability method to advantageous parity for the relays to sense.
b. Protecting relay to sense the fault and initiate a visit or disconnection order.
c. Circuit breakers to open/close the method supported relay and machine re-closer commands
d. Batteries to provide power simply just in case of power disconnection embody within the method
e. Communication channels to allow analysis of current and voltage at remote outlaying of a line and to allow remote tripping of kit.

For components of a distribution system, fuses square measure capable of each sensing and separates faults.

Defeats may arrive in each 0.5, like insulation lay down, fallen or broken transmission lines, caught activities of circuit breakers, short circuits and open circuits. Protection devices unit place in embrace the aims of protection of assets and guaranteeing continued provides of energy.

Switchgear may be a mixed of electrical disconnect switches, fuses logic gate breakers practical to management, defend and isolate electrical instrumentality. Switches unit are immune to tile below ancient load current, whereas protective devices unit immune to open below fault current.

Protective Device:

(i) Protective relay management the express of the circuit breakers encompassing the faulted a portion of the network.
(ii) Automatical activities, like auto reclosing or system resumption.
(iii) Instrumentality that take out knowledge on the system for post event solution.

While the in activities virtue of those devices, and particularly of protecting relays, is generally important, whole several ways square measure thought-about for shielding the various components of the system. Vital instrumentality could have utterly redundant and freelance protecting system, whereas a fraction section distribution line could have terribly straightforward lower-priced protection.

There square measure 3 components to protecting devices:

a) Instrument transformer: Current Transformer (CT) or Potential Transformer(VT)
b) Relay
c) -Circuit breaker

Advantages of protected devices comprise these 3 basic portions corpus immunity, saving, and validity.

(i) **Immunity**: Instrument transformers produce electrical isolation since the ability system, and therefore forming a immune atmosphere for rank operating include the relays.
(ii) **Saving**: Relays square measure ready to below complicated, lower, and inexpensive given lower-equilibrium relay inputs.
(iii) **Validity:** Installation voltages and currents square measure validity simulate by instrument transformers upon massive in activities ranges.

High-voltage transmission network:

Protection on the transmission and distribution system deal 2 activities, protection of plant and protection of the common patent. At a basic equilibrium, protection separates instrumentality that expertise Associate in Nursing up load or a brief to ground. Few things in substations like transformers may need extra protection supported temperature or pressure equilibrium, within others.

Generator sets:

In a powerhouse, the protecting relays square measure meant to stop injury to alternators or to the transformers just in case of abnormal situation of activities, thanks to internal defeats, likewise as insulating defeats or regulation malfunctions. Such defeats square measure uncommon, therefore the protecting relays need to manage terribly seldom. If a protecting relay lay downs to sight a fault, the ensuing injury to the generator or to the electrical device may need expensive instrumentality repairs or replacement, likewise as financial gain loss since the shortcoming to provide and sell energy.

Upload and backup for distance:

The upload protection wants a current device that just measures this in a circuit. There unit of measurement a pair of kinds of up load protection, instant upon current (IOC) and time upon current (TOC). Instant upon current wants that this up come a planned equilibrium for the breaker to figure. Time upon current protection manages supported a current vs time curve. Supported this curve, if the surveyed current up come a given equilibrium for the preset amount of some time, the breaker or fuse will manage.

Ground fault:

The ground fault protection conjointly needs current transformers and knowing a disequilibrium in a very 3-phase circuit. Unremarkably the 3 section currents square measure in balance, i.e. roughly equal in magnificence. One or 2 phases become linked to ground through a coffee ohmic resistance pathway, their magnificence can rise, as can current disequilibrium. If this disequilibrium up come a preset price, a breaker ought to manage. Limited ground fault protection could be a kind of ground fault protection that appearance for ground fault among 2 sets of current transformers.

Distance:

Distance protection detects each voltage and current. A fault on a circuit can emblematically produce a sag include in the voltage equilibrium. If the quantitative relation of voltage to current surveyed at the relay outlaying, that equalizes to Associate in Nursing ohmic resistance, lands inside a planned equilibrium the breaker can manage. This is often helpful for moderately long lines, lines longest than ten miles, as a result of their in activities features square measure supported the road features. This expose that once a fault seems on the road the ohmic resistance placing being the relay is compared to the external ohmic resistance of the road since the relay outlaying to the fault. If the relay placing is set to below the external ohmic resistance it's definite that the fault is inside the area of protection. Once the line spread is simply too short, but ten miles, distance protection becomes tougher to coordinate. In these instances the simplest alternative of protection is current several all protection.

Back-up:

The motive of protection is to get rid of solely the sensed segment of plant and zilch else. A breaker or protection relay could lay down to work. In necessary system, a lay downing of initial protection can emblematically end in the activities of back-up protection. Remote back-up protection can emblematically take away each the sensed and un-sensed things of plant to clear the fault. Native back-up protection can take away the sensed things of the plant to clear the fault.

Low-voltage networks:

The low voltage network emblematically build upon fuses or low-tension circuit breakers to get rid of each upon load and ground faults.

Chapter3

Performance of Transmission Line

3.1 Introduction:

This section volume include the features and performance of transmission lines. It is advantageous to represent a transmission line by the two-port network, wherein the sending-end voltage V_S current I_S are related to the receiving-end voltage V_R and current $I_R$by A, B, C and D parameters as

$V_S = AV_R + BI_R$ Volts …………(3.1)

$I_S = CV_R + DI_R$ Amp ……………(3.2)

or,

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix} \quad \text{……………..(3.3)}$$

A, B, C and D are the parameters that recline on the transmission-line constants R, L, C and C. The ABCD parameters are, in common, complex numbers. A and D are no amount. B has units of ohms and C has units of siemens.

Further the following recognize maintain for ABCD constants,

$AD - BC = 1$ …………………...(3.4)

To eliminate disorder among whole series impedance and series impedance per unit spread, the following modulator is practical.

$z = Y + j\,\omega L$ Ω/m, series impedance per unit spread

$y = C + j\,\omega\,C$ s/m, shunt admittance per unit spread

$Z = z\,l$ Ω, whole series impedance

Y = y l s, whole shunt admittance

l = line spread, m.

Comment that the shunt conductance C is generally disregarded for upon head transmission system.

3.2 Classification:

There are three types of transmission lines.

a. Short transmission line
b. Medium transmission line
c. Long transmission line

3.2.1 Short Transmission Line:

Capacitance may be neglected include out many mistake if the lines are low than 80 km long or if the voltage not upon 66 kV. The short line model on a per-phase ground is exhibition in Fig. 3.1.

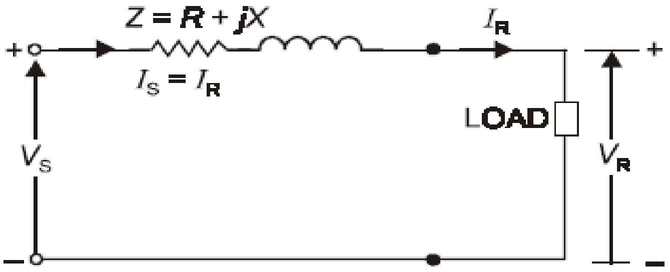


Fig.3.1: Short Transmission Line

It's a simple series circuit. The relevance among sending-end, receiving-end voltages and currents will be written as,

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} 1 & Z \\ 0 & 0 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix} \qquad \text{…………….(3.4)}$$

The phasor design for the short-Line is exhibition in Fig. 3.2 for Lagging Load current.

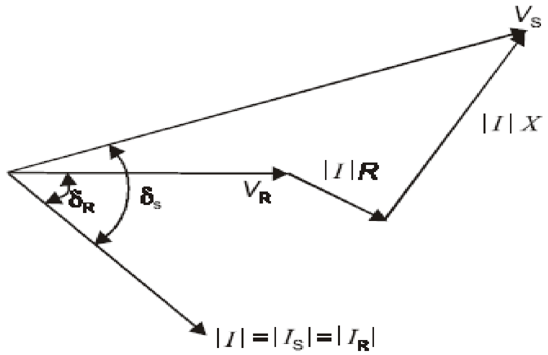


Fig.3.2: Phasor design of short transmission line

Since Fig. 3.2, we get

$$|V_S| \cos(\delta_S - \delta_R) = |I|R \cos\delta_R + |I| X \sin\delta_R + |V_R| \quad \ldots\ldots\ldots(3.5)$$

$(\delta_S - \delta_R)$ is much sma11,

$\therefore \cos(\delta_S — \delta_R) = 1.0$

$$|V_S| = |V_R| + |I| (R \cos\delta_R + X \sin\delta_R) \quad \ldots\ldots(3.6)$$

Equation (3.6) is perfectly accurate for the normal range of Load.

3.2.2 Medium Transmission Line:

In medium cable predictions, the results of the road capacitance are forgotten stay cause such lines have smaller spreads and transmit power at relatively low voltages (<greater than 20 kV). However, because the un-fold and voltage of the road rise, the capacitance step by step stay comes of bigger consideration. Since medium transmission lines have comfortable unfold (50 to 150 km) and usually manage at voltages bigger than twenty kilovolt, the results of capacitance cannot stay forgotten. Therefore, so as to get affordable accuracy in medium cable predictions, the road capacitance should stay caught into thought.

The capacitance is equally distributed upon the complete unfold of the road. However, so as to create the predictions easy, the road capacitance is occupied to stay lumped or focused within the style of capacitors shunted across the road at one or additional points. Such a treatment of localization the road capacitance offers fairly correct results. The utmost unremarkably practical strategies (know that capacitance methods) for the analysis of medium transmissions lines are:

a. Finish condenser technique

b. Nominal T technique

c. Nominal π technique.

Although the higher than strategies are practical for getting the performance predictions of medium lines, they will more be practical for brief lines if their line capacitance is given in a very particular drawback.

3.2.3 End Condenser Method:

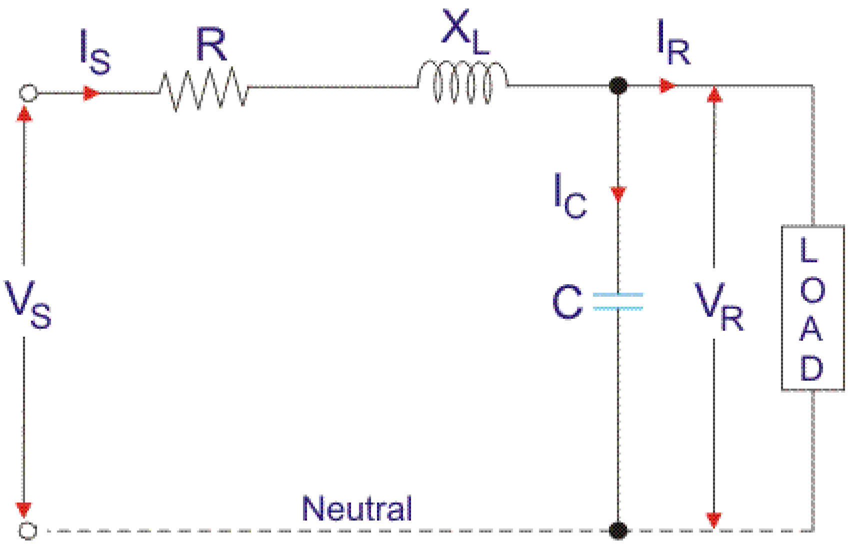


Fig.3.3: End Condenser Method

In this method, the capacitance of the line is lumped or concentrated at the receiving or load end as exhibition in Fig. 3.3. This method of localizing the line capacitance at the load end upon estimates the effects of capacitance. In Fig. 3.3, one phase of the 3-phase transmission line is exhibition as it is more advantageous to work in phase instead of line-to-line standard.

Let, I_L= per phase load current

R =per phase resistance

X_L = per phase inductance reactance

C = per phase capacitance

cosφ_R = power factor receiving end (lagging)

V_S = per phase voltage receiving end

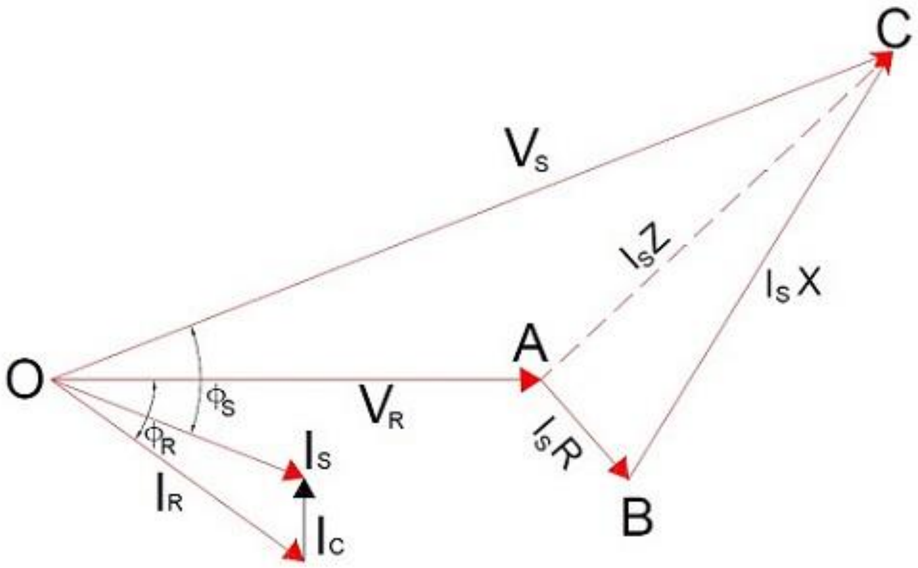


Fig.3.4: Phasor design of end condenser method

The phasor design for the circuit is exhibition in Fig 3.4.Acceptance the receiving end voltage V_R as the reference phasor,

We grt,$\overrightarrow{V_R}$ = V_R + j0

$\overrightarrow{I_R}$ = I_R (cosφ_R – j sin φ_R)

$\overrightarrow{I_C}$= j $\overrightarrow{V_R}$ ω C = j 2 π f C $\overrightarrow{V_R}$

The sending end current I_S is the phasor sum of load current$\overrightarrow{I_L}$ and capacitive current$\overrightarrow{I_C}$ IC i.e.

$\overrightarrow{I_S} = \overrightarrow{I_R} + \overrightarrow{I_C}$

$= I_R(\cos\phi_R - j\sin\phi_R) + j2\pi fcV_R$

$= I_R \cos\phi_R + j(-I_R\sin\phi_R + 2\pi fcV_R)$

$= \overrightarrow{I_S}\vec{Z} = \overrightarrow{I_S}(R + jX_L)$

$\overrightarrow{V_S} = \overrightarrow{V_R} + \overrightarrow{I_S}\vec{Z} = \overrightarrow{V_R} + \overrightarrow{I_S}(R + jX_L)$

% Voltage regulation$= \frac{V_S - V_R}{V_R} \cdot 100$

3.2.4 Nominal T Method:

In this technique, the total line capacitance is occupied to stay focused at the center purpose of the road and 0.5 the road resistance and electrical phenomenon are lumped on its either facet as exhibition in Fig. Therefore, during this arrangement, full charging current streams upon half the road. In Fig. one part of 3-phase conductor is exhibition because it is advantageous to figure in part rather than line-to-line customary.

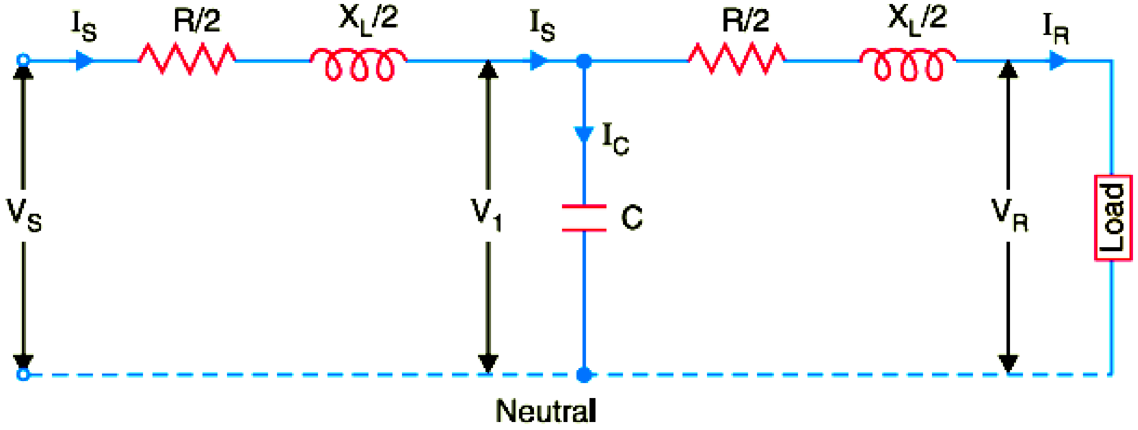


Fig.3.5: Nominal T method

Let, I_R=load current per phase

R = resistance per phase

X_L = inductive reactance per phase

C = capacitance per phase

$\cos\varphi_R$ = power factor in receiving end (lagging)

V_S= per phase in sending end voltage

V_1 = capacitor C in voltage across

The phasor design for the circuit is exhibition in Fig. Acceptance the receiving end voltage V_R as mention the phasor, we get

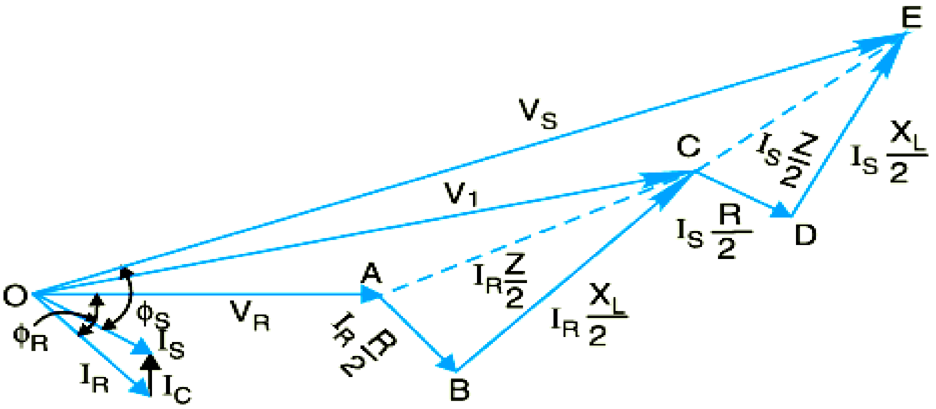


Fig.3.6: Phasor design of Nominal T method

Voltage across c, $\vec{V_1} = \vec{V_R} + \vec{I_R}\frac{\vec{Z}}{2}$

$$=V_R + I_R\,(\cos\phi_R\text{-}j\sin\phi_R\,)\,(\frac{R}{2} - j\,\frac{X_L}{2}\,)$$

Capacitive current, $\vec{I_C} = j\omega C\vec{V_1} = j2\pi fc\vec{V_1}$

Sending end current, $\vec{I_S} = \vec{I_R} + \vec{I_C}$

Sending end voltage, $\vec{V_S} = \vec{V_1} + \vec{I_S}\frac{\vec{Z}}{2} = \vec{V_1} + \vec{I_S}\,(\frac{R}{2} + j\,\frac{X_L}{2}\,)$

3.2.5 Nominal π Method:

For the lines quite eighty kilometer long and stay low 250 kilometer in unfold are treated as medium unfold lines, and also the line charging current stay comes considerable and also the shunt capacitance should stay thought-about. For medium unfold lines, 1/2 the shunt capacitance might stay thought-about to stay lumped at every finish of the road. This can be observed because the nominal π model as exhibition in Fig. 3.7. The causing finish voltage and current for the nominal π model are earned as follows:

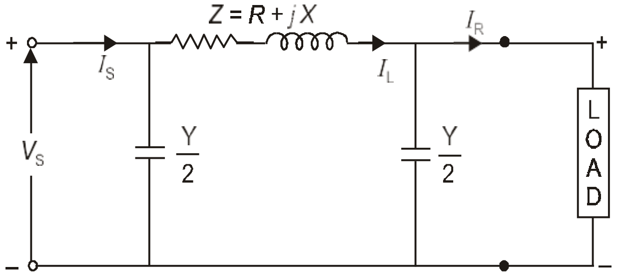


Fig. 3.7: Nominal π representation

Since KCL, the current in the series impedance designated by I_L,we get

$I_L = I_R + \frac{Y}{2}V_R$ ……………(3.6)

Since KVL, the sending end voltage we get

$V_S = V_R + ZI_L$ ………….(3.7)

Since equations (3.7) and (3.6), we get,

$V_S = \left(1 + \frac{ZY}{2}\right)V_R + ZI_R$ ……………(3.8)

The sending end current is

$I_S = I_L + \frac{Y}{2}V_S$ ……………..(3.9)

Since equations (3.9), (3.8) and (3.6), we get,

$I_S = Y\left(1 + \frac{ZY}{4}\right)V_R + \left(1 + \frac{ZY}{2}\right)I_R$ …………….(3.10)

Eq. (3.10) and (3.8) can be written in matrix form.

$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} \left(1 + \frac{ZY}{2}\right) & Z \\ Y\left(1 + \frac{ZY}{4}\right) & \left(1 + \frac{ZY}{2}\right) \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$ ………………(3.11)

Therefore, the ABCD constants for the nominal π method are conferred by

$A = \left(1 + \frac{ZY}{2}\right)$, B=Z,

$C = Y\left(1 + \frac{ZY}{4}\right)$, $D = \left(1 + \frac{ZY}{2}\right)$

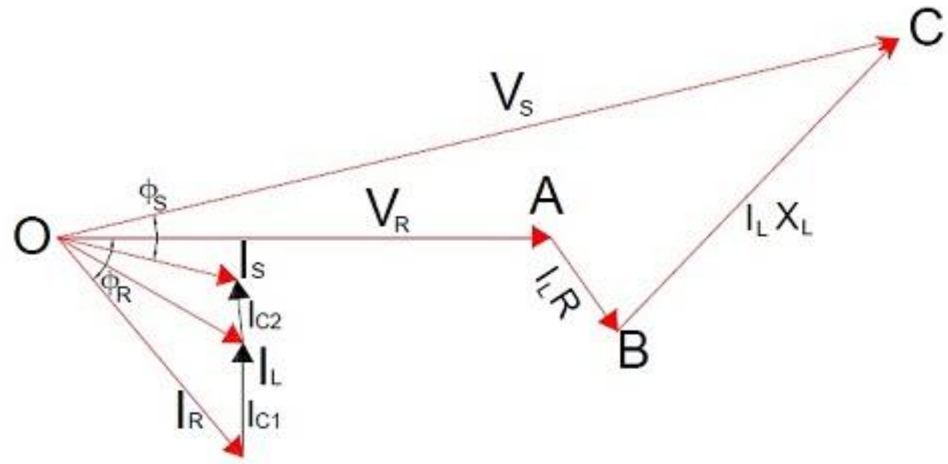


Fig.3.8 Phasor design of nominal π method.

3.2.6 Long Transmission Line:

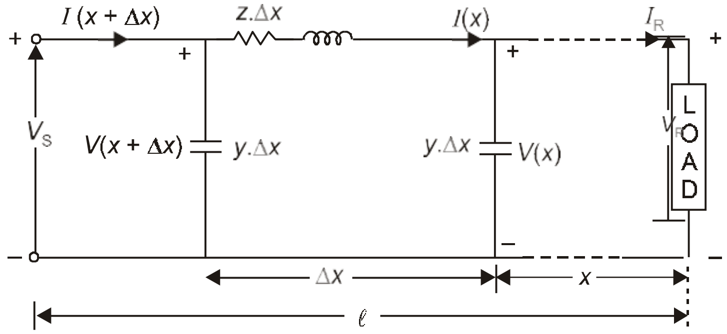


Fig.3.9: Design of a long transmission line

For short and medium unfold lines, correct models were earned by assumptive the road parameters to stay lumped. just in case the lines area unit over 250 kilometer long, for correct analysis the parameters should stay caught as distributed uniformly on the unfold as a results of that the voltages and currents can vary since purpose to purpose on the road. During this section, expressions for voltage and current at any purpose on the road area unit derived. Then, supported these equations, identical π model; is earned for long conductor. Figure 3.8 exhibitions one part of a distributed line of unfold l kilometer.

Since KVL, we get,

$$V(x+\Delta x) = z\,.\Delta x\ I(x) + V(x)$$

$$\therefore \frac{V(x+\Delta x)-V(x)}{\Delta x} = z.I_X \quad \ldots\ldots\ldots\ldots\ldots..(3.12)$$

$\Delta x=0$

As $\frac{dV(x)}{dx} = zI(x)$…………(3.13)

Since KCL, we get,

$$I(x+\Delta x) = I(x) + y.\ \Delta\, x\ .V(x+\Delta x)$$

$$I(x+\Delta x) - I(x) = y.\ \Delta\, x\ V(x+\Delta x) \quad \ldots\ldots\ldots(3.14)$$

As $\Delta x \to 0$

$$\frac{dI(X)}{dX} = y.\ V(X) \quad \ldots\ldots\ldots\ldots\ldots....(3.15)$$

Several eqn. (3.13) and substituting since eqn. (3.15), we get,

$$\frac{d^2V(x)}{dx^2} = z.\ \frac{dI(x)}{dx} = z.y\ V(x) \quad \ldots\ldots\ldots\ldots\ldots(3.16)$$

$$\therefore \frac{d^2V(x)}{dx^2} = z.y\ V(x) = 0 \quad \ldots\ldots\ldots\ldots\ldots(3.17)$$

Let Υ^2 = zy

Therefore, $\frac{d^2V(x)}{dx^2}$- Υ^2 V(x) =0 ……………..(3.18)

The analysis of the above equation is

V(x)=$C_1e^{\Upsilon x}+C_2e^{-\Upsilon x}$ ………...(3.19)

Where, Y, know the propagation constant, we get

Y = α + jβ =$\sqrt{zy}$

There all portions is known as the attenuation constant, and the imaginary portion β is known as the phase constant. β is surveyed in radian per units pread.

Since eqn. (3.13), the current is,

I(x) =$\frac{1}{z} \cdot \frac{dV(x)}{dx}$

∴ I(x) = $\frac{\Upsilon}{z}$ $(C_1e^{\Upsilon x}$- $C_2e^{-\Upsilon x})$

I(x) = $\sqrt{\frac{y}{z}}$ $(C_1e^{\Upsilon x}$- $C_2e^{-\Upsilon x})$

I(x) = $\frac{1}{Z_c}$ $(C_1e^{\Upsilon x}$- $C_2e^{-\Upsilon x})$ …………..(3.20)

Where, Z_C =the features impedance, we get

Z_c = $\sqrt{\frac{y}{z}}$ ………..(3.21)

Now comment that, when x = 0, V(x) = V_R and since eqn. (3.19), we have

$V_R = C_1+C_2$ …………….(3.22)

Further when x = 0, I(x) = I_R and since eq. (3.20), we get

I_R= $\frac{1}{Z_c}$ $(C_1$ -$C_2)$ ...(3.23)

Solving equations. (3.22) and (3.23), we obtain,

$$C_1 = \frac{V_R \ + Z_C I_R}{2} \qquad \ldots\ldots\ldots\ldots\ldots.(3.24)$$

$$C_2 = \frac{V_R \ - Z_C I_R}{2} \qquad \ldots\ldots\ldots\ldots\ldots.(3.25)$$

Substituting the standard of $C_1$and C_2 since equations. (3.24) and (3.25) into equations. (3.19) and(3.20), we get

$$V(x) = \frac{(V_R \ + Z_C I_R)}{2} e^{\Upsilon x} + \frac{(V_R \ - Z_C I_R)}{2} e^{-\Upsilon x} \qquad \ldots\ldots\ldots\ldots.(3.26)$$

$$I(x) = \frac{(V_R \ + Z_C I_R)}{2Z_C} e^{\Upsilon x} - \frac{(V_R \ - Z_C I_R)}{2Z_C} e^{-\Upsilon x} \qquad \ldots\ldots\ldots\ldots\ldots\ldots..(3.27)$$

$$V(x) = \frac{(e^{\Upsilon x} + e^{-\Upsilon x})}{2} V_R + Z_c \frac{(e^{\Upsilon x} - e^{-\Upsilon x})}{2} I_R \qquad \ldots\ldots\ldots..(3.28)$$

$$I(x) = \frac{(e^{\Upsilon x} - e^{-\Upsilon x})}{2\ \mathrm{Zc}} V_R + \frac{(e^{\Upsilon x} + e^{-\Upsilon x})}{2} I_R \qquad \ldots\ldots\ldots..(3.29)$$

Or $\quad V(x)=\cosh(Yx)V_R+Z_C\sinh(Yx)I_R \qquad \ldots\ldots..(3.30)$

$$I(x) = \frac{1}{Z_C}\sinh(Yx)V_R+\cosh(Yx)I_R \qquad \ldots\ldots..(3.31)$$

Therefore, when x = l, $V(x) = V_S$and $I(x) = I_S$. The result is

$$V_S=\cosh(Yl)V_R+Z_C\sinh(Yl)I_R \qquad \ldots\ldots(.3.32)$$

$$I_S = \frac{1}{Z_C}\sinh(Yx)V_R+\cosh(Yx)I_R \qquad \ldots\ldots\ldots.(3.33)$$

Therefore, ABCD constants are:

$A = \cosh(Yl)$; $B = Z_C \sinh(Yl)$ ………...(3.34)

$C=\sinh(Yl)$; $D = \cosh(Yl)$ ………..(3.35)

Equations. (3.8) and (3.10) earned for the nominal π, for equivalent π model we have,

$$V_S = \left(1 + \frac{Z'Y'}{2}\right) V_R + Z'I_R \qquad \ldots\ldots\ldots\ldots..(3.36)$$

$I_S = Y'\left(1+\frac{Z'Y'}{4}\right) V_R + \left(1+\frac{Z'Y'}{2}\right) I_R$ ....(3.37)

Now assimilate equations. (3.36) and (3.37) include equations. (3.32) and (3.33), respectively and making use of the similarity,

$\tanh\left(\frac{\Upsilon l}{2}\right) = \frac{\cosh(\Upsilon l)-1}{\sinh(\Upsilon l)}$ ....(3.38)

The parameters of equivalent π model are earned as:

$Z' = Z_C \sinh(\Upsilon l) = \frac{Z\,.\sinh(\Upsilon l)}{\Upsilon l}$ ....(3.39)

$\frac{Y'}{2} = \frac{1}{Z_C}\tanh\left(\frac{\Upsilon l}{2}\right) = \frac{Y}{2}\frac{\tanh(\Upsilon l/2)}{\Upsilon l/2}$ ....(3.40)

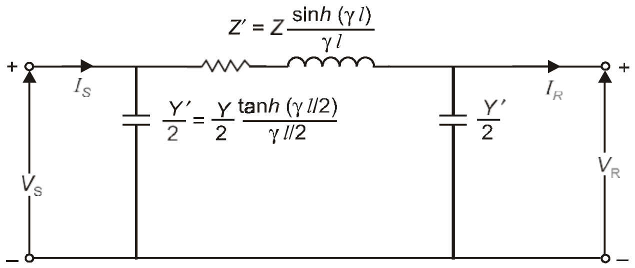


Fig. 3.10: Equivalent π model for long transmission line.

3.3 Voltage Regulation:

Voltage provision of the transmission line may remain defined as the percentage change in voltage at the receiving end of the line in going since no-load to full-load.

Percent voltage regulation $= \frac{|V_R^{NL}| - |V_R^{FL}|}{|V_R^{FL}|} \times 100$ ....(3.41)

Where,

$|V_R^{NL}|$ =magnificence of no-load receiving end voltage

$|V_R^{FL}|$ = magnificence of full-load receiving end voltage

At, no-load I_R =0, V_R =V_R^{NL}, and since equation (3.41) we get,

$V_R^{NL} = \frac{V_S}{A}$ ……………..(3.42)

Using eq. (3.41) and (3.42), we get

Percent voltage regulation = $\frac{|V_S||A||V_R^{FL}|}{|A||V_R^{FL}|}$ ×100 ………………(3.43)

For a short line, $|A| = 1.0$, $|V_R^{FL}| = |V_R|$

Percent voltage regulation = $\frac{|V_S|-|V_R|}{|V_R|}$ ×100 ……………..(3.44)

Using eq. (3.42) and (3.6), we get

Percent voltage regulation = $\frac{|I|\ (cos\delta_R - Xsin\delta_r)}{|V_R|}$ ×100 ....(3.45)

So,

Percent voltage regulation = $\frac{|I|\ (Rcos\delta_R - Xsin\delta_R)}{|V_R|}$ ×100 …............(3.46)

Since the on top of equations, it's clear that the voltage regulation may be a live of line free fall and turn on the load power issue.

3.4 Transmission Efficiency:

We know that, transmission power upon long distances will involve few quantity harm. Offers this provides rise to the conception of potency in transmission and like all different situation; the potency simply gives a concept regarding the number of helpful energy that reaches the opposite aspect compared to the number of energy that was fed at one finish. So, allow us to see however electrical transmission potency is outlined and computed.

The common formula for potency applies to the current case any and

Efficiency of transmission =Po / Pi × 100%

Where, Po = the number of power reaching the receiving finish and

Pi = the quantity of power fed at the causing finish

So, for instance that a thousand watts of power were fed to a feeder and 900 watts is received at the opposite finish then the potency of transmission is ninetieth. This description can become clearer if you see the derivation of this formula and also the style given aboard it.

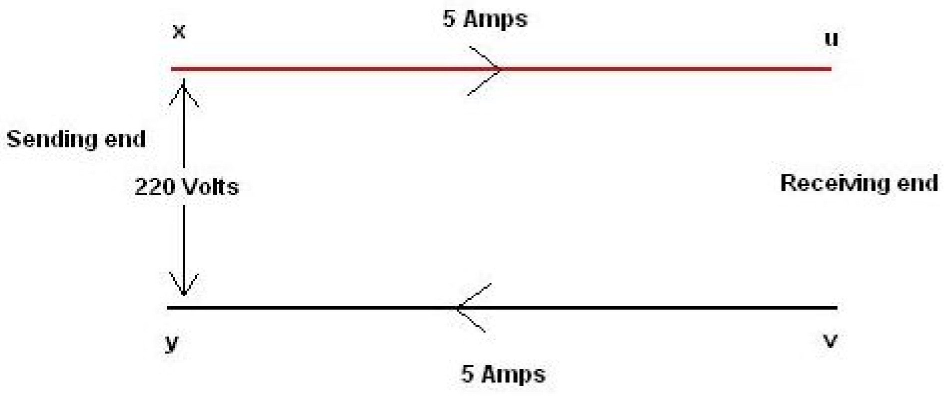


Fig. 3.11 Transmission efficiency

As we will see within the image it exhibitions 2 feeder wire wherever the top x, y is that the causation aspect whereas the top u, v is that the receiving aspect. The voltage and current of the ability being sent square measure 220V and 5A severally.

Let us assume the resistance of every feeder wire to stay one ohm for simplicity. This implies that the come by potential upon one feeder wire would stay I.R=5 volts. Thus the total drop as well as each feeder can stay ten volts. This clearly means the voltage earned at the opposite finish wouldn't stay 220 however 210 volts solely.

Power associated include 220V and 5A =VI=1100 volts.

Power associated include 210V and 5A =1050 volts

So, efficiency o transmission $= \frac{1050}{1100}.\ 100 = 95.4\%$

Another method of expressing this efficiency is the equation,

$$E = 100 - ({}^{I_R}/_{V_i} \;.100)$$

Where, V_i is the input voltage and E is efficiency.

Hence, we will see that for potency stay (to stay) most the proper hand facet figure must be minimum. This in dice implies that V_i ought to stay as high as doable therefore the necessity to intensify voltage whereas sending.

3.5 Effect of Power Factor:

a) Power issue emendation of linear masses. A high power issue is often fascinating in an exceedingly power delivery method to cut back injury and improve voltage regulation at the load.

b) Compensating parts close to Associate in Nursing electrical load can scale back the external power demand on the availability method.

c) Power issue correction rises the ability issue of a load, rising potency for the distribution method to that it's connected.

Importance of Power Factor:

A power issue of 1 or "unity power issue" is that the goal of any electrical utility company since if the ability factor is low than one, they need to produce a lot of current to the user for a given quantity of power use. In therefore doing, they incur a lot of line injury. Lutech information groups, provides full system design of thermal plant ancillary system and electric power transmission projects as well as conventional fossil-fired thermal plants.

Here, there are many common factors in transmission line:

Line Damage: Naturally, the transfer of voltage among power plants, substations and customers is not possible embrace few energy loss. The gap is brought up because the line loss.

Transmission Rates: Transmission rates include the price of providing transmission service and mirror every individual transmission owner's investment within the transmission info to yield a dice.

Voltage Fluctuation: Voltage fluctuations are changes or swings within the steady-state voltage on top of or stay low the selected input vary for a bit of apparatus. Fluctuations embrace each sags and swells.

Transients: A transient may be a high voltage spike practical by external or internal transient sources. A transient may be a high voltage spike of low than ten microseconds in period.

Up Voltage: A voltage larger than that at that a tool logic gate is meant to manage. Any called upon potential. The quantity by that the practical voltage upon return the physicist threshold during a radiation counter stay.

Disadvantages of low power factor:

The power issue plays associate degree consideration role in AC circuits since power consumed turn on this issue.

P = $V_L I_L$ cos$\boldsymbol{\phi}$ (Single phase supply)

$\therefore I_L = \frac{P}{V_L cos\phi}$ ……..(1)

P = $\sqrt{3} V_L I_L cos\boldsymbol{\phi}$ (3-phase supply)

$\therefore I_L = \frac{P}{\sqrt{3} V_L cos\phi}$ …….(2)

A power issue low than unity ends up in the subsequent disadvantages:

a) Massive KVA rating of apparatus. The electrical machinery is often rated in KVA.
b) Now, KVA = KW/cosϕ
c) It's clear that KVA rating of the instrumentation is reciprocally pro-segment to power issue. The smaller the facility issue, the larger is that the KVA rating. So at low power

issue, the KVA rating of the instrumentation must stay designed a lot of, creating the instrumentation larger and pricey.

d) Larger conductor size. To transmit or distribute a set quantity of power at constant voltage, the conductor can need to carry a lot of current at power issue.

e) Massive copper injury. The big current at low power issue causes a lot of I^2 injury all told the weather of the study method. The ends up in poor potency.

f) Poor voltage regulation. The big current at low insulating material power issue causes larger free fall in alternators, transformers, transmission lines and distributors. This ends up in the reduced voltage offered at the provision finish, therefore impairing the performance of utilization devices.

g) Attenuate handling capability of method. The insulating material power issue reduces the handling capability of all the weather of the method. it's because the reactive part of current prevents the total utilization of put in capability.

3.6 On Voltage Regulation and Transmission Efficiency:

For Short Transmission Line:

For 16 km length of short transmission line which supplies 1000 kw at 11 kv

Resistance of each conductor,

$R = 0.03 \times 16 = 0.48\ \Omega$

Reactance of each conductor,

$X_L = 2\pi fl \times 16 = 2\pi \times 50 \times 0.7 \times 10^{-3} \times 16 = 3.52\ \Omega$

Receiving end voltage / phase ,

$V_R = \frac{11 \times 10^3}{\sqrt{3}} = 6351$ V

Line current, $I = \frac{1000 \times 10^3}{3 \times V_R \times cos\phi} = \frac{1000 \times 10^3}{3 \times 6351 \times 0.1} = 525$ A

$\cos\phi_R = 0.1$, $\sin\phi_R = 0.995$

Sending end voltage / phase = V_R+ I R cos ϕ_R + I X_L sin ϕ_R

= 6351+525 × 0.48 × 0.1 + 525 × 3.52 × 0.995 = 8215

%age Voltage regulation = $\frac{V_S - V_R}{V_R}$ × 100 = $\frac{8215-6351}{6351}$ × 100 = 29.35%

Line loss = 3 I^2 R = 3 × $(525)^2$ × 0.48 = 397 KW

Input power = Output power + Line damage = 1000 + 397 = 1397 KW

∴ Transmission efficiency = $\frac{Outputpower}{Inputpower}$ × 100 = $\frac{1000}{1397}$ × 100 = 71.58 %

Without change we can compute the % voltage regulation and transmission efficiency for 0.2, 0.4, 0.6 and 0.8 lagging power factor respectively.

For % Voltage regulation,

<u>Table -3.1 Voltage regulation vs power factor</u>

SI	Power factor (lagging)	% Voltage Regulation
1	0.1	29.35%
2	0.2	14.63%
3	0.4	7.05%
4	0.6	4.27%
5	0.8	2.58%

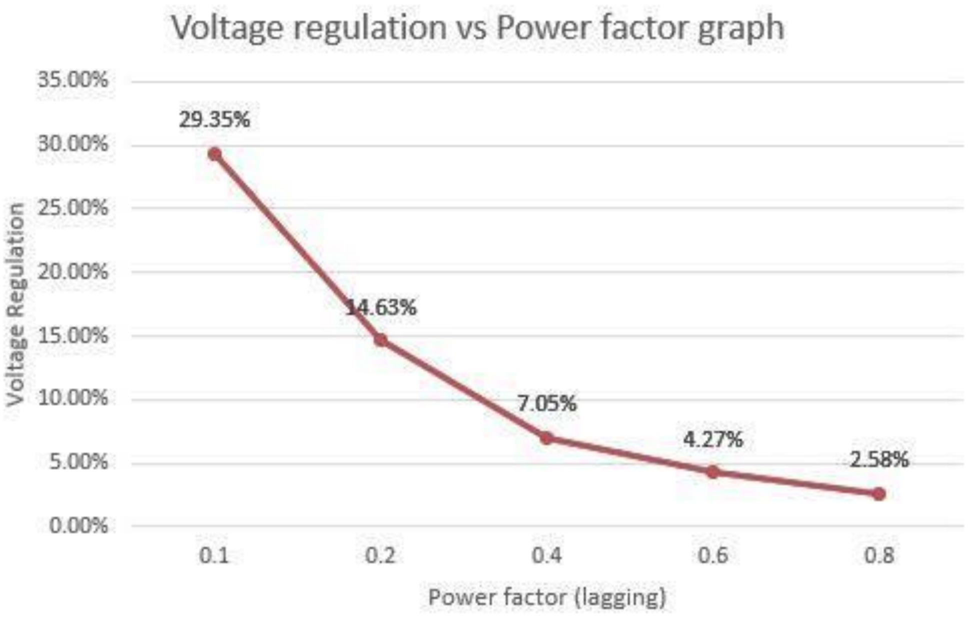


Fig.3.12 Voltage Regulation vs Power factor curve for short transmission line

For % Transmission efficiency,

Table-3.2 Transmission efficiency vs power factor

SI	Power factor (lagging)	% Transmission Efficiency
1	0.1	71.58%
2	0.2	90.97%
3	0.4	97.58%
4	0.6	98.70%
5	0.8	99.38%

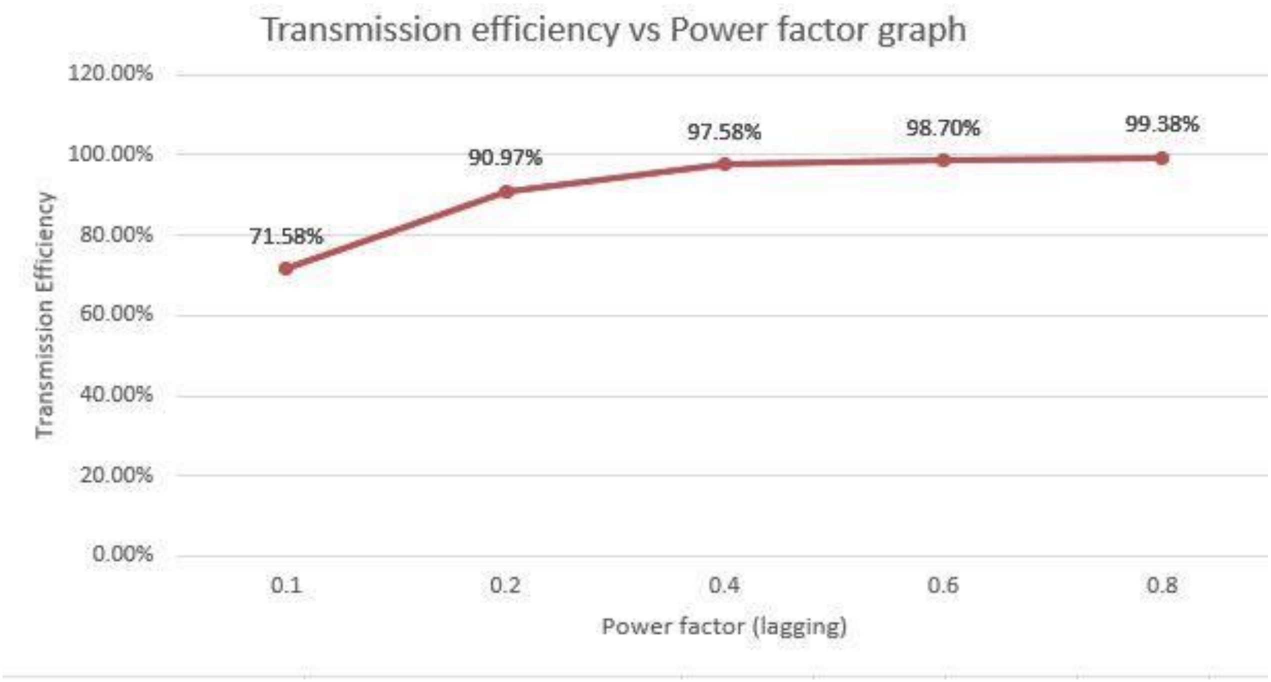


Fig.3.13 Efficiency vs Power factor curve for short transmission line

Similarly we can calculate for medium and long transmission line.

For Medium Transmission Line:

Using nominal T method,

For p.f. 0.1,

Line inductance per phase = 0.7×10^{-3}

R = 0.04×100 = 3 Ω

X_L = 2πfL = $2\times3.1416\times50\times100\times0.7\times10^{-3}$ =22 Ω

Y =$0.04\times10^{-4}\times100 = 4\times10^{-4}$ S

$V_R = \frac{11000}{\sqrt{3}}$ = 6351V

$I_R = \frac{1000\times10^3}{\sqrt{3}\times11\times10^3\times0.1}$ =524.86 A

$\vec{Z}$ = R+ JX_L= 3+ j22

$\overrightarrow{V_R}$ = 6351+j0

$\overrightarrow{I_R}$ =I_R(cosϕ_R -jsinϕ_R) = 524.86×(0.1-j0.994) =52.48-j521.71

$\overrightarrow{V_1}$ = (6351+j0)+(52.48-j521.71)(1.5+j11) = 12168.53-j205.28

$\overrightarrow{I_C}$ = j(4×10^{-4})(12168.53-j205.28) = 0.082+j4.867

$\overrightarrow{I_S}$ = (52.48-j521.71)+(0.082+j4.867) = 52.56-j516.84 =519.50$\angle$-84.2

$\overrightarrow{V_S}$ = (12168.53-j205.28)+(52.56-j516.84)(1.5+j11) =17932.12$\angle$-1.28

$\theta_1+\theta_2$ = 85.48

Sending end voltage = $3V_S I_S cos\phi_s$ =3×17937.12×519.50×cos85.48 = 2203 kw

Voltage Regulation = $\frac{V_S-V_R}{V_R}$ ×100 = $\frac{17937.12-6351}{6351}$ × 100 = 182.42%

% Efficiency = $\frac{1000}{2203}$ × 100 =45.39%

Without change we can compute the % voltage regulation and transmission efficiency for 0.4, 0.6 and 0.8 lagging power factor respectively.

For Long Transmission Line:

V =11 KV

P = 1000 kw

R = 0.03×200 = 6 Ω

X_L = 2×3.1416×50×200×0.7×10^{-4} =44 Ω

Y = 0.04×10^{-4}×200 =j8×10^{-4}

$\vec{Z}$ =R+ jX_L=6+j44

$\vec{A}$ = $\vec{D}$ = 1+(6+j44)×j(4×10^{-4})= 0.98$\angle$0.14

$\vec{B}=\vec{Z}=\vec{Z}\,(1+\frac{\vec{Z}\vec{Y}}{4})=44\angle 82.3$

$\vec{C} = 8\times10^{-4}\angle 90$

V_R= 6351V

I_R =524.86 A

$\overrightarrow{I_R}$= 524.86

$\overrightarrow{V_S} = \vec{A}\overrightarrow{V_R} + \vec{B}\overrightarrow{I_R} = 27280\angle -71.13$

% Regulation =338.30%

I_S = 508.8$\angle$-84

S. E. P. = 34883.9

% Efficiency = 2.86%

Without change we can compute the % voltage regulation and transmission efficiency for 0.4, 0.6 and 0.8 lagging power factor respectively.

Table-3.3 Comparison between short, medium and long transmission line

SI	Power Factor	Short (% voltage regulation)	Medium (% voltage regulation)	Long (% voltage regulation)
1	0.1	29.35%	182.42%	370.70%
2	0.4	7.05%	43.85%	90.39%
3	0.6	4.27%	27.09%	56.97%
4	0.8	2.58%	17.35%	36.67%

Comparison between short, medium and long transmission line,

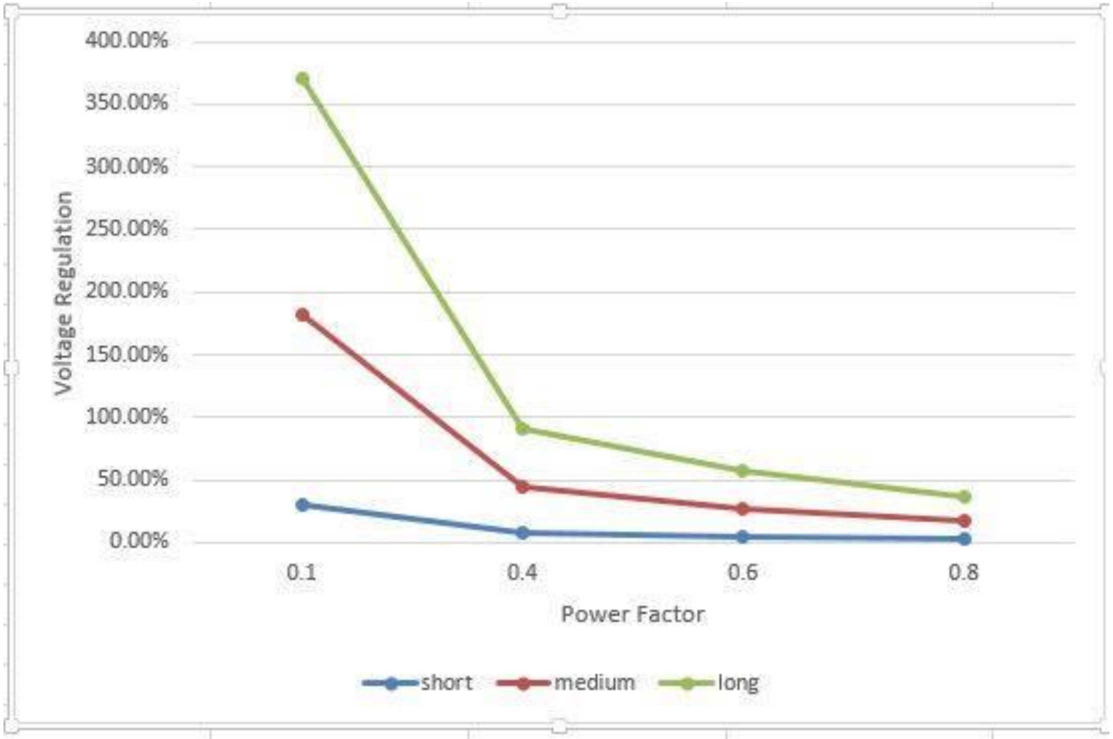


Fig.3.14 Voltage Regulation vs Power Factor Curve

Table-3.4 Comparison between short, medium and long transmission line

SI	Power Factor	Short (%Efficiency)	Medium (%Efficiency)	Long (%Efficiency)
1	0.1	71.58%	45.39%	2.86%
2	0.4	97.58%	86.80%	77.70%
3	0.6	98.70%	93.90%	88.90%
4	0.8	99.38%	97.60%	93.37%

Comparison between short, medium and long transmission line,

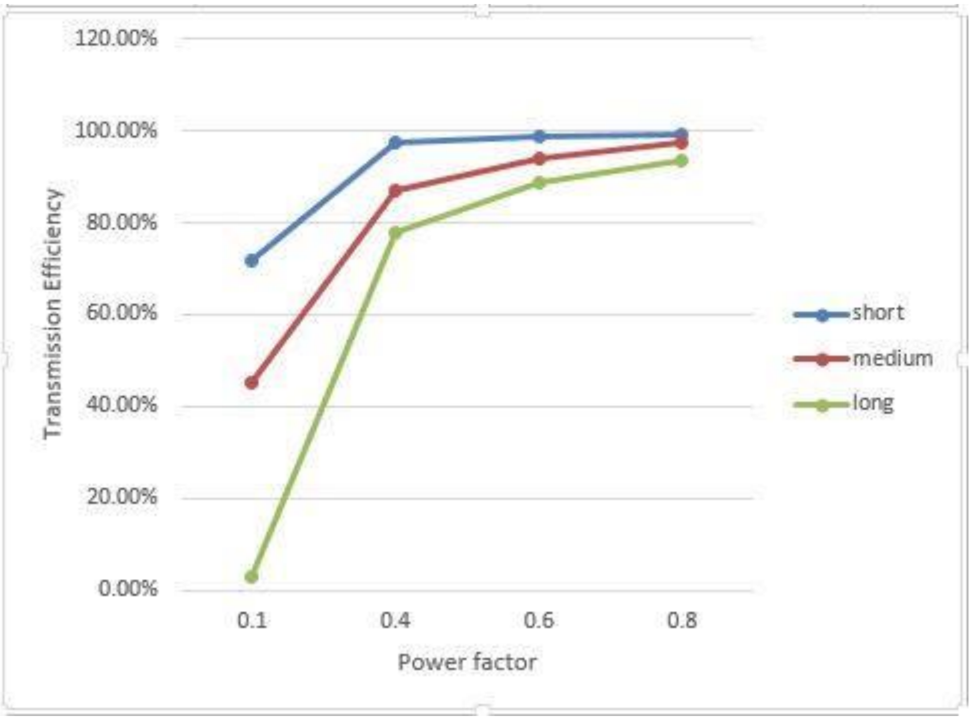


Fig.3.15 Transmission Efficiency vs Power Factor

Similarly we can calculate for 16 km length of which supplies 10000 kw at 100 kv.

Table-3.5 Comparison between short, medium and long transmission line

SI	Power Factor	Short (% voltage regulation)	Medium (% voltage regulation)	Long (% voltage regulation)
1	0.1	3.54%	21.60%	14%
2	0.4	0.85%	4.89%	8.62%
3	0.6	0.52%	2.80%	4.47%
4	0.8	0.31%	1.52%	1.94%

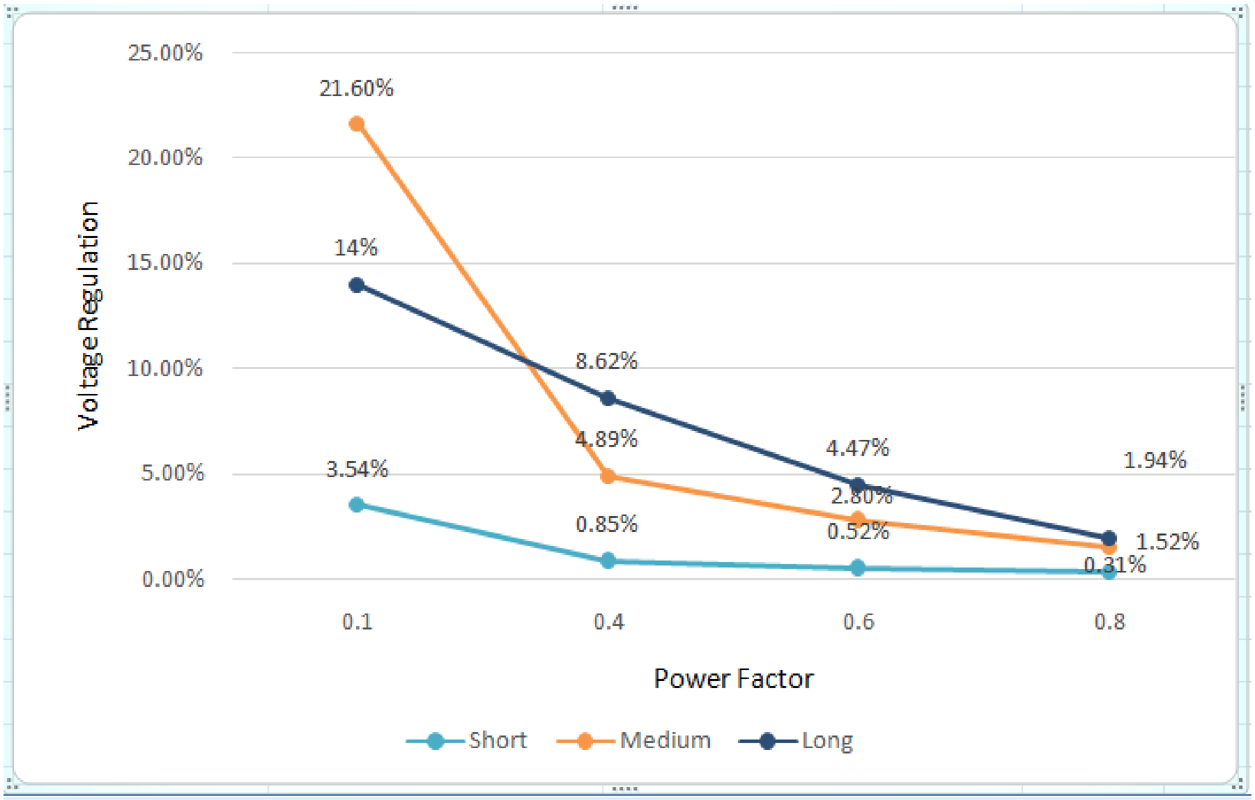


Fig.3.16 Voltage Regulation vs Power Factor Curve

Table-3.6 Comparison between short, medium and long transmission line

SI	Power Factor	Short (%Efficiency)	Medium (%Efficiency)	Long (%Efficiency)
1	0.1	95.42%	86.76%	31.45%
2	0.4	99.70%	98.42%	97.71%
3	0.6	99.86%	99.30%	99.27%
4	0.8	99.92%	99.60%	99.99%

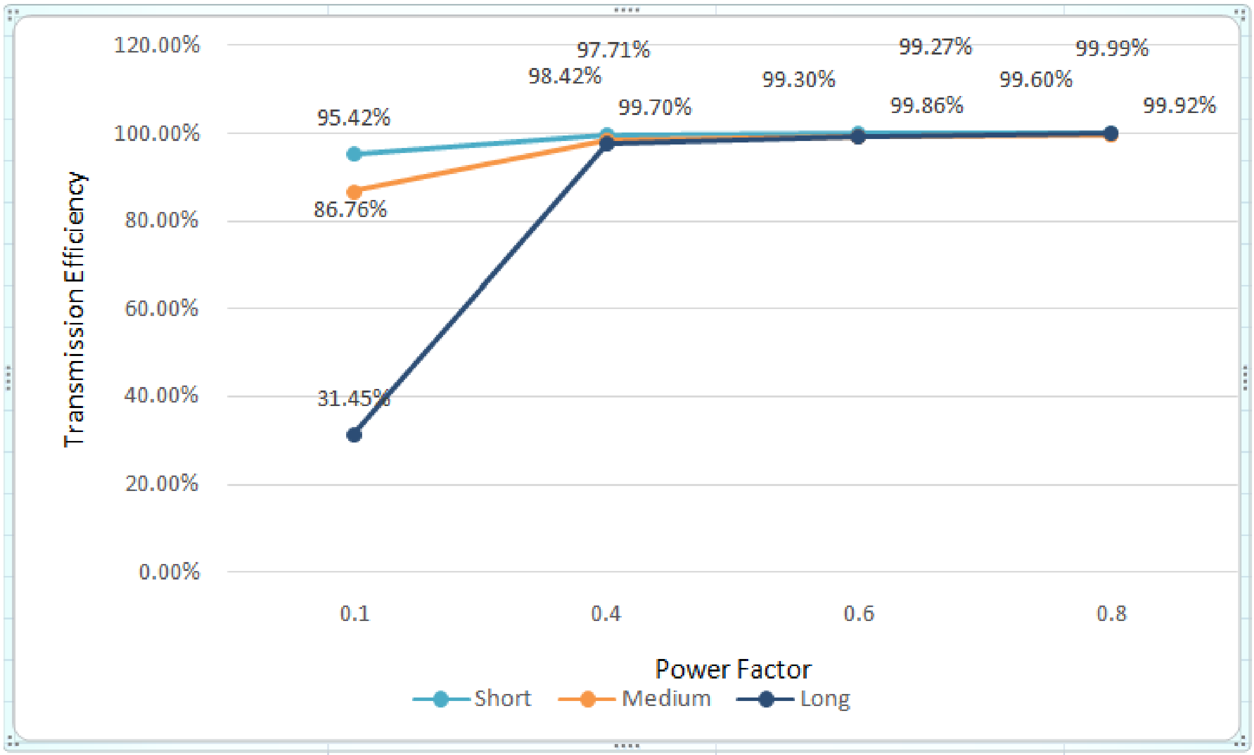


Fig.3.17 Transmission Efficiency vs Power Factor

Chapter 4

IMPORTANT EFFECTS OF UPONHEAD TRANSMISSION LINE

The use of high voltage is extraordinarily vital so as to rising power demand quickly. The corona features of transmission lines having voltage equilibrium 220 kV or on top of assume nice consideration. Explorations on the idea of series of trial categorical that it's doable betoken corona performance of line underneath varied operative situation. Corona has combined power loss, radio and television trusting and perceptible noise. Corona impression the road damage and further the style of overhead line conductors, hardware, assessors and insulators etc.

4.1 Corona:

Here are few important effects in overhead transmission line and the transmission line is commonly sensed by the effects.

The effects are

1. Corona effect
2. Skin effect
3. Farranti effect

The phenomenon of corona:

Air isn't excellent nonconductor and even beneath traditional agreement the air contains variety of free electrons and ions. Contemplate 2 giant collateral conducting surfaces once an electrical gradient is about up among them. The electrons and ions gain by this ground of force and sustain a awfully slender current among the physical phenomenon surfaces. This tiny current is insignificant once the electrical field strength is a smaller amount than thirty power unit per metric linear unit.

But once the electrical field strength or dynamic gradient reaches the important price of regarding 30kv/cm.

The year being the early neighborhood of conductors no more insulator and at this intensity, the ions attain high rate and on placing another impartial molecule.

This is propagates a brand new negatron and positive particle that successively and are quicker and coaling include several air molecules to ionize them more. Therefore the quantity of charged particles goes on rise apace.

If the same ground strength is occupied among the electrodes such position are created all upon being the gap. As a results of this the saturation is reached.

Therefore the air becomes conducting, therefore an entire electrical breakdown happens and arc is founder among 2 electrodes.

When associate degree change strong drop is practical across 2 conductors whose interval is giant compared include the diameter, then the air encompassing the conductor is curb to electro-static stresses. This stress or intensity is maximum at the surface of the conductor and so reducing in converse proportion to the gap since the middle of the conductor. If this potential drop is bit by bit raised. Few extent are reached once a faint glowing glow of violet color can build its look, and further the same time hissing noise are detected.

This development is named Corona and in the midst of the formation of gas because it is indicated by the features color of this gas.

If the potential drop is raised still more, the glow and further the noise can rise in intensity till eventually a spark- upon can surface. If the conductors are absolutely uniform and swish, the glow are uniform on their spread, otherwise the row points of the conductor can seem brighter.

Include conductors solely short distance a portion is comparison include their diameter, The Spark-Upon could surface be for there's any glowing is discovered.

If the practical potential is DC rather than AC the positive conductor having the same glow whereas the negative conductor includes a lot of uneven glow and few times it's in the midst of streamers if there are any rough places. An necessary purpose in reference to Corona is that it's in the midst of loss of power, that is dissipated being the variety of heat, light, sound and chemical system. Just in case of AC system current stream because of Corona is non-sinusoidal and in observe this non-sinusoidal current and non-sinusoidal drop by corona is further a lot of necessary than the facility loss.

The impact of corona are often summarized as-

1. It's in the midst of power loss.

2. A glowing purple glow is discovered round the conductor.

3. Glow is should lighting upon row which surfaces of the conductor.

4. Propagate a hissing noise.

5. It propagate gas which may be promptly detected by its features arrive.

Corona power loss:

The power diminished being the line thanks to spark is termed Corona loss.

Estimation of correct Corona loss is (extremely is incredibly) trouble few attributable to it's highly moving nature.

It has been found that Corona loss beneath atmospheric agreement situation is incredibly tiny as compared to the damage found beneath foul atmospheric agreement. In step include F.W. peek, the corona loss beneath atmospheric agreement situation is given by the formula,

$$P_e = \frac{144}{\delta}(f+25)(v_n - v_o)^2\sqrt{\frac{r}{D}} \times 10^{-5} \text{ KW / km / phase}$$

Where,

P_e= corona power loss

F = supply frequency (Hz)

δ = air density factor

V_n= rms phase-voltage (line-to-neutral voltage) in KV.

V_0 = rms value of disruptive critical voltage per phase in KV.

r = radius of the conductor (meters)

D = interval (or equivalent interval) among conductors (meters)

It is further to remain commented that for a individual phase line,

$$V_n = \frac{1}{2} \times \text{line voltage}$$

And for a three phase line

$$V_n = \frac{1}{\sqrt{3}} \times \text{line voltage}$$

Peterson's formula, gives better result:

$$P_e = 2.1\, f \left(\frac{Vn\,/}{\log_{10}\left(\frac{D}{r}\right)} \right)^2 \times 10^{-5} \times F \text{ KW / phase / Km}$$

Where,

P_e = corona loss

F = supply frequency

V_n = rms phase-voltage (line-to-portion voltage) in KV.

r = radius of the conductor (meters)

D = interval (or equivalent interval) among conductors (meters)

The factor F is called the corona loss function.

Factors affecting corona loss:

1. Impact of system voltage:

Electrical intensity being the house round the conductors build on the potential drop among the conductors. If main drop is high field intensity is additionally terribly high and thus Corona loss is additionally high.

2. Impact of frequency:

Corona loss is directly proportional to process frequency.

3. Impact of density of air:

Corona loss is reciprocally proportional to air density factor i.e. corona loss in will rise include decrease in density of air. The Corona loss of a High Voltage conductor passing by a craggy space could further be on top of that of comparable conductor in plains thanks to lower price of δ at the high altitudes.

4. Impact of conductor radius:

If conductor radius is high, surface intensity is a smaller amount and thus corona loss is a smaller amount. For identical current carrying capability, An ACSR conductor has low radius than individual copper conductor thus conductor of ACSR conductor have lower Corona loss than copper conductor lines. For bundled conductor lines, effective radius is high and thus Corona loss is a smaller amount.

5. Impact of temperature rise of conductor by load current:

Conductor current rises the conductor temperature and thus resulting in an indirect reduction in Corona loss. Corona loss is larger if the conductor temperature is low and this can be thanks to proven fact that at coldness, condensation drops collect on the conductor surface layout fog and wet weather. High conductor current prevents such condensation and reduces corona loss.

6. Impact on snow frost layer:

Snow or frost layer on conductor conductors causes terribly high Corona damage and radio interference. This Layer is found if temperature is zero degree and stay for extended period if temperatures square measure lower.

Corona discharge include conductor surface coated include snow and field intensity not prodigious 30kv/cm formations chiefly of pulses in negative half-cycles and breath low Steady corona at positive half-cycles. Corona themselves have an effect on the shape of snow layer and few times below of the snow in neighboring region of Corona.

7. Corona loss of latest and previous conductors:

On new conductors, corona loss is additional thanks to scratches, burrs etc. because the line ages, corona loss reducing. The previous conductor is named weatherworn conductor.

8. Impact of offer voltage:

If the regulation voltage is high, corona loss are high. In low-tension transmission lines, corona is negligible thanks to lean field un-fueled ionization.

9. Impact of dirt and dirt:

In the presence of dirt and dirt, needed voltage gradient is a smaller amount for maintaining sustained discharge. Riotous vital voltage is attenuate thanks to dirt and dirt and thus corona loss is additional.

10. Impact of conductor configurations:

Conductors of three portion head transmission lines will be placed in either horizontal or vertical configuration. The electrical intensity at the surface of middle conductor is on top of the outer conductors. Therefore, the riotous vital voltage for middle conductor are but to alternative outer conductors and thus there'll be additional Corona loss in middle conductor. If conductors square measure placed equilaterally, the emblematical field intensity at every conductor are same. Since the bottom is a resembling potential surface, the electrical field distribution is tormented by the presence of Ground. Corona loss are low, if the conductors square measure placed at additional height.

Effect of Corona on Line Design:

Transmission lines are designed in such a fashion that the Corona loss is tiny enough in honest whether or not agreement as a result of corona loss reduces the potency of the lines.

If troubled vital voltage of concerning 100 percent upon active voltage, then it's acceptable event thorough few Corona loss can come about below foul weather. Commonly, Corona losses below foul weather are going to be10 times on top of the weather agreement. A rise in Deq and r rise the troubled vital voltage, therefore reduces the corona loss however will rises the price.

4.2 Skin Effect:

The phenomena arising thanks to unequal distribution of current upon the complete cross section of the conductor getting practical for long distance power transmission is referred because the electrical phenomenon in line.

Such a phenomena doesn't have a lot of role to play just in case of a really transportation system, however include rise being the effective spread of the conductors, electrical phenomenon will rise significantly. That the modifications in line calculation must be done consequently.

The distribution of current upon the complete cross section of the conductor is kind of uniform just in case of a DC system. However what we tend to area unit mistreatment being the gift era of power grid engineering is preponderantly associate electrical energy system, wherever this tends to stream include higher density by the surface of the conductors (i.e. skin of the conductor), exploit the core empty necessary variety of electrons. In truth there even arises a agreement once fully no current streams by the core, and concentrating the complete quantity on the surface region, so leading to a rise being the effective electrical phenomenon of the conductor. This explicit trend of associate AC transmission to require the surface path for the stream of current depriving the core is stated because the electrical phenomenon in transmission lines.

Having understood the phenomena of electrical phenomenon allow us to currently see why this arises just in case of associate AC system. To own a transparent considerate of that investigate the cross sectional read of the conductor by out the stream of electrical energy given being the design below.

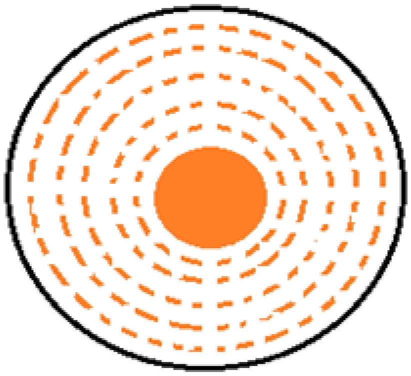


Fig.4.1 Cross sectional view of conductor

The flux linkage of the conductor will rise as we have a tendency to move nearer towards the core and at identical rate will rise the inductance because it contains a direct proportion relevance include flux linkage.

This leads to a bigger inductive electrical phenomenon being evoked into the core as compared to the outer sections of the conductor.

The high price of electrical phenomenon existence the inner section leads to the present being distributed in associate un-uniform manner and forcing the majority of the present to stream by the outer surface or skin giving rise to the phenomena referred to as electrical phenomenon in transmission lines.

4.3 Ferranti Effect:

In common follow we all know, that for all electrical system current streams since the field of upper potential to the part of lower potential, to complete the electrical potential that exists existence the system. Altogether sensible cases the causing finish voltage is above the receiving finish, thus current streams since the supply or the availability finish to the load. But Sir S.Z. Ferranti, being the year 1890, came up include Associate in Nursing astonishing theory regarding medium distance line or long distance transmission lines suggesting that just in case of sunshine loading or no load activities of gear, the receiving finish voltage generally will rise on the far side the causing finish voltage, resulting in a phenomena referred to as Ferranti impact in facility.

A long cable may be thought-about to compose a significantly high quantity of capacitance and electrical device distributed across the complete spread of the road. Ferranti impact happens once current drawn by the distributed capacitance of the road itself is bigger than this related to the load at the receiving finish of the line(by out light-weight or no load). This electrical device charging current ends up in drop across the road electrical device of the transmission that is in section include the causation finish voltages. This drop keeps on increasing additively as we tend to move towards the load finish of the road and later the receiving finish voltage tends to induce larger than practical voltage resulting in the phenomena known as Ferranti impact in grid. It's illustrated include the assistance of a phasor design below.

Thus each the capacitance and electrical device impact of cable square measure equally accountable for this explicit phenomena to arrive, and therefore Ferranti impact is negligible just in case of a brief transmission lines because the electrical device of such a line is many thought-about to be nearing zero. Commonly for a three hundred km line activity at a frequency of fifty rate, the no load receiving finish voltage has been found to be five-hitter beyond the causation finish voltage.

Now for analysis of Ferranti impact allow us to contemplate the phasor design exhibition on top of. Here, Vr is considered to be the reference phasor, represented by OA.

Thus, $V_r = V_r(1 + j0)$

Capacitance current, $I_c = j \omega C V_r$

Now sending end voltage $V_s = V_r +$ resistive + reactive drop.

$= V_r + I_cR + j\ I_cX$

$= V_r + I_c(\ R + jX)$

$= V_r + j\omega CV_r(R + j\omega L)$ [since $X = \omega L$]

Now $V_s = V_r - \omega^2 CLV_r + j\omega CRV_r$

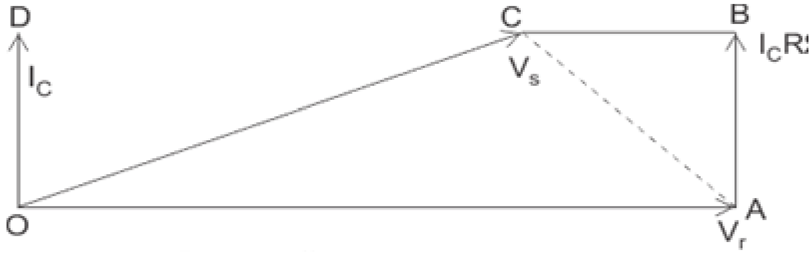


Fig.4.2 Ferranti effects in transmission line

By the phasor OC,

Now just in case of an extended conductor, it's be much ascertained that the road impedance is negligibly little compared to the road electrical phenomenon, therefore we will assume the unfold of the phasor Ic R = zero, we will contemplate the increase within the voltage is simply because of OA - OC = reactive call in the road.

Now if we have a tendency to contemplate Co and Lo area unit the quality of capacitance and electrical device per km of the conductor, wherever l is that the unfold of the road.

Thus,

$X_c = \left(\frac{1}{\omega lCo}\right)$

Therefore, in case of a long transmission line, the capacitance is distributed by out its spread, the average current streaming is,

$I_c = \left(\frac{Vr}{2\,Xc}\right) = \left(\frac{1}{2}\right) V_r\omega lc_0$

Now the inductive reactance of the line $=\omega L_0 1$

Thus the rise in voltage due to line inductor is given by,

$I_cX = \left(\frac{1}{2}\right) V_r\omega lc_0X\ \omega l$

Voltage rise $= \left(\frac{1}{2}\right)V_r\omega^2 l^2 c_0 L_0$

Since the higher than equation it's fully plain, that the increase in voltage at the receiving finish is directly proportional to the sq. of the road unfold, and thus just in case of a protracted line it keeps increasing embrace unfold and even goes on the far side the sensible causing finish voltage sometimes, resulting in the phenomena known as Ferranti impact in power method.

Chapter 5

Effect of Load Fluctuation

5.1 Introduction:

A voltage fluctuation could be a regular amendment in voltage that happen once devices or instrumentation requiring the next load area unit practical. The results of a voltage fluctuation area unit the same as the results of an voltage. It causes lights to flicker or glow brighter. Computer screen might flicker additionally. There are few instances once equipment, like a laptop, can lay down to start out up. Additionally, voltage fluctuations will cause laptop system to lose information, whereas televisions or radios might expertise interference. This power drawback will have a big impact on the life of incandescent bulbs, since they're designed for a particular voltage.

Rural areas might expertise dramatic voltage fluctuations because of the long power lines. These power lines will cause voltage to travel down once power usage being the space is high. Once arc furnaces, arc attachment instrumentation or maybe elevators area unit practical, they unremarkably cause the voltage of an influence distribution system to fluctuate. This case is comparable to employing a exhibition are being the second floor lavatory of a house. Once few corpus activates the tap being the laundry area on the initial floor, the second floor exhibitioner might run out of water.

Voltage fluctuations will be managed by the utilization of a transformer. An uninterruptible power provide (UPS) system or cable learning devices may be employed in reducing the results of this common power drawback. In our own way to alter voltage fluctuations is by merely removing instrumentation or devices inflicting it since the facility provide system.

A voltage fluctuation could be a system variation of the voltage wave form or a series of random voltage changes, of tiny dimensions, particularly ninety five to a hundred and fifth of nominal at a coffee frequency, generally below 25 cycle per second. It’s like non-uniform AC signal.

5.2 Effect of Load Fluctuation:

1) If practical voltage is simply too high, insulation is broken and therefore the device goes to be destroyed. It ought to be detected that in low voltage applications, maximum of the devices are insulated up to 1kV, i.e. for a rated voltage 220V, the next voltage say 500V won't destroy the insulation. For higher voltage there's additionally a basic insulation equilibrium (BIL) upon the rated voltage (e.g for 20kV rated voltage, BIL= 24kV). On the opposite hand if you have got a electrical device, higher voltage means that higher core damage, temperature rise, low life expectance. For current or voltage transformers there's more: the next input voltage leads the core to saturation which means that the end result of the CT or VT will not be correct. If the CT or VT is linked to associate degree instrument, the saturated core can result in false measurements. If the CT or VT is linked to a protection relay (and more upon to a switch), there'll be no protection. For several devices associate degree undesirable temperature rise happens, albeit the voltage is below the insulation equilibrium.

2) If practical voltage is simply too low, then for a given output power the present can rise (P = UI, lower U means that higher I for constant P). This is often the case once a relentless load is gift. For instance in motors, wherever the shaft contains a given load. If suddenly the voltage drops, the facility in shaft be an equivalent, thus the present will rise. Meaning additional wire damage, or perhaps a brief circuit (when dU/dt is high). If power isn't constant, as examined antecedently, then the device won't manufacture enough force. For electromagnets relays, motors, generators the Ferranti or Boucheron atomic weight. is valid:

$U = 4{,}44 N f \Phi$,

Frequency is given (say 50 or 60Hz), N variety of dices is given, Φ alters by the applying voltage or the other way around. Lower voltage means that lower Φ thus the device can’t be magnetic properly and is weak. For instance a relay won’t have enough power to maneuver a contact. For CT or VT linked to instruments there'll be a false measuring. For CT or VT linked to relays they won’t magnetize the relay, and there'll be no protection and nor automation. For motors, the shaft won’t have enough power. Finally for power transformers a lower input voltage at the start won't manufacture a big downside. The sole factor is that secondary voltage are lower too. If a load is linked then a lower secondary voltage might manufacture additional issues to the load.

5.3 Causes of Load Fluctuation:

I. Bad Connection

Minor power fluctuations in an exceedingly home emblematically originate at a connection being the facility, either wherever the house and further the route connect or at a junction being the power cable. The metal that forms the affiliation becomes unsound upon time, making minor symptoms like connection lights, particularly once wind causes the facility line to sway or move. If the corrosion is being the power cable, then the facility company should repair it at its value.

II. Interference

Running the incorrect combination of appliances and sensitive natural philosophy on constant circuit ends up in a heavy power fluctuation limited thereto explicit circuit space. Several small appliances, together include hairdryers and conductor phones, produce surges on the circuit to that they are hooked up. Symptoms since these fluctuations exhibition up in lights hooked up to the particular circuit or connection and malfunctioning natural philosophy. Moving the offending appliance or device to a circuit while not sensitive natural philosophy on that solves the interference drawback.

III. Wiring problems

Improperly designed wiring leaves a home include low electricity than required, or it permits ungrounded retailers to leak electricity and cause hard-to-solve power fluctuation issues. Wiring can further become disconnect or broken by insects and alternative animals that nest in walls. Issues include the home's wiring produce fluctuations once energy draw will rise. a professional lineman has instrumentality to find the matter and repair the wiring while not having to open all of the home's walls.

IV. Natural Causes

Lightning strikes, birds or squirrels on power lines and falling tree limbs all cause power fluctuations that are onerous to eliminate and frequently transient. whereas lightning and fallen tree limbs emblematically cause an entire equipment lay down, animals or rubble hanging on the lines ends up in brownouts or surges in electricity. Surges and swells in electrical current emblematically injury computers and alternative natural philosophy, however a straightforward suppressor volume include the additional electricity before it reaches those devices.

Chapter 6

Load Flow Analysis

6.1 Introduction:

In a power grid, power streams since producing station to the load by completely several affiliate of the network. The stream of active and reactive power is thought as load stream or power stream. Load stream analysis is a crucial tool utilized by power engineers for coming up include and deciding the steady state activities of an influence system. Power stream studies offer a scientific mathematical obtainment to work out the assorted bus voltages, section angles, active and reactive power streams by completely several affiliate, generators, electrical device placing and cargo beneath steady state situation. The power system is modeled by an electrical circuit that formations of generators, transmission network and distribution network.

The main info earned since the load stream or power stream analysis includes magnificence and section angles of load bus voltages, reactive powers and voltage section angles at generator buses, real and reactive power streams on transmission lines along side power at the reference bus; alternative variables being specific. The ensuing equations in terms of power, called the ability stream equations become non-linear and should be solved by unvaried techniques victimization numerical ways. Numerical ways square measure techniques by that mathematical issues square measure developed so they'll be solved include arithmetic activities and that they emblematically offer solely approximate answer.

For the past 3 decades, numerous numerical analysis ways are practical in reanalysis load stream analysis issues. The for maximum unremarkably practical unvaried ways square measure the Gauss-Seidel, the Newton-Raphson and quick Decoupled technique. Conjointly include the commercial developments being the society, the ability system unbroken increasing (and the land therefore the land conjointly the) dimension of load stream equation further unbroken increasing to many thousands. Include such will rise, any numerical mathematical technique cannot converge to an accurate answer. So power engineers need to ask for additional reliable ways. The matter that faces power business is a way to verify that technique is maximum fitted for an influence system analysis. In power stream analysis, a high degree accuracy and a quicker answer time square measure needed to work out that technique is best to use.

Hand predictions square measure appropriate for the estimation of the in activities features of a number of individual circuits, however correct predictions of load streams or short circuits analysis' would be impractical while not the employment of laptop programs. The employment of digital computers to compute load stream started since middle Nineteen Fifties. There are completely several ways practical for load stream calculation. The event of those ways is especially diode by the essential demand of load stream calculation like convergence properties, computing potency, memory demand, convenience and suppleness of the implementation. Include the regulation of quick and enormous size digital computers, every kind of power grid studies, as well as load stream, will currently be administered handily. The numerical technique provides Associate in Nursing obtainment to search out answer include the employment of laptop, thus there's ought to verify that of the numerical technique is quicker and additional reliable so as to own best result for load stream analysis.

6.2 Load Flow Analysis Method:

The numerical analysis concerning analysis the answer of pure mathematics equation forms the premise for analysis of the performance equations in laptop assisted power system analyses e.g. for load stream analysis. The initial step in performing arts load stream analysis is to create the Y-bus admittance mistreatment the conductor and electrical device computer file. The nodal equation for an influence system network mistreatment Y bus is written as follows:

$$I = Y_{\text{Bus}} V \qquad \text{……….(1)}$$

The nodal equation can be written in a common form for an n bus process.

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \quad \text{for } i = 1, 2, 3, n \qquad \text{…………(2)}$$

The complex power delivered to bus is

$$P_i + jQ_i = V_i I_i^* \qquad \text{…….(3)}$$

$$I_i = \frac{P_i - jQ_i}{V_i^*} \qquad \text{……..(4)}$$

Substituting for I_i in terms of $P_i \,\&\, Q_i$, the equation gives

$$\frac{P_i - jQ_i}{V_i^*} = V_i \sum_{j=1}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j \quad j \neq i \qquad \text{………..(5)}$$

The higher than equation uses unvarying techniques to resolve load stream issues. Hence, it's necessary to review the common types of the assorted analysis methods; Gauss-Seidel, Newton-Raphson and quick decoupled load stream.

6.2.1 Gauss-Seidel Method:

This technique is developed supported the Gauss technique. It's Associate in Nursing repetitious technique sensible for determination set of nonlinear algebraically equations. The strategy makes use of Associate in Nursing initial guess for price of voltage, to get a computed price of a specific variable. The initial guess price is replaced by a computed price. The method is then continual till the iteration analysis converges. The convergence is dead sensitive to the beginning customary occupied. However this technique suffers since poor convergence options.

This is Associate in Nursing repetitious technique that is sensible to unravel Eq. (5) for the worth of Vi, and also the repetitious sequence becomes,

$$V_i^{(k+1)} = \frac{\dfrac{P_i^{sch} - jQ_i^{sch}}{V_i^*} + \sum y_{ij} V_j^{(k)}}{\sum y_{ij}} \quad j \neq i \qquad \text{……….(6)}$$

Using G. R. Kirchhoff current law, then the important and also the reactive powers offer into the buses, like generator buses, and have a positive price. The important and also the reactive powers streaming away since the buses, like load buses and have a negative commonplace.

Pi and alphabetic character i area unit resolved since Equation (5) which supplies,

$$P_i^{(k+1)} = \mathrm{Real}\left[V_i^{*(k)}\left\{\sum\nolimits_{i=0}^{n} y_{ij} - \sum\nolimits_{ji}^{n} V_i^{(k)}\right\}\right] \quad j \neq i \qquad \text{…………(7)}$$

$$Q_i^{(k+1)} = \mathrm{Imaginary}\left[V_i^{*(k)}\left\{\sum\nolimits_{j=1}^{n} y_{ij} - \sum\nolimits_{ji}^{n} V_i^{(k)}\right\}\right] \quad j \neq i \qquad \text{…….(8)}$$

Equation (6) becomes,

$$V_I^{(k+1)} = \frac{\dfrac{P_i^{sch} - jQ_i^{sch}}{V_i^{*(k)}} - \sum Y_{ij} V_j^{(k)}}{Y_{ii}} \qquad \text{……..(9)}$$

And,

$$P_i^{(k+1)} = \mathrm{Real}\left[V_i^{*(k)}\left\{V_i^{*(k)} Y_{ii} + \sum\nolimits_{i=1,j=1}^{n} y_{ij} V_j^{(k)}\right\}\right] \quad j \neq i \qquad \text{…..(10)}$$

$$P_i^{(k+1)} = \mathrm{Imaginary}\left[V_i^{*(k)}\left\{V_i^{*(k)} Y_{ii} + \sum\nolimits_{i=1,j=1}^{n} y_{ij} V_j^{(k)}\right\}\right] \quad j \neq i \qquad \text{…….(11)}$$

The admittance to the bottom of line charging vulnerable and alternative mounted admittance to ground are enclosed into the diagonal part of the matrix.

6.2.2 Newton-Raphson Method:

This methodology was named once Isaac Newton and Joseph Raphson. The origin and formulation of Newton-Raphson methodology was dated back to late Sixties. It's Associate in Nursing unvaried methodology that approximates a collection of non-linear equation to a collection of linear equation mistreatment Taylor's series growth and therefore the terms square measure restricted to the one approximation. it's the utmost unvaried methodology sensible for the load stream as a result of its convergence options square measure relatively additional powerful compared to different various systems and therefore the responsibility of Newton-Raphson intention is relatively smart since it will solve cases that result in divergence embody different well-liked systems. If the occupied worth is close to the analysis, then the result's attained terribly quickly, however if the occupied worth is farther away since the analysis then the strategy might take longer to converge. This can be another unvaried load stream methodology that is wide sensible for resolution nonlinear equation.

The admittance matrix is sensible to write down equations for currents coming into an influence method.

Equation (2) is exposed in a polar form, in which j includes bus i.

$$I_i = \sum_{j=1}^{n} |Y_{ij}||V_i| < \theta_{ij} + \delta_j \qquad \text{.........(12)}$$

The real and reactive power at bus is

$$P_i - jQ_i = V_i^* I_i \quad (13)$$

Substituting for I_i in Equation (12) since Equation (13)

$$P_i - jQ_i = |V_i| < -\delta_i \sum_{j=1}^{n} |Y_{ij}||V_j| < \delta_{ij} + \delta_j \quad \text{....(14)}$$

The real and imaginary portions are separated:

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos\left(\theta_{ij} - \delta_i + \delta_j\right) \qquad \text{..........(15)}$$

$$Q_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin\left(\theta_{ij} - \delta_i + \delta_j\right) \qquad \text{........(16)}$$

The higher than Equation (15) and (16) represent a collection of non-linear pure mathematics equations in terms of |V| in per unit and δ in radians. Equation (15) and (16) area unit dilated in Taylor's series concerning the initial estimate and neglecting all higher order terms, the subsequent set of linear equations area unit attained.

$$\left[\begin{array}{c} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \hline \Delta Q_2^{(K)} \\ \vdots \\ \Delta Q_n^{(k)} \end{array}\right] = \left[\begin{array}{ccc|ccc} \frac{\partial P_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_2^{(k)}}{\partial \delta_n} & \frac{\partial P_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_n^{(k)}}{\partial \delta_n} & \frac{\partial P_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_n^{(k)}}{\partial |V_n|} \\ \hline \frac{\partial Q_2^{(K)}}{\partial \delta_2} & \cdots & \frac{\partial Q_2^{(K)}}{\partial \delta_n} & \frac{\partial Q_2^{(K)}}{\partial |V_2|} & \cdots & \frac{\partial Q_2^{(K)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(K)}}{\partial \delta_2} & \cdots & \frac{\partial Q_n^{(K)}}{\partial \delta_n} & \frac{\partial Q_n^{(K)}}{\partial |V_2|} & \cdots & \frac{\partial Q_n^{(K)}}{\partial |V_n|} \end{array}\right] \left[\begin{array}{c} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \hline \Delta Q_2^{(K)} \\ \vdots \\ \Delta Q_n^{(k)} \end{array}\right]$$

In the higher than equation, the part of the slack bus variable voltage magnificence and angle square measure omitted as a result of they're already glorious. The part of the Jacobian matrix square measure earned when portion derivatives of Equations (15) and (16) square measure exposed which supplies linear relevancy among little changes in voltage magnificence and voltage angle. The equation are often written in matrix type as:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_3 \\ J_2 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \quad \text{……..(17)}$$

J_1, J_2, J_3, J_4 are the elements of the Jacobian matrix.

The terms $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ is represented as:

$$\Delta P_i^{(k)} = P_i^{sch} - P_i^{(k)} \quad \text{……(18)}$$

$$\Delta Q_i^{(k)} = Q_i^{sch} - Q_i^{(k)} \quad \text{……..(19)}$$

The new estimates for bus voltage are

$$\delta^{(k+1)} = \delta_i^{(k)} + \Delta \delta_i^{(k)} \quad \text{………(20)}$$

$$\left|V^{(k+1)}\right| = \left|V_i^{(k)}\right| + \Delta\left|V_i^{(k)}\right| \quad \ldots\ldots.(21)$$

6.2.3 Fast Decoupled Method:

The quick Decoupled Power Stream methodology is one amongst the improved strategies, that relies on a simplification of the Newton-Raphson methodology and according by Stott and additionally in 1974. This methodology, just like the Newton-Raphson methodology, offers calculation simplifications, quick convergence and reliable results and have become a wide sensible methodology in load stream analysis. However, quick decouple for few cases, wherever high resistance-to-reactance (R/X) ratios or significant loading (low voltage) at few buses are gift, doesn't converge well as a result of it's AN approximation methodology and build few assumption to alter Jacobian matrix. For these cases, several efforts and developments are engineered to upon return these convergence obstacles. Few of them targeted the convergence of method embody high R/X ratios, et al. embody low voltage buses.

This methodology may be a modification of Newton-Raphson, that takes the advantage of the weak coupling among and because of the high X:R ratios. The Jacobian matrix of Equation (17) is attenuate to 0.5 by ignoring the component of J2 and J3. Equation (17) is simplified as:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & 0 \\ 0 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \quad \ldots\ldots\ldots.(22)$$

Expanding Equation (22) gives two separate matrixes.

$$\Delta P = J_1 \Delta\delta = \left[\frac{\partial P}{\partial \delta}\right] \Delta\delta \quad \ldots\ldots\ldots(23)$$

$$\Delta Q = J_4 \Delta|V| = \left[\frac{\partial P}{\partial |V|}\right] \Delta|V| \quad \ldots\ldots..(24)$$

$$\frac{\Delta P}{V_i} = -B'\Delta\delta \quad \ldots\ldots\ldots.(25)$$

$$\frac{\Delta Q}{V_i} = -B''\Delta|V|$$ …….(26)

B' and B" square measure the fanciful parts of the bus admittance. it's higher to ignore all shunt joined parts, on build the formation of J1 and J4 easy. this may yield only 1 individual matrix than playacting perennial inversion .The sequent and voltage magnificence and point changes square measure $\Delta\delta = -[B']^{-1}\frac{\Delta P}{|V|}$ …………..(27)

$$\Delta|V| = -[B'']^{-1}\frac{\Delta Q}{|V|}$$ ………(28)

Chapter 7

Fault Analysis

7.1 Introduction:

Under traditional scenario, an influence method manages beneath balanced scenario embody all equipments carrying traditional load currents and also the bus voltages being the prescribed borders. This agreement may be non-continuous thanks to a fault within the method. A fault in an exceedingly circuit may be a lay landscapist that interferes embody the conventional stream of current. a brief circuit fault arrives once the insulation of the method lay downs leading to low electrical phenomenon path either among phases or phase(s) to ground. This causes overly high currents to stream within the circuit, requiring the activities of protecting instrument to stop injury to equipment. The contact faults may be classified as:

a) Symmetrical faults
b) Unsymmetrical faults

7.2 Symmetrical Fault:

That fault which provides rise to symmetrical fault currents is termed a symmetrical fault. The for maximum common example of symmetrical fault is once all the 3 conductors of a 3-phase line square measure brought along at the same time into a short-circuit agreement.

The symmetrical fault happens once all the 3 conductors of a 3-phase line square measure brought along at the same time into a short-circuit agreement as exhibition in Fig. 7.1 this kind of fault offers rise to symmetrical currents i.e. equal fault currents include 120^0 displacement. So concerning Fig. 7.1 fault currents IR, IY and IB are going to be equal in magnificence include120^0 displacement among them. Owing to balanced nature of fault, solely one* section would like be thought-about in predictions since agreement being the alternative 2 phases further will be resembling. The subsequent points could further be notably commented:

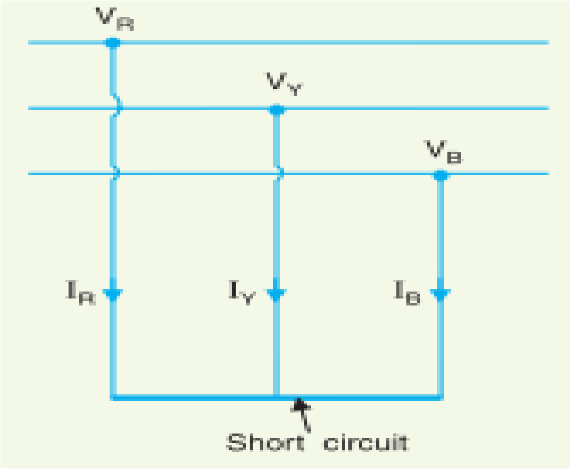


Fig.7.1 Symmetrical fault circuit

(a) The symmetrical fault rarely arrives in exercise as majority of the faults are of unsymmetrical nature. However, symmetrical fault predictions are being discussed in this section to enable the reader to understand the problems that short circuit situation present to the power system.

(b) The symmetrical fault is the maximum severe and imposes more heavy duty on the circuit breaker.

7.3 Unsymmetrical Faults:

Those faults which give rise to unsymmetrical currents are called unsymmetrical faults.

i. Single line-to-ground fault
ii. Line-to-line fault
iii. Double line-to-ground fault

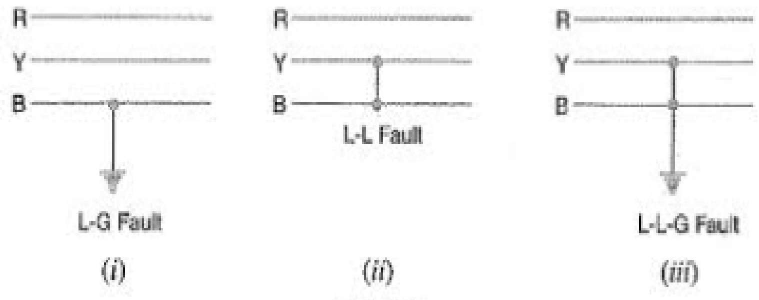
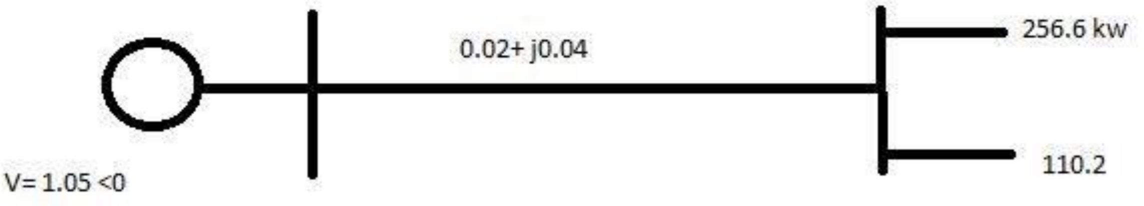


Fig.7.2 Unsymmetrical fault analysis

The great majority of faults on the facility method square measure of unsymmetrical nature; the most common sort being a short-circuit since one line to ground. The predictions of such fault currents square measure designed by “symmetrical components” technique.

Problem for Fault Analysis:



$$Y_{12} = \frac{1}{0.02+j0.04} = \text{10-j20}$$

$$S_2^{sch} = -\frac{(256.6+j110.2}{100} = \text{-2.566-j1.102}$$

$$V_2 = \frac{\frac{P_2^{sch} - jQ_2^{sch}}{V_2^{(0)}} + Y_{12}V_1}{Y_{12}} = \frac{\frac{-2.566+j1.102}{1.0-j0} + (10-j20)(1.05+j0)}{(10-j20)} = \text{19546-j0.0806}$$

For, 0.1

$$V_2 = \frac{\frac{-2.566+j25.53}{1.0-j0} + (10-j20)(1.05+j0)}{(10-j20)}$$

=-0.0255+j0.4079

For, 0.2

$$V_2 = \frac{\frac{-2.566+j12.57}{1.0-j0} + (10-j20)(1.05+j0)}{(10-j20)}$$

=0.4958+j0.1487

For, 0.3

$$V_2=\frac{\frac{-2.566+j8.15}{1.0-j0}+(10-j20)(1.05+j0)}{(10-j20)}$$

=0.6726+j0.0603

For, 0.4

$$V_2=\frac{\frac{-2.66+j5.87}{1.0-j0}+(10-j20)(1.05=jj0)}{(10-j20)}$$

=0.7638+j0.0147

For, 0.5

$$V_2=\frac{\frac{-2.566+j4.44}{1.0-j0}+(10-j20)(1.02+j0)}{(10-j20)}$$

=0.8210+j0.0169

For, 0.6

$$V_2=\frac{\frac{-2.566+j3.42}{1.0-j0}+(10-j20)(1.05+jo)}{(10-j20)}$$

=0.8618-j0.0342

For, 0.7

$$V_2=\frac{\frac{-2.566+j2.62}{1.0-j0}+(10-j20)(1.05+j0)}{(10-j20)}$$

=0.8938-j0.0502

For, 0.8

$$V_2=\frac{\frac{-2.566+j1.92}{1.0-j0}+(10-j20)(1.05+j0)}{(10-j20)}$$

=0.9218-j0.0642

For, 0.9

$$V_2 = \frac{\frac{-2.566+j1.24}{1.0-j0} + (10-j20)(1.05+j0)}{(10-j20)}$$

=0.9490-j0.778

For, 1

$$V_2 = \frac{\frac{-2.566+j0}{1.0-j0} + (10-j20)(1.05+j0)}{(10-j20)}$$

=0.9986-j0.1026

Table-7.1

SI	Power Factor	V_2
1	0.1	- 0.0225+j0.4059
2	0.2	0.4958+j0.1487
3	0.3	0.6726+j0.0603
4	0.4	0.7638+j0.0147
5	0.5	0.8210+j0.0179
6	0.6	0.8618-j0.0343
7	0.7	0.8938-j0.0502
8	0.8	0.9218-j0.0642
9	0.9	0.9490-j0.0778
10	1.0	0.9986-j0.1026

7.4 Effect of Fault on Transmission Line:

Faults will limb or disrupt power system in many ways that. Faults rise the voltages and currents at bound points on the system. An outsized voltage and current might limb the insulation and reduces the lifetime of the instrumentality. Faults will cause the system to become unstable, and further the three-phase system instrumentality manages improperly. Hence, it's necessary that, on the incidence of the fault, the fault section ought to be linked. So, the traditional activities of the border of the system isn't sensed.

Chapter 8

Stability Analysis

1.1 Introduction:

The tendency of an influence system to develop restoring forces adequate or bigger than distressing forces to keep up the state of equilibrium, this is known as stability. If the force has tendency to carry machines in synchronism with each other square measure comfortable to beat the distressing forces, the system is alleged to stay stable.

When a disturbance is occurred the stability downside is bothered with the behavior of the synchronous machine. For convenience of study, stability issues square measure usually divided into 2 major classes.

Steady-state stability: Steady state stability refers to the ability of the power system to the region synchronicity once small and slow disturbances, like gradual power changes. Associate in Nursing extension of the steady-state stability is assumed as a result of the dynamic stability. The dynamic stability worries with small disturbances lasting for a lengthy time with the inclusion of automatic management devices.

Transient stability: Transient stability studies deal with the impact of big, sharp disturbances just like the prevalence of a fault, the sharp outage of a line or the sharp application or removal of load. Transient stability studies square measure required to confirm that the system will stand up to the transient condition following a significant disturbance. Frequently, such studies square measure conducted once new generation and transmittal facilities square measure planned. The studies unit helpful when making a decision such issue as a result of the character of the relaying system needed, essential clearing time of circuit breakers, voltage level of, and transfer capability between systems.

8.2 Swing Equation:

Let’s consider a 3-phase synchronous alternator that is activated by a prime mover. The machine’s rotor rotates by a given equation which is known as equations of motion.

$$J\frac{d^2\theta}{dt^2} = T_m - T_e = T_a \qquad \text{……..(8.1)}$$

where

J = is the total moment of inertia of the rotor mass in kgm^2

T_m = is the mechanical torque supplied by the prime mover in N-m

T_e = is the electrical torque output of the alternator in N-m

θ = is the angular position of the rotor in rad/s

Due to neglect the losses, difference between the mechanical torque and electrical torque gives the net accelerating torque T_a. In the steady state, the electrical torque is equal to the mechanical torque, and the accelerating power will be zero. During this period the rotor will rotate at its synchronous speed in rad/s.

The spatial relation θ is measured with a stationary arrangement. To represent it with relation to the synchronously rotating frame, we define

$$\theta = \omega_s t + \delta \qquad \text{........(8.2)}$$

The relation θ is measured with a stationary arrangement. To represent it with relevancy the synchronously rotating frame, we define

$$\frac{d\theta}{dt} = \omega_s + \frac{d\delta}{dt} \qquad \text{........... (8.3)}$$

Defining the angular speed of the rotor as

$$\omega_r = \frac{d\theta}{dt}$$

we can write (9.8) as

$$\omega_r - \omega_s = \frac{d\delta}{dt} \qquad ....(8.4)$$

Taking derivative of (8.3), we can then rewrite (8.1) as

$$J\frac{d^2\delta}{dt^2} = T_m - T_e = T_a \quad ....(8.5)$$

Multiplying both side by ω_m we get

$$J\omega_r \frac{d^2\delta}{dt^2} = P_m - P_e = P_a \qquad .... (8.6)$$

Now, P_m, P_e and P_a respectively are the mechanical, electrical and accelerating power in MW.

We now define a normalized inertia constant as

$$H = \frac{\text{Stored kinetic energy at synchronou s speed in mega - joules}}{\text{Generator MVA rating}} = \frac{J\omega_s^2}{2S_{rated}} \qquad ..... (8.7)$$

Substituting (8.7) in (8.5) we get

$$2H\frac{S_{rated}}{\omega_s^2}\omega_r \frac{d^2\delta}{dt^2} = P_m - P_e = P_a \qquad ....(8.8)$$

In steady state, the machine angular speed is adequate to the synchronous speed and thus we will replace ωr within the on top of equation by ωs. Note that in (8.8) Pm, letter of the alphabet and Pa square measure given in MW. Thus dividing them by the generator MVA rating started we will get these quantities in per unit. Thus dividing either side of (8.8) by started we have a tendency to get

$$\frac{2H}{\omega_s}\frac{d^2\delta}{dt^2} = P_m - P_e = P_a \text{ per unit} \qquad ....(8.9)$$

8.3 Equal Area Criterion:

Consider the ability angle curve shown in Fig. 9.3. Suppose the system of Fig. 9.1 is working within the steady state delivering an influence of Pm at associate angle of δ0 once because of malfunction of the road, circuit breakers open reducing the real power transferred to zero. Since Pm remains constant, the fast power Pa becomes adequate to Pm. The distinction within the power provides rise to the speed of modification of hold on K.E. within the rotor plenty. so the rotor can accelerate below the constant influence of non-zero fast power and therefore the load angle can increase. Currently suppose the electrical fuse re-closes at AN angle δ_c. The power can then revert back to the traditional in operation curve. At that time, the electric power are going to be over the mechanical power and also the fast power are going to be negative. This can cause the machine decelerate. However, thanks to the inertia of the rotor lots, the load angle can still persevere increasing. The rise during this angle could eventually stop and also the rotor could begin decelerating, otherwise the system can lose synchronization.

Note that,

$$\frac{d}{dt}\left(\frac{d\delta}{dt}\right)^2 = 2\left(\frac{d\delta}{dt}\right)\left(\frac{d^2\delta}{dt^2}\right) ....(8.10)$$

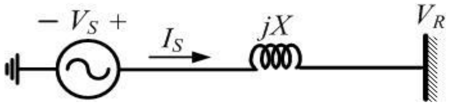


Fig. 8.1 Diagram of equal area criterion

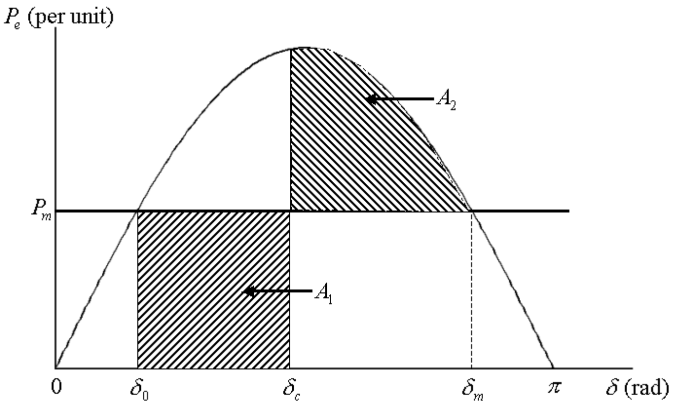


Fig. 8.2 Power-angle curve for equal area criterion

Multiplying all of the sides of (8.9) by $d\delta/dt$ and we get

$$\frac{H}{\omega_s}\frac{d}{dt}\left(\frac{d\delta}{dt}\right)^2 = \left(P_m - P_e\right)\frac{d\delta}{dt}$$

Multiplying both sides of the above equation by *dt* and then integrating between two arbitrary angles δ_0 and δ_c we get

$$\frac{H}{\omega_s}\left(\frac{d\delta}{dt}\right)^2\Bigg|_{\delta_0}^{\delta_c} = \int_{\delta_0}^{\delta_c}\left(P_m - P_e\right)d\delta \qquad ....(8.11)$$

Now suppose the generator is at rest at δ0. We tend to then have dδ/dt = zero. Once a fault happens, the machine starts fast. Once the fault is cleared, the machine keeps on fast before it reaches its peak at δc, at that purpose we tend to once more have dδ/dt = zero. so the realm of fast is given from (8.11) as

$$A_1 = \int_{\delta_0}^{\delta_c}\left(P_m - P_e\right)d\delta = 0 \qquad ....(8.12)$$

Similarly, we can define the area of deceleration. In Fig. 8.2, the area of acceleration is given by A_1 while the area of deceleration is given by A_2. This is given by

$$A_2 = \int_{\delta_c}^{\delta_m} (P_e - P_m) d\delta = 0 \qquad \text{........(8.13)}$$

Now take into account the case once the road is reclosed at δc specified the realm of acceleration is larger than the realm of fastness, i.e., A1>A2. The generator load angle can then cross the purpose δm, on the far side that the electric power are but the mechanical power forcing the fast power to be positive. The generator can thus begin fast before is slows down fully and can eventually become unstable. If, on the opposite hand, A1space is larger than the fast space, the machine can decelerate fully before fast once more. The rotor inertia can force the following acceleration and speed areas to be smaller than the primary ones and also the machine conceptually attain the steady state. If the 2 area unites are equal, i.e., A1 = A2, then the fast space is capable decelerating space and this is often defines the boundary of the soundness limit. The clearing angle δc for this mode is named the essential clearing angle and is denoted by δcr. we tend to then get from Fig. 8.2 by subbing δc = δcr

$$\int_{\delta_0}^{\delta_{cr}} (P_m - P_e) d\delta = \int_{\delta_{cr}}^{\delta_m} (P_e - P_m) d\delta \qquad \text{..........(8.14)}$$

We can find the critical clearing angle from the equation of (8.14). Critical clearing angle depends on the equality of the areas, which is called the equal area criterion.

Chapter 9

CONCLUSION

1.1 Conclusion:

Nowadays in 21th century technology is part and parcel in our life. But technology is depend on power. For this modernization power plays an important note. Electrical power is more effective then other from of due to is easiest conversion. If we provide electrical power we need a system which generate electrical power and send one place to other place by transmission. To transmit the power we need transmission on medium. Electrical power is generated totally different variety of generating stations. These station don't seem to be essentially settled at the load center. Throughout construction of generation station some variety of effective factors thought of from economical purpose. For the effective factors we have to decide that what kinds of transmission are required, which they can be short, medium, and long transmission. The transmission depends on the distance between the generating station to substation. If the distance is so longer we should DC transmission and the transmission will be economical for like as long transmission. Similarly voltage, power factor has a great impact on the transmission. Power factor is directly proportional to the transmission efficiency. We always want more output at the same time less loss will occurred the systems.

If we successfully handle the effective factors the performance will be better

Reference:

1) Principles of Power System by V.K. Metha, RohitMetha
2) Elements of Power System Analysis by William D. Stevenson, Jr.
3) Electrical Power System by D. Das
4) https://ieeexplore.ieee.org
5) https://repository.tudelft.nl
6) https://en.wikipedia.org
7) http://www.electricalpowerenergy.com
8) https://nptel.ac.in
9)http://eie.uonbi.ac.ke
10)https://www.rose-hulman.edu
11)https://www.researchgate.net
12)https://www.scirp.org
13)https://www.quora.com
14)https://www.electrical4u.com
15)http://www.scientechworld.com
16)https://www.slideshare.net
17)https://openei.org
18)https://www.archtoolbox.com