

UNIT - V

A.C DISTRIBUTION

AC Distribution Calculations:

AC Distribution Calculations differ from those of D.C. distribution in the following respects:

- In the case of D.C. system, the voltage drop is due to resistance alone. However, in A.C. system, the voltage drops are due to the combined effects of resistance, inductance and capacitance.
- In a D.C. system, additions and subtractions of currents or voltages are done arithmetically but in case of A.C. system, these operations are done vectorially.
- In an A.C. system, power factor (p.f.) has to be taken into account. Loads tapped off from the distributor are generally at different power factors.
- There are two ways of referring power factor viz
- It may be referred to supply or receiving end voltage which is regarded as the reference
- It may be referred to the voltage at the load point itself.

There are several ways of solving AC Distribution Calculations. However, symbolic notation method has been found to be most convenient for this purpose. In this method, voltages, currents and impedances are expressed in complex notation and the calculations are made exactly as in D.C. distribution.

Methods of Solving AC Distribution Problems:

In AC Distribution Calculations, power factors of various load currents have to be considered since currents in different sections of the distributor will be the vector sum of load currents and not the arithmetic sum. The power factors of load currents may be given

- (i) w.r t. receiving or sending end voltage or
- (ii) w.r.t. to load voltage itself. Each case shall be discussed separately.

(i) **Power Factors Referred To Receiving End Voltage:** Consider an a.c. distributor AB with concentrated loads of I_1 and I_2 tapped off at points C and B as shown in Fig. 14.1. Taking the receiving end voltage V_B as the reference vector, let lagging power factors at C and B be $\cos \Phi_1$ and $\cos \Phi_2$ w.r.t. V_B . Let R_1, X_1 and R_2, X_2 be the resistance and reactance of sections AC and CB of the distributor.

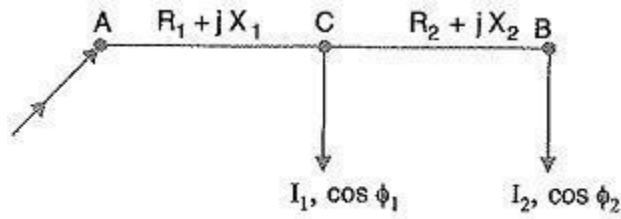


Fig. 14.1

Impedance of section AC, $\overrightarrow{Z_{AC}} = R_1 + jX_1$

Impedance of section CB, $\overrightarrow{Z_{CB}} = R_2 + jX_2$

Load current at point C, $\overrightarrow{I_1} = I_1 (\cos \phi_1 - j \sin \phi_1)$

Load current at point B, $\overrightarrow{I_2} = I_2 (\cos \phi_2 - j \sin \phi_2)$

Current in section CB, $\overrightarrow{I_{CB}} = \overrightarrow{I_2} = I_2 (\cos \phi_2 - j \sin \phi_2)$

Current in section AC, $\overrightarrow{I_{AC}} = \overrightarrow{I_1} + \overrightarrow{I_2}$
 $= I_1 (\cos \phi_1 - j \sin \phi_1) + I_2 (\cos \phi_2 - j \sin \phi_2)$

Voltage drop in section CB, $\overrightarrow{V_{CB}} = \overrightarrow{I_{CB}} \overrightarrow{Z_{CB}} = I_2 (\cos \phi_2 - j \sin \phi_2) (R_2 + jX_2)$

Voltage drop in section AC, $\overrightarrow{V_{AC}} = \overrightarrow{I_{AC}} \overrightarrow{Z_{AC}} = (\overrightarrow{I_1} + \overrightarrow{I_2}) Z_{AC}$
 $= [I_1 (\cos \phi_1 - j \sin \phi_1) + I_2 (\cos \phi_2 - j \sin \phi_2)] [R_1 + jX_1]$

Sending end voltage, $\overrightarrow{V_A} = \overrightarrow{V_B} + \overrightarrow{V_{CB}} + \overrightarrow{V_{AC}}$

Sending end current, $\overrightarrow{I_A} = \overrightarrow{I_1} + \overrightarrow{I_2}$

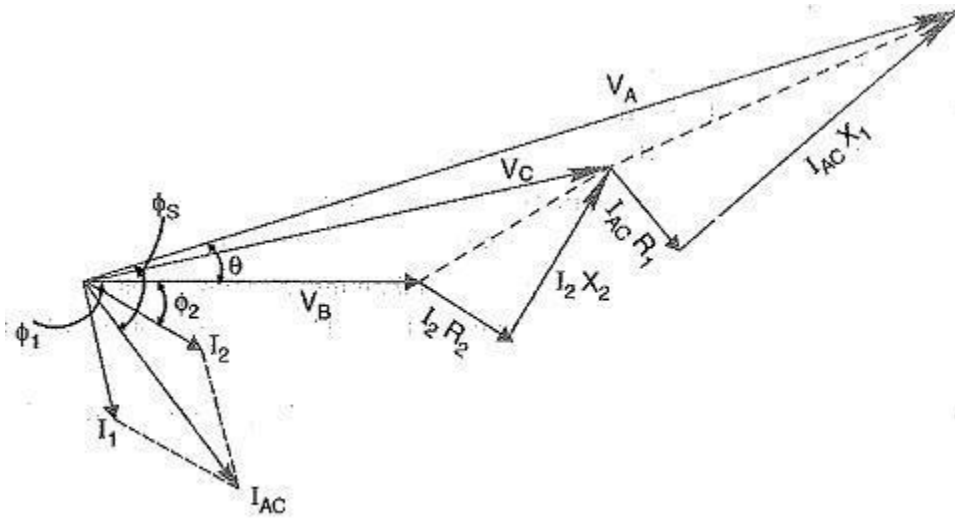


Fig. 14.2

The vector diagram of the AC Distribution Calculations under these conditions is shown in Fig. 14.2. Here, the receiving end voltage V_B is taken as the reference vector. As power factors of loads are given w.r.t. V_B , therefore, I_1 and I_2 lag behind V_B by ϕ_1 and ϕ_2 respectively.

(ii) **Power Factors Referred To Respective Load Voltages:** Suppose the power factors of loads in the previous Fig. 14.1 are referred to their respective load voltages. Then ϕ_1 is the phase angle between V_C and I_1 and ϕ_2 is the phase angle between V_B and I_2 . The vector diagram under these conditions is shown in Fig. 14.3.

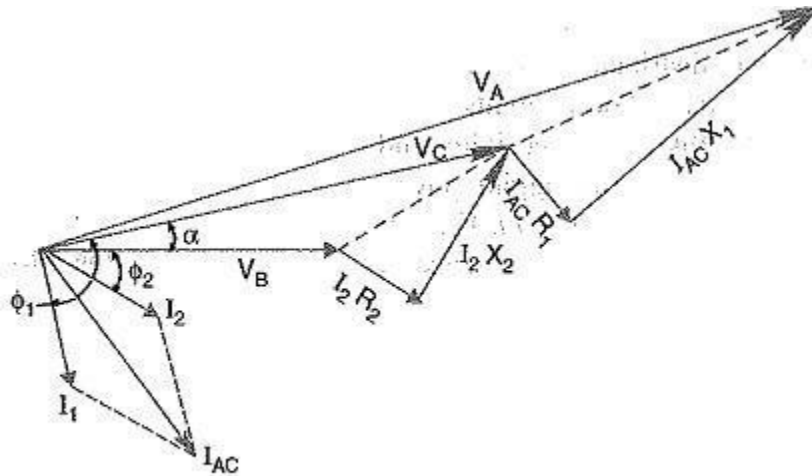


Fig. 14.3

$$\text{Voltage drop in section } CB = \vec{I}_2 \vec{Z}_{CB} = I_2 (\cos \phi_2 - j \sin \phi_2) (R_2 + j X_2)$$

$$\text{Voltage at point } C = \vec{V}_B + \text{Drop in section } CB = V_C \angle \alpha \text{ (say)}$$

$$\vec{I}_1 = I_1 \angle -\phi_1 \text{ w.r.t. voltage } V_C$$

$$\vec{I}_1 = I_1 \angle -(\phi_1 - \alpha) \text{ w.r.t. voltage } V_B$$

$$\vec{I}_1 = I_1 [\cos (\phi_1 - \alpha) - j \sin (\phi_1 - \alpha)]$$

$$\vec{I}_{AC} = \vec{I}_1 + \vec{I}_2$$

Introduction

Power generated in power stations pass through large and complex networks like transformers, overhead lines, cables and other equipment and reaches at the end users.

It is fact that the unit of electric energy generated by Power Station does not match with the units distributed to the consumers. Some percentage of the units is lost in the distribution network.

This difference in the generated and distributed units is known as Transmission and Distribution loss. Transmission and Distribution loss are the amounts that are not paid for by users.

$$\text{T\&D Losses} = (\text{Energy Input to feeder(Kwh)} - \text{Billed Energy to Consumer(Kwh)}) / \text{Energy Input kwh} \times 100$$

There are two types of Transmission and Distribution Losses:

1. **Technical Losses**
2. **Non Technical Losses (Commercial Losses)**

1. Technical Losses

The technical losses are due to energy dissipated in the conductors, equipment used for transmission line, transformer, sub transmission line and distribution line and magnetic losses in transformers. Technical losses are normally **22.5%**, and directly depend on the network characteristics and the mode of operation.

The major amount of losses in a power system is in primary and secondary distribution lines. While transmission and sub-transmission lines account for only about 30% of the total losses. Therefore the primary and secondary distribution systems must be properly planned to ensure within limits.

- The unexpected load increase was reflected in the increase of technical losses above the normal level
- Losses are inherent to the distribution of electricity and cannot be eliminated.

There are two Type of Technical Losses.

1. Permanent / Fixed Technical losses

- Fixed losses do not vary according to current. These losses take the form of heat and noise and occur as long as a transformer is energized
- Between 1/4 and 1/3 of technical losses on distribution networks are fixed losses. Fixed losses on a network can be influenced in the ways set out below
- Corona Losses
- Leakage Current Losses
- Dielectric Losses
- Open-circuit Losses
- Losses caused by continuous load of measuring elements
- Losses caused by continuous load of control elements

2. Variable Technical losses

Variable losses vary with the amount of electricity distributed and are, more precisely, proportional to the square of the current. Consequently, a 1% increase in current leads to an increase in losses of more than 1%.

- Between 2/3 and 3/4 of technical (or physical) losses on distribution networks are variable Losses.
- By increasing the cross sectional area of lines and cables for a given load, losses will fall. This leads to a direct trade-off between cost of losses and cost of capital expenditure. It has been suggested that optimal average utilization rate on a distribution network that considers the cost of losses in its design could be as low as 30 per cent.
- Joule losses in lines in each voltage level
- Impedance losses
- Losses caused by contact resistance.

Main Reasons for Technical Losses

1. Lengthy Distribution lines

In practically **11 KV and 415 volts lines**, in rural areas are extended over long distances to feed loads scattered over large areas. Thus the primary and secondary distributions lines in rural areas are largely radial laid usually extend over long distances.

This results in high line resistance and therefore high I^2R losses in the line.

- Haphazard growths of sub-transmission and distribution system in to new areas.
- Large scale rural electrification through long 11kV and LT lines.

2. Inadequate Size of Conductors of Distribution lines

The size of the conductors **should be selected on the basis of KVA x KM capacity of standard conductor for a required voltage regulation**, but rural loads are usually scattered and generally fed by radial feeders. The conductor size of these feeders should be adequate.

3. Installation of Distribution transformers away from load centers

Distribution Transformers are not located at Load center on the Secondary Distribution System.

In most of case Distribution Transformers are not located centrally with respect to consumers. Consequently, the farthest consumers obtain an extremity low voltage even though a good voltage levels maintained at the transformers secondary.

This again leads to higher line losses. (The reason for the line losses increasing as a result of decreased voltage at the consumers end therefore in order to reduce the voltage drop in the line to the farthest consumers, the distribution transformer should be located at the load center to keep voltage drop within permissible limits.)

4. Low Power Factor of Primary and secondary distribution system

In most LT distribution circuits normally the Power Factor ranges from 0.65 to 0.75. A low Power Factor contributes towards high distribution losses.

For a given load, if the Power Factor is low, the current drawn in high And the losses proportional to square of the current will be more. Thus, line losses owing to the poor PF can be reduced by improving the Power Factor.

This can be done by application of shunt capacitors.

- Shunt capacitors can be connected either in secondary side (11 KV side) of the 33/11 KV power transformers or at various point of Distribution Line.

- The optimum rating of capacitor banks for a distribution system is 2/3rd of the average KVAR requirement of that distribution system.
- The vantage point is at 2/3rd the length of the main distributor from the transformer.
- A more appropriate manner of improving this PF of the distribution system and thereby reduce the line losses is to connect capacitors across the terminals of the consumers having inductive loads.
- By connecting the capacitors across individual loads, the line loss is reduced from 4 to 9% depending upon the extent of PF improvement.

5. Bad Workmanship

Bad Workmanship contributes significantly role towards increasing distribution losses.

Joints are a source of power loss. Therefore the number of joints should be kept to a minimum. Proper jointing techniques should be used to ensure firm connections. Replacement of deteriorated wires and services should also be made timely to avoid any cause of leaking and loss of power.

6. Feeder Phase Current and Load Balancing>

One of the easiest loss savings of the distribution system is balancing current along three-phase circuits.

Feeder phase balancing also tends to balance voltage drop among phases giving three-phase customers less voltage unbalance. Amperage magnitude at the substation doesn't guarantee load is balanced throughout the feeder length.

Feeder phase unbalance may vary during the day and with different seasons. Feeders are usually considered "balanced" when phase current magnitudes are within 10. Similarly, balancing load among distribution feeders will also lower losses assuming similar conductor resistance. This may require installing additional switches between feeders to allow for appropriate load transfer.

Bifurcation of feeders according to Voltage regulation and Load.

7. Load Factor Effect on Losses

Power consumption of customer varies throughout the day and over seasons.

Residential customers generally draw their highest power demand in the evening hours. Same commercial customer load generally peak in the early afternoon. Because current level (hence,

load) is the primary driver in distribution power losses, keeping power consumption more level throughout the day will lower peak power loss and overall energy losses.

Load variation is Called load factor and It varies from 0 to 1.

Load Factor = Average load in a specified time period / peak load during that time period.

For example, for 30 days month (720 hours) peak Load of the feeder is 10 MW. If the feeder supplied a total energy of 5,000 MWh, the load factor for that month is $(5,000 \text{ MWh}) / (10 \text{ MW} \times 720) = 0.69$.

Lower power and energy losses are reduced by raising the load factor, which, evens out feeder demand variation throughout the feeder.

The load factor has been increase by offering customers “time-of-use” rates. Companies use pricing power to influence consumers to shift electric-intensive activities during off-peak times (such as, electric water and space heating, air conditioning, irrigating, and pool filter pumping).

With financial incentives, some electric customers are also allowing utilities to interrupt large electric loads remotely through radio frequency or power line carrier during periods of peak use. Utilities can try to design in higher load factors by running the same feeders through residential and commercial areas.

8. Transformer Sizing and Selection

Distribution transformers use **copper conductor windings** to induce a magnetic field into a grain-oriented silicon steel core. **Therefore, transformers have both load losses and no-load core losses.**

Transformer copper losses vary with load based on the resistive power loss equation ($P_{\text{loss}} = I^2 R$). For some utilities, economic transformer loading means loading distribution transformers to capacity-or slightly above capacity for a short time-in an effort to minimize capital costs and still maintain long transformer life.

However, since peak generation is usually the most expensive, **total cost of ownership (TCO)** studies should take into account the cost of peak transformer losses. Increasing distribution transformer capacity during peak by one size will often result in lower total peak power dissipation-more so if it is overloaded.

Transformer no-load excitation loss (iron loss) occurs from a changing magnetic field in the transformer core whenever it is energized. Core loss varies slightly with voltage but is essentially considered constant. Fixed iron loss depends on transformer core design and steel lamination molecular structure. Improved manufacturing of steel cores and introducing amorphous metals (such as metallic glass) have reduced core losses.

9. Balancing 3 phase loads

Balancing 3-phase loads periodically throughout a network can reduce losses significantly. It can be done relatively easily on overhead networks and consequently offers considerable scope for cost effective loss reduction, given suitable incentives.

10. Switching off transformers

One method of **reducing fixed losses** is to switch off transformers in periods of low demand. If two transformers of a certain size are required at a substation during peak periods, only one might be required during times of low demand so that the other transformer might be switched off in order to reduce fixed losses.

This will produce some **offsetting increase in variable losses** and might affect security and quality of supply as well as the operational condition of the transformer itself. However, these trade-offs will not be explored and optimized unless the cost of losses are taken into account.

11. Other Reasons for Technical Losses

- Unequal load distribution among three phases in L.T system causing high neutral currents.
- leaking and loss of power
- Over loading of lines.
- Abnormal operating conditions at which power and distribution transformers are operated
- Low voltages at consumer terminals causing higher drawl of currents by inductive loads.
- Poor quality of equipment used in agricultural pumping in rural areas, cooler air-conditioners and industrial loads in urban areas.

SYSTEM GROUNDING

The process of connecting some electrical part of the power system (e.g. neutral point of a star-connected system, one conductor of the secondary of a transformer etc.) to earth (i.e. soil) is called System Grounding. The system grounding has assumed considerable importance in the fast expanding power system. By adopting proper schemes of system grounding, we can achieve many advantages including protection, reliability and safety to the power system network. But before discussing the various aspects of neutral grounding, it is desirable to give two examples to appreciate the need of system grounding. (i) Fig. 26.5 (i) shows the primary winding of a distribution transformer connected between the line and neutral of a 11 kV line. If the secondary conductors are ungrounded, it would appear that a person could touch either secondary conductor without harm because there is no ground return. However, this is not true. Referring to Fig. 26.5, there is capacitance C1 between primary and secondary and capacitance C2 between secondary

and ground. This capacitance coupling can produce a high voltage between the secondary lines and the ground.

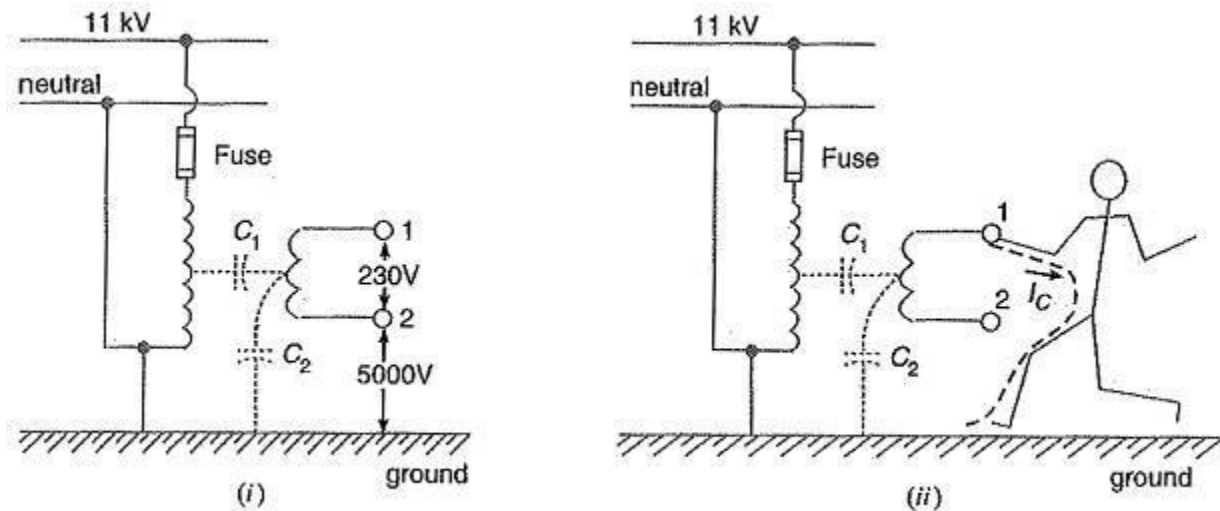


Fig. 26.5

Depending upon the relative magnitudes of C_1 and C_2 , it may be as high as 20% to 40% of the primary voltage. If a person touches either one of the secondary wires, the resulting capacitive current I_C flowing through the body could be dangerous even in case of small transformers [See Fig. 26.5(U)]. For example, if I_C is only 20 mA, the person may get a fatal electric shock. If one of the secondary conductors is grounded, the capacitive coupling almost reduces to zero and so is the capacitive current I_C . As a result, the person will experience no electric shock. This explains the importance of system grounding.

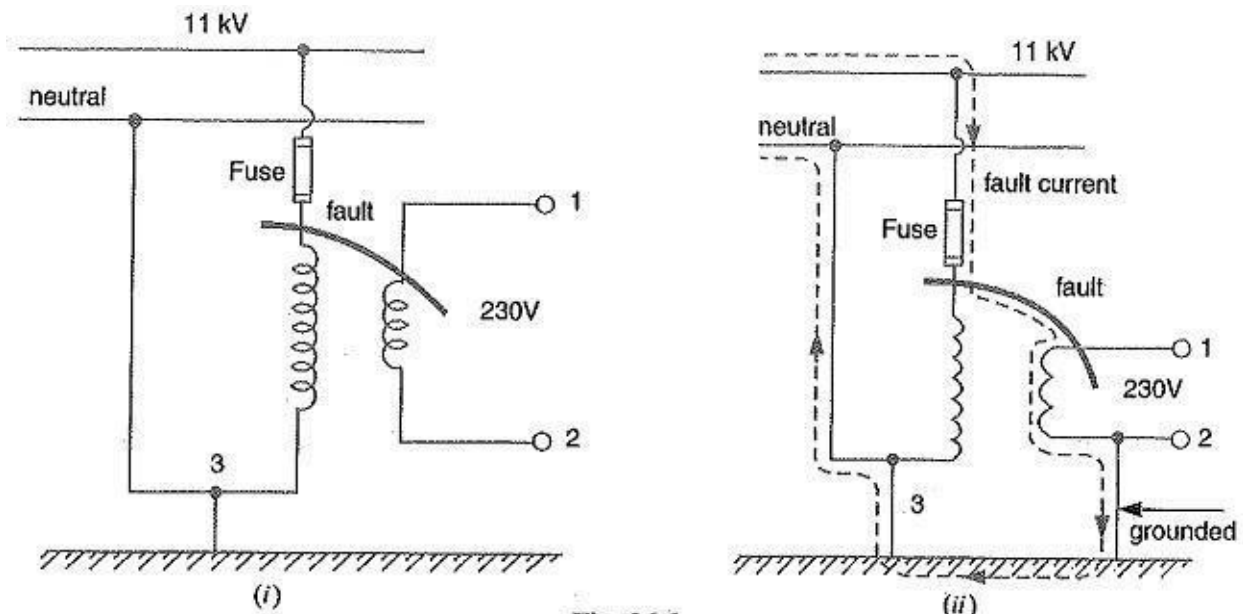


Fig. 26.6

(ii) Let us now turn to a more serious situation. Fig. 26.6 (i) shows the primary winding of a distribution transformer connected between the line and neutral of a 11 kV line. The secondary conductors are ungrounded. Suppose that the high voltage line (11 kV in this case) touches the 230 V conductor as shown in Fig. 26.6 (i). This could be caused by an internal fault in the transformer or by a branch or tree falling across the 11 kV and 230 V lines. Under these circumstances, a very high voltage is imposed between the secondary conductors and ground. This would immediately puncture the 230 V insulation, causing a Massive flashover. This flashover could occur anywhere on the secondary network, possibly inside a home or factory. Therefore, ungrounded secondary in this case is a potential fire hazard and may produce grave accidents under abnormal conditions. If one of the secondary lines is grounded as shown in Fig. 26.6(ii), the accidental contact between a 11 kV conductor and a 230 V conductor produces a dead short. The short-circuit current (Le. fault current) follows the dotted path shown in Fig. 26.6 (ii). This large current will blow the fuse on the 11 kV side, thus disconnecting the transformer and secondary distribution system from the 11 kV line. This explains the importance of system grounding in the line of the power system.

METHODS OF NEUTRAL GROUNDING

1. Grounding - Introduction

2. Neutral Grounding - Advantages of Neutral Grounding

3. Methods of Neutral Grounding

(i) Solid or effective grounding

(ii) Resistance grounding

(iii) Reactance grounding

(iv) Peterson-coil grounding

1. GROUNDING - INTRODUCTION

In power system, grounding or earthing means connecting frame of electrical equipment (non-current carrying part) or some electrical part of the system (e.g. neutral point in a star-connected system, one conductor of the secondary of a transformer etc.) to earth i.e. soil. This connection to earth may be through a conductor or some other circuit element (e.g. are resistor, a circuit breaker etc.) depending up on the situation, grounding or earthing offers two principal advantages. First, it provides protection to the power system. For example, If the neutral point of a star-connected system is grounded through a circuit breaker and phase to earth fault occurs on any one line, a large fault current will flow through the circuit breaker. The circuit breaker will open to isolate the faulty line. This protects the power system from the harmful effects of the fault. Secondly, earthing of electrical equipment ensures the safety of the persons handling the equipment. For example, if insulation fails, there will be a direct contact of the live

conductor with the metallic part (i.e. frame) of the equipment. Any person in contact with the metallic part of this equipment will be subjected to a dangerous electrical shock which can be fatal. In this chapter, we shall discuss the importance of grounding or earthing in the line of power system with special emphasis on neutral grounding.

Concept of Grounding

The process of connecting the metallic frame (i.e. non-current carrying part) of electrical equipment or some electrical part of the system (e.g. neutral point in a star-connected system, one conductor of the secondary of a transformer etc.) to earth (i.e. soil) is called grounding or earthing. It is strange but true that grounding of electrical systems is less understood aspect of power system. Nevertheless, it is a very important subject. If grounding is done systematically in the line of the power system, we can effectively prevent accidents and damage to the equipment of the power system and at the same time continuity of supply can be maintained. Grounding or earthing may be classified as: (i) Equipment grounding (ii) System grounding. Equipment grounding deals with earthing the non-current-carrying metal parts of the electrical equipment. On the other hand, system grounding means earthing some part of the electrical system e.g. earthing of neutral point of star-connected system in generating stations and substations.

2. Neutral Grounding

The process of connecting neutral point of 3-phase system to earth (i.e. soil) either directly or through some circuit element is called neutral grounding. Neutral grounding provides protection to personal and equipment. It is because during earth fault, the current path is completed through the earthed neutral and the protective devices (e.g. a fuse etc.) operate to isolate the faulty conductor from the rest of the system. This point is illustrated in Fig.

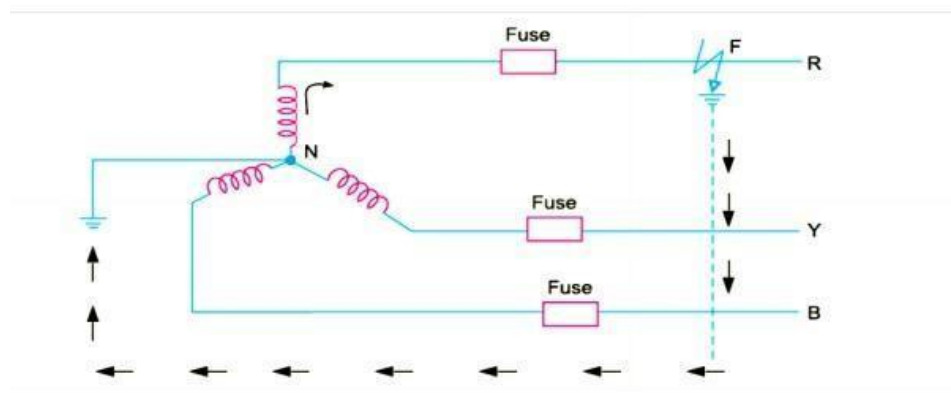


Fig. shows a 3-phase, star-connected system with neutral earthed. Suppose a single line to ground fault occurs in line R at point F. This will cause the current to flow through ground path as shown in Fig.1. Note that current flows from R phase to earth, then to neutral point N and

back to R-phase. Since the impedance of the current path is low, a large current flows through this path. This large current will blow the fuse in R-phase and isolate the faulty line R. This will protect the system from the harmful effects of the fault. One important feature of grounded neutral is that the potential difference between the live conductor and ground will not exceed the phase voltage of the system i.e. it will remain nearly constant.

Advantages of Neutral Grounding

The following are the advantages of neutral grounding

- (i) Voltages of the healthy phases do not exceed line to ground voltages i.e. they remain nearly constant.
- (ii) The high voltages due to arcing grounds are eliminated.
- (iii) The protective relays can be used to provide protection against earth faults. In case earth fault occurs on any line, the protective relay will operate to isolate the faulty line.
- (iv) The over voltages due to lightning are discharged to earth.
- (v) It provides greater safety to personnel and equipment.
- (vi) It provides improved service reliability.
- (vii) Operating and maintenance expenditures are reduced

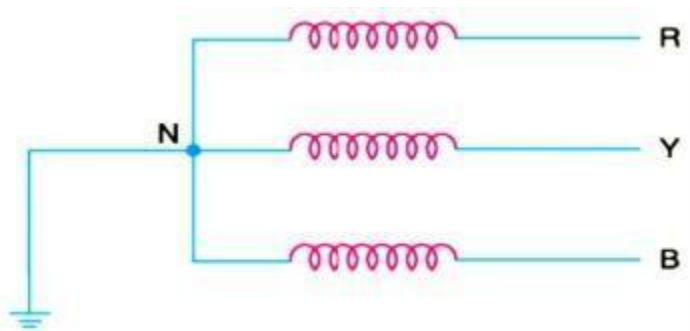
3. Methods of Neutral Grounding

The methods commonly used for grounding the neutral point of a 3-phase system are:

- (i) Solid or effective grounding
- (ii) Resistance grounding
- (iii) Reactance grounding
- (iv) Peterson-coil grounding

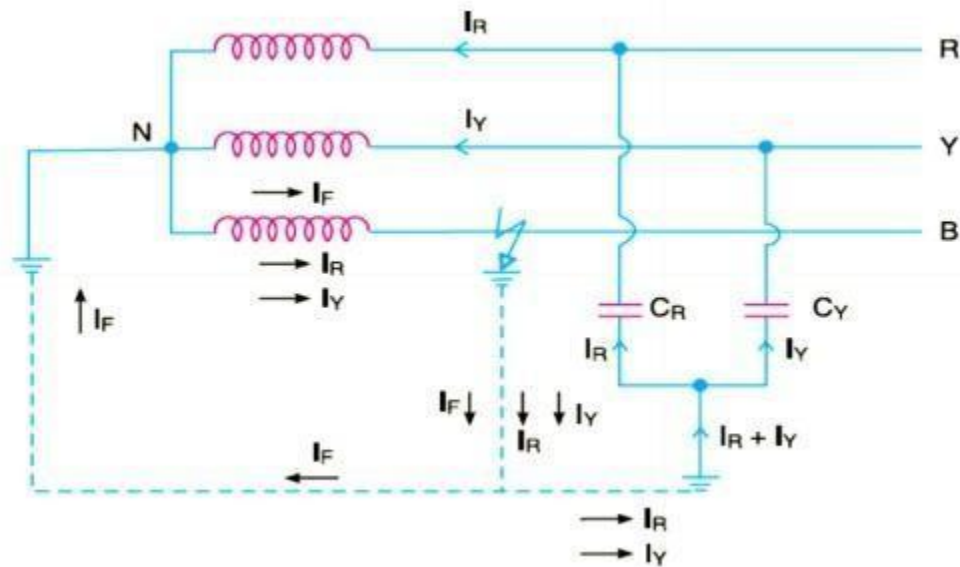
The choice of the method of grounding depends upon many factors including the size of the system, system voltage and the scheme of protection to be used.

(i) Solid Grounding



When the neutral point of a 3-phase system (e.g. 3-phase generator, 3-phase transformer etc.) is directly connected to earth (i.e. soil) through a wire of negligible resistance and reactance, it is

called solid grounding or effective grounding. Fig. shows the solid grounding of the neutral point. Since the neutral point is directly connected to earth through a wire, the neutral point is held at earth potential under all conditions. Therefore, under fault conditions, the voltage of any conductor to earth will not exceed the normal phase voltage of the system.



Advantages

The solid grounding of neutral point has the following advantages:

(i) The neutral is effectively held at earth potential.

(ii) When earth fault occurs on any phase, the resultant capacitive current I_C is in phase opposition to the fault current I_F . The two currents completely cancel each other. Therefore, no arcing ground or over-voltage conditions can occur. Consider a line to ground fault in line B as shown in Fig. The capacitive currents flowing in the healthy phases R and Y are I_R and I_Y respectively. The resultant capacitive current I_C is the phasor sum of I_R and I_Y . In addition to these capacitive currents, the power source also supplies the fault current I_F . This fault current will go from fault point to earth, then to neutral point N and back to the fault point through the faulty phase. The path of I_C is capacitive and that of I_F is inductive. The two currents are in phase opposition and completely cancel each other. Therefore, no arcing ground phenomenon or over-voltage conditions can occur.

(iii) When there is an earth fault on any phase of the system, the phase to earth voltage of the faulty phase becomes zero. However, the phase to earth voltages of the remaining two healthy phases remain at normal phase voltage because the potential of the neutral is fixed at earth potential. This permits to insulate the equipment for phase voltage. Therefore, there is a saving in the cost of equipment.

(iv) It becomes easier to protect the system from earth faults which frequently occur on the system. When there is an earth fault on any phase of the system, large fault current flows between the fault point and the grounded neutral. This permits the easy operation of earth fault relay.

Disadvantages

The following are the disadvantages of solid grounding :

- (i) Since most of the faults on an overhead system are phase to earth faults, the system has to bear a large number of severe shocks. This causes the system to become unstable.
- (ii) The solid grounding results in heavy earth fault currents. Since the fault has to be cleared by the circuit breakers, the heavy earth fault currents may cause the burning of circuit breaker contacts.
- (iii) The increased earth fault current results in greater interference in the neighboring communication lines.

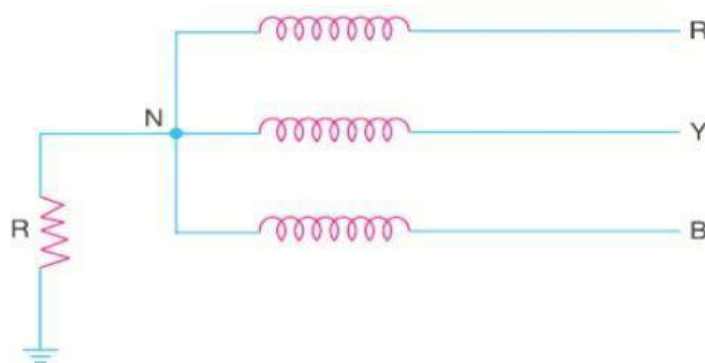
Applications

Solid grounding is usually employed where the circuit impedance is sufficiently high so as to keep the earth fault current within safe limits. This system of grounding is used for voltages up to 33 kV with total power capacity not exceeding 5000 kVA.

(ii) Resistance Grounding

In order to limit the magnitude of earth fault current, it is a common practice to connect the neutral point of a 3-phase system to earth through a resistor. This is called resistance grounding. When the neutral point of a 3-phase system (e.g. 3-phase generator, 3-phase transformer etc.) is connected to earth (i.e. soil) through a resistor, it is called resistance grounding. Fig. shows the grounding of neutral point through a resistor R . The value of R should neither be very low nor very high. If the value of earthing resistance R is very low, the earth fault current will be large and the system becomes similar to the solid grounding system.

On the other hand, if the earthing resistance R is very high, the system conditions become similar to ungrounded neutral system. The value of R is so chosen such that the earth fault



current is limited to safe value but still sufficient to permit the operation of earth fault protection system. In practice, that value of R is selected that limits the earth fault current to 2 times the normal full load current of the earthed generator or transformer.

Advantages

The following are the advantages of resistance earthing:

- i) The earth fault current is small due to the presence of earthing resistance. Therefore, interference with communication circuits is reduced.
- ii) It improves the stability of the system.

Disadvantages

The following are the disadvantages of resistance grounding :

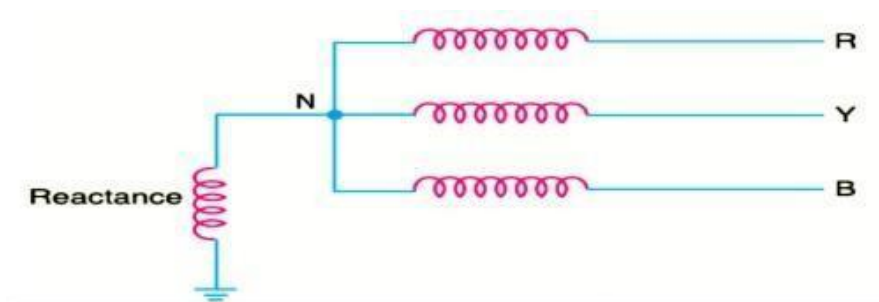
- (i) Since the system neutral is displaced during earth faults, the equipment has to be insulated for higher voltages.
- (ii) This system is costlier than the solidly grounded system.
- (iii) A large amount of energy is produced in the earthing resistance during earth faults. Sometimes it becomes difficult to dissipate this energy to atmosphere.

Applications

It is used on a system operating at voltages between 2.2 kV and 33 kV with power source capacity more than 5000 kVA.

(iii) Reactance Grounding

In this system, a reactance is inserted between the neutral and ground as shown in Fig. The purpose of reactance is to limit the earth fault current. By changing the earthing reactance, the earth fault current can be changed to obtain the conditions similar to that of solid grounding. This method is not used these days because of the following

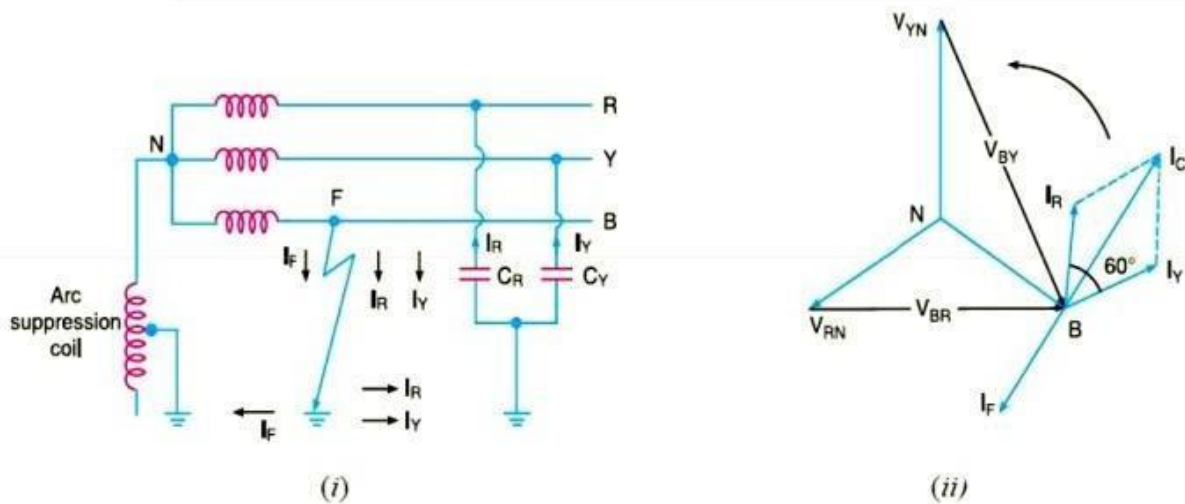


Disadvantages

- (i) In this system, the fault current required to operate the protective device is higher than that of resistance grounding for the same fault conditions.
- (ii) High transient voltages appear under fault conditions.

(IV) Arc Suspension Grounding (Or Resonant Grounding)

We have seen that capacitive currents are responsible for producing arcing grounds. These capacitive currents flow because capacitance exists between each line and earth. If inductance L of appropriate value is connected in parallel with the capacitance of the system, the fault current I_F flowing through L will be in phase opposition to the capacitive current I_C of the system. If L is so adjusted that $I_L = I_C$ then resultant current in the fault will be zero. This condition is known as resonant grounding. When the value of L of arc suppression coil is such that the fault current I_F exactly balances the capacitive current I_C , it is called resonant grounding.



Value of L for resonant grounding . For resonant grounding, the system behaves as an ungrounded neutral system. Therefore, full line voltage appears across capacitors C_R and C_Y

$$\therefore I_R = I_Y = \frac{\sqrt{3}V_{ph}}{X_C}$$

$$\therefore I_C = \sqrt{3}I_R = \sqrt{3} \times \frac{\sqrt{3}V_{ph}}{X_C} = \frac{3V_{ph}}{X_C}$$

Here, X_C is the line to ground capacitive reactance.

Fault current,
$$I_F = \frac{V_{ph}}{X_L}$$

Here, X_L is the inductive reactance of the arc suppression coil.

For resonant grounding, $I_L = I_C$.

or
$$\frac{V_{ph}}{X_L} = \frac{3V_{ph}}{X_C}$$

or
$$X_L = \frac{X_C}{3}$$

or
$$\omega L = \frac{1}{3\omega C}$$

$$\therefore L = \frac{1}{3\omega^2 C} \quad \dots(i)$$

Exp. (i) gives the value of inductance L of the arc suppression coil for resonant grounding.

Advantages

The Peterson coil grounding has the following advantages:

- (i) The Peterson coil is completely effective in preventing any damage by an arcing ground.
- (ii) The Peterson coil has the advantages of ungrounded neutral system.

Disadvantages

The Peterson coil grounding has the following disadvantages:

- (i) Due to varying operational conditions, the capacitance of the network changes from time to time. Therefore, inductance L of Peterson coil requires readjustment.
- (ii) The lines should be transposed.