**UNIT I INTRODUCTION**

**Introduction:**

In the early power systems were mainly Neutral ungrounded due to the fact that the first ground fault did not require the tripping of the system. An unscheduled shutdown on the first ground fault was particularly undesirable for continuous process industries. These power systems required ground detection systems, but locating the fault often proved difficult. Although achieving the initial goal, the ungrounded system provided no control of transient over-voltages.

A capacitive coupling exists between the system conductors and ground in a typical distribution system. As a result, this series resonant L-C circuit can create over-voltages well in excess of line-to-line voltage when subjected to repetitive re-strikes of one phase to ground. This in turn, reduces insulation life resulting in possible equipment failure.

Neutral grounding systems are similar to fuses in that they do nothing until something in the system goes wrong. Then, like fuses, they protect personnel and equipment from damage. "Damage comes from two factors, how long the fault lasts and how large the fault current is. Ground relays trip breakers and limit how long a fault lasts and Neutral grounding resistors limit how large the fault current is".

**Importance of Neutral Grounding:**

There are many neutral grounding options available for both Low and Medium voltage power systems. The neutral points of transformers, generators and rotating machinery to the earth ground network provides a reference point of zero volts. This protective measure offers many advantages over an ungrounded system, like,

1. Reduced magnitude of transient over voltages
2. Simplified ground fault location
3. Improved system and equipment fault protection
4. Reduced maintenance time and expense
5. Greater safety for personnel
6. Improved lightning protection
7. Reduction in frequency of faults.

**Method of Neutral Earthing:**

There are five methods for Neutral earthing.

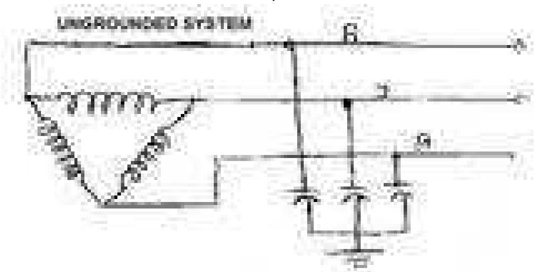
1. Unearthed Neutral System
2. Solid Neutral Earthed System.
3. Resistance Neutral Earthing System.
    1. Low Resistance Earthing.
    2. High Resistance Earthing.
4. Resonant Neutral Earthing System.
5. Earthing Transformer Earthing.

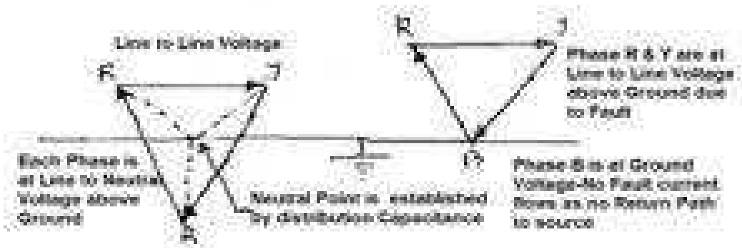
**(1) Ungrounded Neutral Systems:**

In ungrounded system there is no internal connection between the conductors and earth. However, as system, a capacitive coupling exists between the system conductors and the adjacent grounded surfaces. Consequently, the “ungrounded system” is, in reality, a “capacitive grounded system” by virtue of the distributed capacitance.

Under normal operating conditions, this distributed capacitance causes no problems. In fact, it is beneficial because it establishes, in effect, a neutral point for the system; As a result, the phase conductors are stressed at only line-to-neutral voltage above ground.

But problems can rise in ground fault conditions. A ground fault on one line results in full line-to-line voltage appearing throughout the system. Thus, a voltage 1.73 times the normal voltage is present on all insulation in the system. This situation can often cause failures in older motors and transformers, due to insulation breakdown.




**Advantage:**

1. After the first ground fault, assuming it remains as a single fault, the circuit may continue in operation, permitting continued production until a convenient shut down for maintenance can be scheduled.

**Disadvantages:**

1. The interaction between the faulted system and its distributed capacitance may cause transient over-voltages (several times normal) to appear from line to ground during normal switching of a circuit having a line-to ground fault (short). These over voltages may cause insulation failures at points other than the original fault.
2. A second fault on another phase may occur before the first fault can be

cleared. This can result in very high line-to-line fault currents, equipment damage and disruption of both circuits.

3. The cost of equipment damage.
4. Complicate for locating fault(s), involving a tedious process of trial and error: first isolating the correct feeder, then the branch, and finally, the equipment at fault. The result is unnecessarily lengthy and expensive down downtime.

**(2) Solidly Neutral Grounded Systems:**

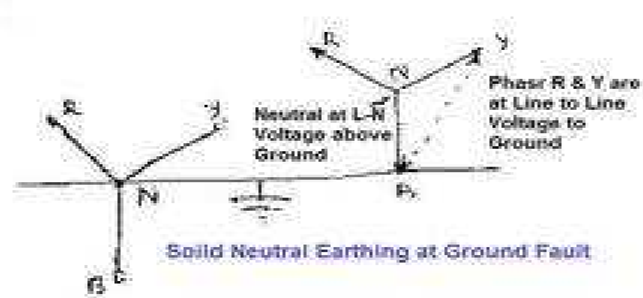
Solidly grounded systems are usually used in low voltage applications at 600 volts or less.

In solidly grounded system, the neutral point is connected to earth.

Solidly Neutral Grounding slightly reduces the problem of transient over voltages found on the ungrounded system and provided path for the ground fault current is in the range of ***25 to 100% of the system three phase fault current.*** However, if the reactance of the generator or transformer is too great, the problem of transient over voltages will not be solved.

While solidly grounded systems are an improvement over ungrounded systems, and speed up the location of faults, they lack the current limiting ability of resistance grounding and the extra protection this provides.

To maintain systems health and safe, Transformer neutral is grounded and grounding conductor must be extend from the source to the furthest point of the system within the same raceway or conduit. Its purpose is to maintain very low impedance to ground faults so that a relatively high fault current will flow thus insuring that circuit breakers or fuses will clear the fault quickly and therefore minimize damage. It also greatly reduces the shock hazard to personnel

If the system is not solidly grounded, the neutral point of the system would "float" with respect to ground as a function of load subjecting the line-to-neutral loads to voltage unbalances and instability.

The single-phase earth fault current in a solidly earthed system may exceed the three phase fault current.

The magnitude of the current depends on the fault location and the fault resistance. One way to reduce the earth fault current is to leave some of the transformer neutrals unearthed.

**Advantage:**

1. The main advantage of solidly earthed systems is low over voltages, which makes the earthing design common at high voltage levels (HV).

**Disadvantage:**

1. This system involves all the drawbacks and hazards of high earth fault current: maximum damage and disturbances.
2. There is no service continuity on the faulty feeder.
3. The danger for personnel is high during the fault since the touch voltages created are high.

**Applications:**

1. Distributed neutral conductor.
2. 3-phase + neutral distribution.
3. Used when the short-circuit power of the source is low.

**3) Resistance earthed systems:**

Resistance grounding has been used in three-phase industrial applications for many years and it resolves many of the problems associated with solidly grounded and ungrounded systems.

Resistance Grounding Systems limits the phase-to-ground fault currents. The reasons for limiting the Phase to ground Fault current by resistance grounding are:

1. To reduce burning and melting effects in faulted electrical equipment like switchgear, transformers, cables, and rotating machines.
2. To reduce mechanical stresses in circuits/Equipments carrying fault currents.
3. To reduce electrical-shock hazards to personnel caused by stray ground fault.
4. To reduce the arc blast or flash hazard.
5. To reduce the momentary line-voltage dip.
6. To secure control of the transient over-voltages while at the same time.
7. To improve the detection of the earth fault in a power system.

Grounding Resistors are generally connected between ground and neutral of transformers, generators and grounding transformers ***to limit maximum fault current as per Ohms Law to a value which will not damage the equipment*** in the power system and allow sufficient flow of fault current to detect and operate

Earth protective relays to clear the fault.

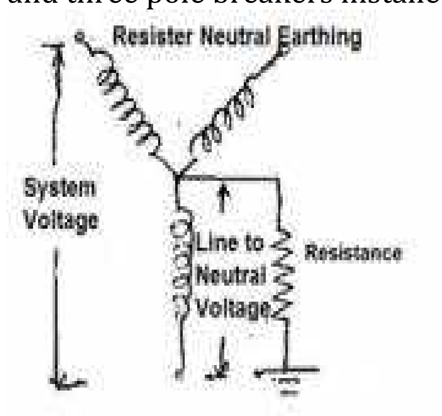
Therefore, it is the most common application to limit single phase fault currents with low resistance Neutral Grounding Resistors to approximately rated current of transformer and / or generator.

In addition, limiting fault currents to predetermined maximum values permits the designer to selectively coordinate the operation of protective devices, which minimizes system disruption and allows for quick location of the fault.

There are two categories of resistance grounding:

(1) Low resistance Grounding. (2) High resistance Grounding.

Ground fault current flowing through either type of resistor when a single phase faults to ground will increase the phase-to-ground voltage of the remaining two phases. As a result, ***conductor insulation and surge arrestor ratings must be based on line-to-line voltage***. This temporary increase in phase-to- ground voltage should also be considered when selecting two and three pole breakers installed on resistance




grounded low voltage systems.

Neither of these grounding systems (low or high resistance) reduces arc-flash hazards associated with phase-to-phase faults, but both systems significantly reduce or essentially eliminate the arc-flash hazards associated with phase-to-ground faults. Both types of grounding systems limit mechanical stresses and reduce thermal damage to electrical equipment, circuits, and apparatus carrying faulted current.

The difference between Low Resistance Grounding and High Resistance Grounding is a matter of perception and, therefore, is not well defined. ***Generally speaking high-resistance grounding refers to a system in which the NGR let-through current is less than 50 to 100 A. Low resistance grounding indicates that NGR current would be above 100 A.***

A better distinction between the two levels might be alarm only and tripping. An alarm-only system continues to operate with a single ground fault on the system for an unspecified amount of time. In a tripping system a ground fault is automatically removed by protective relaying and circuit interrupting devices. Alarm-only systems usually limit NGR current to 10 A or less.

**Rating of The Neutral grounding resistor:**

1. Voltage: Line-to-neutral voltage of the system to which it is connected.
2. Initial Current: The initial current which will flow through the resistor with rated voltage applied.
3. Time: The "on time" for which the resistor can operate without exceeding the allowable temperature

**(A).Low Resistance Grounded:**

Low Resistance Grounding is used for large electrical systems where there is a high investment in capital equipment or prolonged loss of service of equipment has a significant economic impact and it is not commonly used in low voltage systems because the limited ground fault current is too low to
reliably operate breaker trip units or fuses. This makes system selectivity hard to achieve. Moreover, low resistance grounded systems are not suitable for 4-wire loads and hence have not been used in commercial market applications
A resistor is connected from the system neutral point to ground and generally sized to permit only ***200A to 1200 amps*** of ground fault current to flow. Enough current must flow such that protective devices can fault point.

Since the grounding impedance is in the form of resistance, any transient over voltages are quickly damped out and the whole transient overvoltage phenomena is no longer applicable. Although theoretically possible to be applied in low voltage systems (e.g. 480V),significant amount of the system voltage dropped across the grounding resistor, there is not enough voltage across the arc forcing current to flow, for the fault to be reliably detected. For this reason**, low resistance grounding is not used for low voltage systems** (under 1000 volts line to-line).

**Advantages:**

1. Limits phase-to-ground currents to 200-400A.
2. Reduces arcing current and, to some extent, limits arc-flash hazards associated with phase-to-ground arcing current conditions only.
3. May limit the mechanical damage and thermal damage to shorted transformer and rotating machinery windings.

**Disadvantages:**

1. Does not prevent operation of over current devices.
2. Does not require a ground fault detection system.
3. May be utilized on medium or high voltage systems.
4. Conductor insulation and surge arrestors must be rated based on the line to-line voltage. Phase-to-neutral loads must be served through an isolation transformer.

**Used:** Up to 400 amps for 10 sec are commonly found on medium voltage systems.

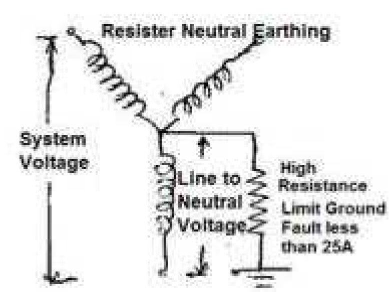
**(B).High Resistance Grounded:**

High resistance grounding is almost identical to low resistance grounding except that the ground fault current magnitude is typically limited to ***10 amperes or less***. High resistance grounding accomplishes two things.

The first is that the ***ground fault current magnitude is sufficiently low enough such*** that no appreciable damage is done at the fault point. This means that the faulted circuit need not be tripped off-line when the fault first occurs. Means that once a fault does occur, we do not know where the fault is located. In this respect, it performs just like an ungrounded system.

The second point is it can ***control the transient overvoltage phenomenon*** present on ungrounded systems if engineered properly.

Under earth fault conditions, the resistance must dominate over the system charging capacitance but not to the point of permitting excessive current to flow and thereby excluding continuous operation




High Resistance Grounding (HRG) systems limit the fault current when one phase of the system shorts or arcs to ground, but at lower levels than low resistance systems.

In the event that a ground fault condition exists, the HRG typically limits the current to 5-10A.

HRG's are continuous current rated, so the description of a particular unit does not include a time rating. Unlike NGR's, ground fault current flowing through a HRG is usually not of significant magnitude to result in the operation of an over current device. Since the ground fault current is not interrupted, a ground fault detection system must be installed.

These systems include a bypass contactor tapped across a portion of the resistor that pulses (periodically opens and closes). When the contactor is open, ground fault current flows through the entire resistor. When the contactor is closed a portion of the resistor is bypassed resulting in slightly lower resistance and slightly higher ground fault current.

**To avoid transient over-voltages, an HRG resistor must be sized so that the amount of ground fault current** the unit will allow to flow exceeds the electrical system's charging current. As a rule of thumb, charging current is estimated at 1A per 2000KVA of system capacity for low voltage systems and 2A per 2000KVA of system capacity at 4.16kV. These estimated charging currents increase if surge suppressors are present. Each set of suppressors installed on a low voltage system results in approximately 0.5A of additional charging current and each set of suppressors installed on a 4.16kV system adds 1.5A of additional charging current.

A system with 3000KVA of capacity at 480 volts would have an estimated charging current of 1.5A.Add one set of surge suppressors and the total charging current increases by 0.5A to 2.0A. A standard 5A resistor could be used on this system. Most resistor manufacturers publish detailed estimation tables that can be used to more closely estimate an electrical system's charging current.

**Advantages:**

1. Enables high impedance fault detection in systems with weak capacitive connection to earth
2. Some phase-to-earth faults are self-cleared.
3. The neutral point resistance can be chosen to limit the possible over voltage transients to 2.5 times the fundamental frequency maximum voltage.
4. Limits phase-to-ground currents to 5-10A.
5. Reduces arcing current and essentially eliminates arc-flash hazards associated with phase-to-ground arcing current conditions only.
6. Will eliminate the mechanical damage and may limit thermal damage to shorted transformer and rotating machinery windings.
7. Prevents operation of over current devices until the fault can be located (when only one phase faults to ground).
8. May be utilized on low voltage systems or medium voltage systems up to 5kV. IEEE Standard 141-1993 states that "high resistance grounding should be restricted to 5kV class or lower systems with charging currents of about 5.5A or less and should not be attempted on 15kV systems, unless proper grounding relaying is employed".
9. Conductor insulation and surge arrestors must be rated based on the line to-line voltage. Phase-to-neutral loads must be served through an isolation transformer.

**Disadvantages:**

1. Generates extensive earth fault currents when combined with strong or moderate capacitive connection to earth Cost involved.
2. Requires a ground fault detection system to notify the facility engineer that a ground fault condition has occurred.

**(4) Resonant earthed system:**

Adding inductive reactance from the system neutral point to ground is an easy method of limiting the available ground fault from something near the maximum 3 phase short circuit capacity (thousands of amperes) to a relatively low value (200 to 800 amperes).
To limit the reactive part of the earth fault current in a power system a neutral point reactor can be connected between the transformer neutral and the station earthing system.
A system in which at least one of the neutrals is connected to earth through an

1. Inductive reactance.
2. Petersen coil / Arc Suppression Coil / Earth Fault Neutralizer.

The current generated by the reactance during an earth fault approximately compensates the capacitive component of the single phase earth fault current, is called a resonant earthed system.
The system is hardly ever exactly tuned, i.e. the reactive current does not exactly equal the capacitive earth fault current of the system.

A system in which the inductive current is slightly larger than the capacitive earth fault current is over compensated. A system in which the induced earth fault current is slightly smaller than the capacitiveearth fault current is under compensated
However, experience indicated that this inductive reactance to ground resonates with the system shunt capacitance to ground under arcing ground fault conditions and creates very high transient over voltages on the system.
To control the transient over voltages, the design must permit at least 60% of the 3 phase short circuit current to flow underground fault conditions.
Example. A 6000 amp grounding reactor for a system having 10,000 amps 3 phase short circuit capacity available. Due to the high magnitude of ground fault current required to control transient over voltages, inductance grounding is ***rarely used within industry.***

**Petersen Coils:**

A Petersen Coil is connected between the neutral point of the system and earth, and is rated so that the capacitive current in the ***earth fault is compensated by an inductive current passed by the Petersen Coil.*** A small residual current will remain, but this is so small that any arc between the faulted phase and earth will not be maintained and the fault will extinguish. Minor earth faults such as a broken pin insulator, could be held on the system without the supply being interrupted. Transient faults would not result in supply interruptions.

Although the standard ‘Peterson coil’ does not compensate the entire earth fault current in a network due to the presence of resistive losses in the lines and coil, it is now possible to apply ‘residual current compensation’ by injecting an additional 180° out of phase current into the neutral via the Peterson coil. The fault current is thereby reduced to practically zero. Such systems are known as ‘Resonant earthing with residual compensation’, and can be considered as a special case of reactive earthing.
Resonant earthing can reduce EPR to a safe level. This is because the Petersen coil can often effectively act as a high impedance NER, which will substantially reduce any earth fault currents, and hence also any corresponding EPR hazards (e.g. touch voltages, step voltages and transferred voltages, including any EPR hazards impressed onto nearby telecommunication networks).

**Advantages:**

1. Small reactive earth fault current independent of the phase to earth capacitance of the system.
2. Enables high impedance fault detection.

**Disadvantages:**

1. Risk of extensive active earth fault losses.
2. High costs associated.

**(5) Earthing Transformers:**

For cases where there is no neutral point available for Neutral Earthing (e.g. for a delta winding), an earthing transformer may be used to provide a return path for single phase fault currents

In such cases the impedance of the earthing transformer may be sufficient to act as effective earthing impedance. Additional impedance can be added in series if required. A special ‘zig-zag’ transformer is sometimes used for earthing delta windings to provide a low zero-sequence impedance and high positive and negative sequence impedance to fault currents.

**<u>Protective Relaying</u>**

A protective relaying scheme should have certain important qualities. Such an essential qualities of protective relaying are,

1. Reliability
2. Selectivity and Discrimination
3. Speed and Time
4. Sensitivity
5. Stability
6. Adequateness
7. Simplicity and Economy

1.1 Reliability

A protective relaying should be reliable is its basic quality. It indicates the ability of the relay system to operate under the predetermined conditions. There

are various components which go into the operation before a relay operates. Therefore every component and circuit which is involved in the operation of a relay plays an important role. The reliability of a protection system depends on the reliability of various components like circuit breakers, relays, current transformers (C.T.s), potential transformers (P.T.s), cables, trip circuits etc. The proper maintenance also plays an important role in improving the reliable operation of the system. The reliability can not be expressed in the mathematical expressions but can be adjusted from the statistical data. The statistical survey and records give good idea about the reliability of the protective system. The inherent reliability is based on the design which is based on the long experience. This can be achieved by the factors like, i) Simplicity ii) Robustness
iii) High contact pressure iv) Dust free enclosure
iv) Good contact material vi)
Good workmanship and vii)
Careful Maintenance

1.2 Selectivity and Discrimination

The selectivity id the ability of the protective system to identify the faulty part correctly and disconnect that part without affecting the rest of the healthy part of system. The discrimination means to distinguish between. The discrimination quality of the protective system is the ability to distinguish between normal condition and abnormal condition and also between abnormal condition within protective zone and elsewhere. The protective system should operate only at the time of abnormal condition and not at the time of normal condition. Hence it must clearly discriminate between normal and abnormal condition. Thus the protective system should select the fault part and disconnect only the faulty part without disturbing the healthy part of the system.

1.3 Speed and Time

a protective system must disconnect the faulty system as fast as possible. If the faulty system is not disconnect for a long time then,
1. The devices carrying fault currents may get damaged.
2. The failure leads to the reduction in system voltage. Such low voltage may affect the motors and generators running on the consumer sude.

The total time required between the instant of fault and the instant of final arc interruption in the circuit breaker is called fault clearing time. It is the sum of relay time and circuit breaker time. The relay time is the time between the instant of fault occurrence and the instant of closure of relay contacts. The circuit breaker times is the time taken by the circuit breaker to operate to open the contacts and to extinguish the arc completely. The fault clearing time should be as small as possible to have high speed operation of the protective system.

Though the small fault clearing time is preferred, in practice certain time lag is provided. This is because,

1. To have clear discrimination between primary and backup protection

2. To prevent unnecessary operation of relay under the conditions such as transient, starting inrush of current etc.

Thus fast protective system is an important quality which minimises the damage and it improves the overall stability of the power system.

1.4 Sensitivity

The protective system should be sufficiently sensitive so that it can operate reliably when required. The sensitivity of the system is the ability of the relay system to operate with low value of actuating quantity.

It indicates the smallest value of the actuating quantity at which the protection starts operating in relation with the minimum value of the fault current in the protected zone.

The relay sensitivity is the function of the volt-amperes input to the relay coil necessary to cause its operation. Smaller the value of volt-ampere input, more sensitive is the relay. Thus 1 VA input relay is more sensitive than the 5VA input relay.

Mathematically the sensitivity is expressed by a factor called sensitivity factor . It is the ratio of minimum short circuit current in the protected zone to the minimum operating current required for the protection to start.

$$K_S = I_S/I_O$$

where $K_S$ = sensitivity factor

$I_S$ = minimum short circuit current in the zone

$I_O$= minimum operating current for the protection

1.5 Stability

The stability is the quality of the protective system due to which the system remains inoperative and stable under certain specified conditions such as transients, disturbance, through faults etc. For providing the stability, certain modifications are required in the system design. In most of the cases time delays, filter circuits, mechanical and electrical bias are provided to achieve stable operation during the disturbances.

1.6 Adequateness

There are variety of faults and disturbance those may practically exists in a power system. It is impossible to provide protection against each and every abnormal condition which may exist in practice, due to economical reasons. But the protective system must provide adequate protection for any element of the system. The adequateness of the system can be assessed by considering following factors,

1. Ratings of various equipments
2. Cost of the equipments
3. Locations of the equipments
4. Probability of abnormal condition due to internal and external causes.
5. Discontinuity of supply due to the failure of the equipment

1.7 Simplicity and Economy

In addition to all the important qualities, it is necessary that the cost of the system should be well within limits. In practice sometimes it is not necessary to use ideal protection scheme which is economically unjustified. In such cases compromise is done. As a rule, the protection cost should not be more than 5% of the total cost. But if the equipments to be protected are very important, the economic constrains can be relaxed.

The protective system should be as simple as possible so that it can be easily maintained. The complex system are difficult from the maintenance point of view. The simplicity and reliability are closely related to each other. The simpler system are always more reliable.

**Nature and causes of Faults:**

Any faults in electrical apparatus are nothing but the defect in its electrical circuit which makes current path directed from its intended path. Normally due to breaking of conductors or failure of insulation, these faults occur. The other reasons for occurrence of fault include mechanical failure, accidents. Excessive internal and external stresses. The impedance of the path in the fault is low and the fault currents are comparatively large. The induction of insulation is not considered as a fault until it shows some effect sucj as excessive current flow or reduction of impedance between conductors or between conductors and earth.

When a fault occurs on a system, the voltage of the three phases become unbalanced. As the fault currents are large, the apparatus may get damaged. The flow of power is diverted towards the fault which affects the supply to the neighboring zone.

A power system consists of generators, transformers, switchgear, transmission and distribution circuits. There is always a possibility in such a large network that some fault will occur in some part of the system. The maximum possibility of fault occurrence is on the transmission lines due to their greater lengths and exposure to atmospheric conditions.

The faults cannot be classified according to the causes of their incidence. The breakdown may occur at normal voltage due to deterioration of insulation. The breakdown may also occur due to damage on account of unpredictable causes which include perching of birds, accidental short circuiting by snakes, kite strings, three branches etc. The breakdown may occur at abnormal voltages due to switching surges or surges caused by lighting.

## Types of faults in power system

### *Active Faults*

The “Active” fault is when actual current flows from one phase conductor to another (phase-to-phase) or alternatively from one phase conductor to earth (phase-to-earth). This type of fault can also be further classified into two areas, namely the “solid” fault and the “incipient” fault.

### *Passive Faults*

Passive faults are not real faults in the true sense of the word but are rather conditions that are stressing the system beyond its design capacity, so that ultimately active faults will occur.

Typical examples are:

Overloading - leading to overheating of insulation (deteriorating quality, reduced life and ultimate failure).

under frequency - causing plant to behave incorrectly.

Power swings - generators going out-of-step or synchronism with each other

### *Transient & Permanent Faults*

Transient faults are faults which do not damage the insulation permanently and allow the circuit to be safely re-energized after a short period of time. A typical example would be an insulator flashover following a lightning strike, which would be successfully cleared on opening of the circuit breaker, which could then be automatically reclosed.

Transient faults occur mainly on outdoor equipment where air is the main insulating medium.

Permanent faults, as the name implies, are the result of permanent damage to the insulation. In this case, the equipment has to be repaired and reclosing must not be entertained.

### *Symmetrical & Asymmetrical Faults*

A symmetrical fault is a balanced fault with the sinusoidal waves being equal about their axes, and represents a steady state condition.

An asymmetrical fault displays a d.c. offset, transient in nature and decaying to the steady state of the symmetrical fault after a period of time:

### F*aults on a Three Phase System*

The types of faults that can occur on a three phase A.C. system are as follows:

***Types of Faults on a Three Phase System***. (A) Phase-to-earth fault

(B) Phase-to-phase fault

(C) Phase-to-phase-to-earth fault

(D) Three phase fault

(E) Three phase-to-earth fault

**Ferranti surge absorber.**

Surge absorbers are protective devices used to absorb the complete surge i,e. due to lightening surge or any transient surge in the system..........unlike the lightening arrestor in which a non-linear resistor is provided which provides a low resistance path to the dangerously high voltages on the system to the earth...

**Ferranti surge absorber**

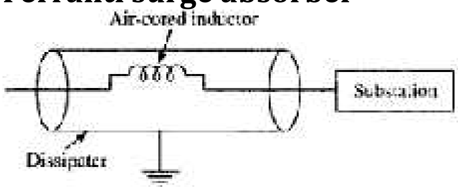



FIGURE 14.16 Ferranti surge absorber.

Surge absorber are of following types:

***Ferranti surge absorber:*** Ferranti surge absorber consists of an air core inductor which is connected in series with the line and surrounded by an earth metallic sheet. The earth metallic sheet is known as *dissipater*. The dissipater is insulated from the inductor by the air as shown in Figure 14.16. This surge absorber acts like an air-cored transformer whose primary is the low inductance inductor and the dissipater as the single-turn short circuit secondary.

Whenever a travelling wave is incident on the surge absorber, energy is transformed by mutual inductance between the coil and dissipater. Because of the series inductance the steepness of the wave is also reduced.

***ERA surge absorber:*** An improved form of the surge absorber is the Electrical Research Association (ERA)-type surge filter as shown in Figure 14.17 incorporated a gap *G* and expulsion gap *E*. When a wave reaches the inductor *L*, a high voltage is induced across it causing the gap *G* to break down putting the resistor *R* and expulsion gap *E* into circuit. An incoming wave is thus flattened by the inductor and the resistor and its amplitude is reduced by the expulsion gap.

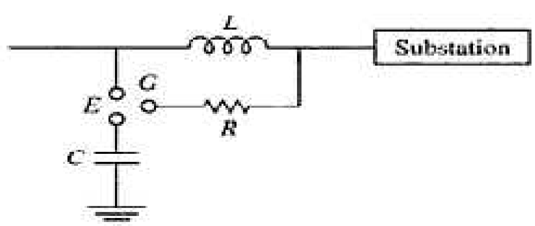



FIGURE 14.17 ERA surge absorber.

## Causes of over voltage on a power system

**Overvoltage - Causes and Protection**

Over voltages occur in a system when the system voltage rises over 110% of the nominal rated voltage. Overvoltage can be caused by a number of reasons, sudden reduction in loads, switching of transient loads, lightning strikes, failure of control equipment such as voltage regulators, neutral displacement,. Overvoltage can cause damage to components connected to the power supply and lead to insulation failure, damage to electronic components, heating, flashovers, etc.

Overvoltage relays can be used to identify overvoltages and isolate equipment.

These relays operate when the measured voltage exceeds a predetermined set-point. The voltage is usually measured using a Potential Transformers. The details of the ratio of the potential transformer are also entered into the relay. These relays are usually provided with a time delay. The time delay can be either instantaneous, fixed time or for IDMT (inverse definite minimum time) curves.

Generally, overvoltage relays are provided with sufficient time delay in order to avoid unwanted trippings due to transients (See article on Transients).

These relays can be used to isolate feeders and other equipment connected to the network. In the case of generators, these relay also switch off the excitation system to the generators thereby preventing voltage build- up.

**ii) Rod gap**

It is a very simple type of diverter and consists of two 1.5 cm rods, which are bent at right angles with a gap in between as shown in Fig 8. One rod is connected to the line circuit and the other rod is connected to earth. The distance between gap and insulator (i.e. distance P) must not be less than one third of the gap length so that the arc may not reach the insulator and damage it. Generally, the gap length is so adjusted that breakdown should occur at 80% of spark-voltage in order to avoid cascading of very steep wave fronts across the insulators. The string of insulators for an overhead line on the bushing of transformer has frequently a rod gap across it. Fig 8 shows the rod gap across the bushing of a transformer. Under normal operating conditions, the gap remains non-conducting. On the occurrence of a high voltage surge on the line, the gap sparks over and the surge current is conducted to earth. In this way excess charge on the line due to the surge is harmlessly conducted to earth

**Limitations:**

(i) After the surge is over, the arc n the gap is maintained by the normal supply voltage, leading to short-circuit on the system.

(ii) The rods may melt or get damaged due to excessive heat produced by the arc.
(iii) The climatic conditions (e.g. rain, humidity, temperature etc.) affect the performance of rod gap arrester. (iv) The polarity of the f the surge also affects the performance of this arrester.

Due to the above limitations, the rod gap arrester is only used as a back-up protection in case of main arresters.

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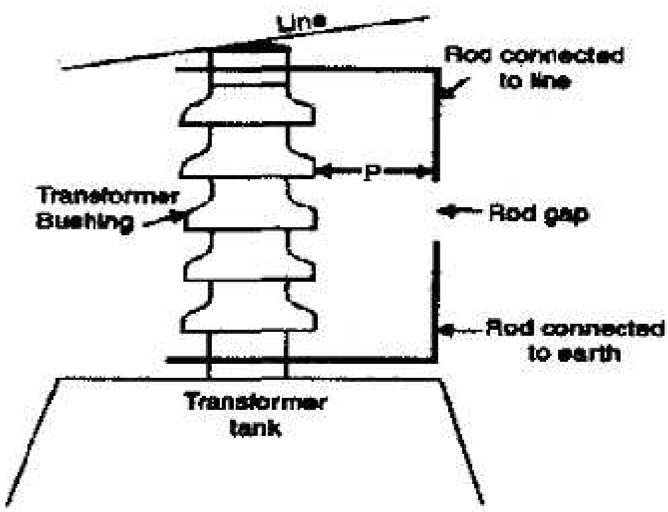


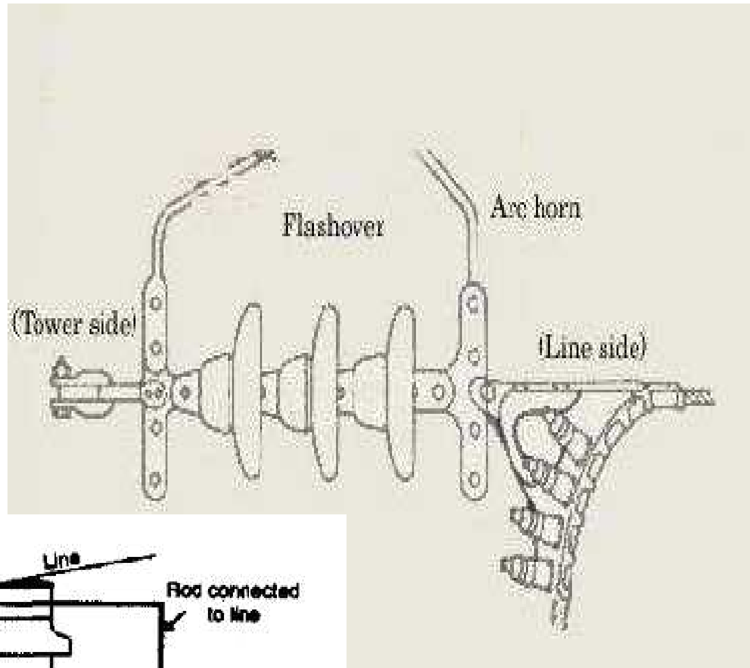

fig 8

## (iii) Arcing horns

Transmission and other electrical equipment can be exposed to overvoltages. Overvoltages can be caused by a number of reasons such as lightning strikes, transient surges, sudden load fluctuation, etc. In the event of an overvoltage, the insulating equipment such as the insulators on a transmission line or bushings in a transformer can be exposed to high voltages which may lead to their failure.

Arcing horns are protective devices that are constructed in the form of projections in the conducting materials on both sides of an insulator. Arcing horns are fitted in pairs. Thus in transmission lines they are found on the conducting line and the transmission tower across the insulators. In transmission lines, in the event of a lightning strike on the tower, the tower potential rises to dangerous levels and can result in flashovers across the insulators causing their failure. Arcing horns prevent this by conducting the arc across the air gap across them.

Arcing horns function by bypassing the high voltage across the insulator using air as a conductive medium. The small gap between the horns ensures that the air between them breaks down resulting in a flashover and conducts the voltage surge rather than cause damage to the insulator.The horns are constructed in pair so that one horn is on the line side and the other is on the ground side.



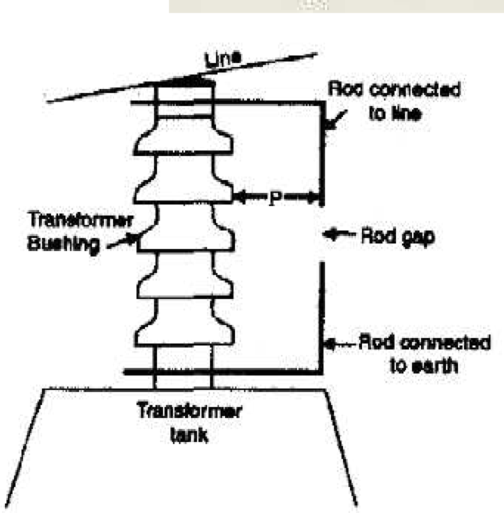




fig 8

g with air insulated switchgear equipment.
e to damage due to arcing. Arcing horns
lves thus protecting the switching
move the arc away from the bushings or the

Under normal conditions, the gap is non-conducting i.e. normal supply voltage is insufficient to initiate the arc between the gap. On the occurrence of an over voltage, spark-over takes place across the small gap G. The heated air around the arc and the magnetic effect of the arc cause the arc to travel up the gap. The arc moves progressively into positions 1,2 and 3. At some position of the arc (position 3), the distance may be too great for the voltage to maintain the arc; consequently, the arc is extinguished. The excess charge on the line is thus conducted through the arrester to the ground.

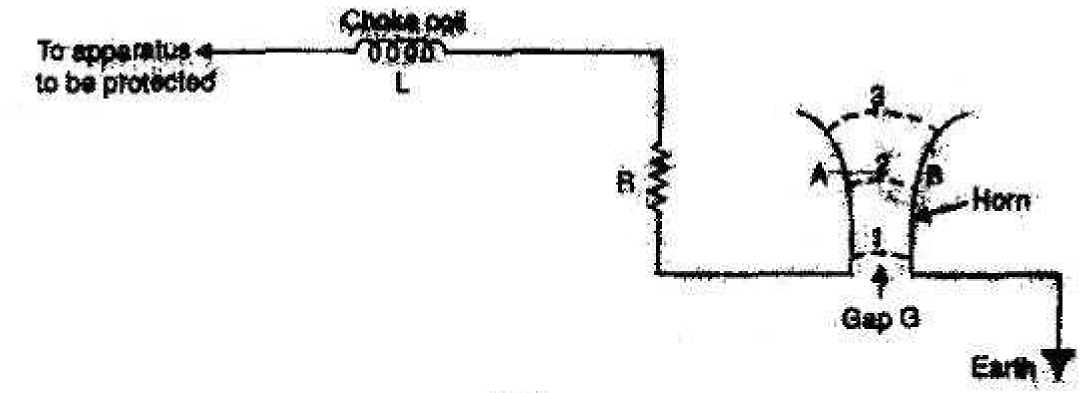



fig 9

### (iv) Basic impulse insulation level

BIL or basic impulse insulation level is the dielectric insulation gradient of a material tested to withstand the voltage stress at a voltage impressed between the material and a conductive surface beyond the BIL rating, an electric tracking starts to occur which will then result into an arcing flashover to the conductive surface. In

addition it is the capacity of an equipment to withstand mechanical stress like lightning strike without causing any damage to the equipment.