UNIT-VI

PROTECTION AGAINST OVER VOLTAGE AND GROUNDING

Sources of Transients or Surges in Extra High Voltage Lines

Switching of high voltage transmission lines is required for ordinary functioning of an electrical network. The switching of an unloaded line, opening and closing of isolating switches, and interruption of an inductive current (reactor) and capacitive circuit (capacitor hanks) produce transient overvoltages. This abrupt increase in the voltage above the rated value for a short duration in the power system is known as a voltage surge or transient voltage. Though transients or surges are temporary, they cause overvoltage in the power system. Transient disturbances in power systems may damage main equipment, thus affectingsystem reliability .The switching surges produced in an electrical system depend on how repeatedly the routine switching operations are performed in a Particular system. Moreover, the existence of transients and surges in the system depend on the number of faults and their clearance as well as on the changes in the system parameters and alterations of system configuration. Lightning strikes are the main source of over voltage. Although they are few in number they drastically affect the performance of the power system components, including complete failure of insulation in case of severe lightning discharge. The probable causes of transients and surges in a power network are discussed in the following subsections.

Switching of Transmission Line

Whenever a high voltage overhead transmission line is energized by closing the line circuit breaker, switching surges are generated in the line and supply network. The magnitude and shape of a switching transient depend on the transmission line, system parameters, and the arrangement of the network. Even with the same system parameters and network configuration, the switching overvoltages are highly dependent on the distinctiveness of the circuit breaker operation and the amount of trapped charges in transmission lines during circuit energizing. Moreover, the severity depends on the difference between the supply voltage and the line voltage at the instant of energization. Large travelling waves are injected in the transmission lines during the closing of the circuit breaker at an instant when this voltage difference is high. When these waves reach the open far end of the line, they are reflected and a high transient overvoltage is experienced. Such switching transients are more dangerous for extra high voltage (EHV) transmission networks, especially for long transmission lines. Hence, the transient voltages generated from the switching of transmission lines have an impact on equipment design and protection.

Switching of Capacitor Bank:

Shunt capacitor banks are commonly installed at the distribution level as well as at transmission levels because of their effective performance. Capacitor bank switching is one of the most frequent utility operations depending on the need for system voltage or VAR (volt-ampere reactive) requirement from the banks. However, switching of such utility capacitor bank can have a negative impact on the power quality, especially for supply network and consumer power systems, Larger capacitor banks have more stored energy, and hence systems with high X R ratio are of more concern in supply networks. High magnitude and high frequency transients occur during the switching of shunt capacitor banks. When a capacitor bank is energized, it draws transient inrush current from the bus or transformer. The transient inrush is distinguished by a surge of current with a high magnitude and a frequency of several hundred Hertz. This transient manifests itself as a voltage increase due to the exciting system resonances or dynamic overvoltages when a capacitor bank is energized. This leads to a transient overvoltage on the bus and the neighbouring power system, which iscaused by the surge of inrush current from the system source and bank outrush current due to faults in the vicinity of the capacitor banks. successive switching of the capacitor bank adjoining the previously energized bank results in a much higher magnitude of current with high frequency compared to the energization of only one capacitor bank. As the series connection of capacitor banks provides lower inductance. the efficiency of the capacitor is reduced.

In case of a series-compensated transmission line using a series capacitor hank, switching surge overvoltages are produced because of the trapped charges present on the bank at the instant of the line reclosing. This phenomenon increases the potential of phase-to-ground and phase-to-phase voltage of transmission lines. Moreover, the transient recovery voltage (TRV) experienced by the first circuit breaker to clear the faults in a series-compensated line is of very high magnitude.

Switching of Coupling Capacitor Voltage Transformer

Coupling capacitor voltage transformers (CCVTs.) are used in the pow er system network over many years for protective relaying and as measuring instruments. They have capacitance voltage dividing networks. Under steady-state operating conditions, theperformance of the CCVT is not troublesome. How ever. the normal switching operation of the CCVT can create unexpected over voltages, which can affect the reliability of the power system and even lead to system failure in some CCVT units. The ferro resonance and non-linear behaviour of the potential transformer (PT) magnetic core, and effect of stray capacitances in Some CCVT elements are some of the causes of transient over voltages generated during switching operation in several 230 kV and 400kV CCVTs.

Switching of Reactor:

To compensate the leading reactive power and to depress the voltage rise at the end terminal of a long EHV transmission line, shunt reactors are used in the power system. Such a high voltage reactor is frequently switched on during periods of low load and is switched off with the rise of load. However, unavoidable high frequency TRV is caused at the terminal of the circuit breaker during the switching operation. Each switching operation involves a complex interaction between the circuit breaker, the supply network, and the load side shunt reactor. This interaction results in overvoltages dependent on system parameters and characteristics of the load. Energizing the reactors rarely generates high overvoltages, but excessive overvoltages are generated during de-energization. Current chopping (current interruption before its natural zero crossing) by the switching device (circuit breaker) when it interrupts the inductive currents and discharge of energy stored in the reactor inductance will cause electromagnetic transients, which lead to the switching overvoltages.

Arcing Ground:

In case of an ungrounded three-phase system, during line-to-ground fault, the magnitude of current is sufficient to maintain an arc. The phenomenon ofintermittent arc during such faults, whiich results in the production of transients, is known as arcing ground. During- arcing ground.

the inductance of the generator winding or line and the system capacitance establish a cycle charging and discharging. which results in high frequency oscillations. This oscillation builds up a very high voltages and the arc may reignite, which results in supplementary transient disturbances. The transients produced by arcing ground are cumulative and may cause serious damage to the equipment in the power system by causing breakdown of insulation.

Lightning Strokes

Lightning is a huge spark caused by the electrical discharge occurring between clouds, within the same cloud. and between clouds and the earth. During the movement of hot moist air from the earth towards the clouds, the friction between the air and water particles causes build-up of charges. Hence, updraft of hot air is responsible for charge separation within the cloud, such as in a huge electrostatic generator, which leads to the creation of electric fields within and around the cloud and ultimately to the electric breakdown (discharge) called lightning. The air between the cloud and earth cannot withstand the electrical field created in the cloud. and hence. the air gets ionized: finally, a streamer of very high current strikes between the clouds and earth resulting in the discharge of the clouds. Figure shows the penetration of a lightning stroke towards the earth from a cloud.

There are two types of lightning strokes, direct lightning stroke and indirect lightning stroke. In the former, lightning discharge (i.e., current path) takes place directly from the cloud to the electrical equipment, as in an overhead line. In the latter, the discharge results from the electrostatically induced charges on the conductors of the overhead line because of the presence of charged clouds, that is, a positively charged cloud is above the line and induces a negative charge on the line through electrostatic induction. Most surges in the transmission lines are caused by indirect lightning strokes. However, the effect of a direct stroke in terms of overvoltage due to the lightning discharge on the transmission line may be large enough to flashover the line component if not protected. The lightning stroke current rises to a peak value very fast and then starts decaying at a low rate as shown in Fig.. The generalized wave shape can be described as a crest or peak value, and the maximum value of this current is 400 kA; the wave front time varies from 1 to 10us, and the time at which the stroke current reduces to 50% of that peak value varies from 10 to 100 us. Moreover, the waveform of the surge voltages imposed on the insulation of a system due to the lightning stroke may vary extensively because of reflection in the line and the position of the stroke on transmission lines.A lightning surge may occur at any point and at any time. Lightning is one of the most serious causes of overvoltage. If the power equipment, especially at the outdoor substation, is not protected, the overvoltage will cause complete failure of insulation. Thus, it results in complete shutdown of the power and loss of revenue and equipment.

Protection against Lightning:

Electrical equipment can he damaged because of. over voltages such as switching surge overvoltage, Iightning surge overvoltage, TRV, and power frequency temporary overvoltage (TOV) in the transmission line and at the receiving end of the substation. It is important to protect power equipment against them wherever possible in the system through reliable and efficient approaches. Transients or surges in a power system may originate from switching and from other causes. but the most important surges are those caused by lightning. The lightning surges may cause serious damage to the expensive equipment in the power system (e.g..generators, transformers, etc.) either by direct stroke on the equipment or by strokes on the transmission lines that reach the equipment as travelling waves. It is necessary to protect the equipment against both kinds of surges. The most commonly used devices for protection against lightning surges are earthing screen, overhead ground wires, and LAs or surge diverters. Earthing screens protect the power station and substation against direct strokes, whereas overhead ground wires protect the transmission lines against direct lightning strokes. LAs or surge diverters protect the station apparatus against both direct strokes and the strokes that come into the apparatus as travelling waves.

Lightning Arrester (Surge Diverter):

The earthing screen and ground wires can well protect the electrical system against direct lightning strokes, but they fail to protect against travelling waves, which may reach the terminal apparatus. The LAs or surge diverters protect the system against such surges. Lightning arrester is the device that protects electrical equipment from damages caused by lightning overvoltage. So, it is required to connect the LA at the terminal end of the transmission line, substation, high voltage transformers, and low voltage transformers. The induction of electromagnetic transient in a power system mainly depends on the operating voltage, lengths of the lines, characteristic of circuit breakers, and substation and line configurations. Hence, the types of lighting arrester and its specification can be chosen correctly on the basis of the above-mentioned factors. An LA can act as an open circuit during normal operation of the system. It limits the transient voltages to a safe level and brings the system back to its normal operational mode as soon as the transient voltages are suppressed. Therefore, a lightning or surge arrester must have an extremely high resistance during normal system operation and a relatively low resistance during transient overvoltages. which is due to its non-linear voltage—current (V—I) characteristic.

Valve Type Arrester:

It is also known as non linear surge diverter. It is improved but more expensive lightning arrester. It consists of a multiple spark gap assembly in series with non-linear resistor as shown in fig. The spark gap assembly keeps the circuit open between line and earth under normal working conditions.

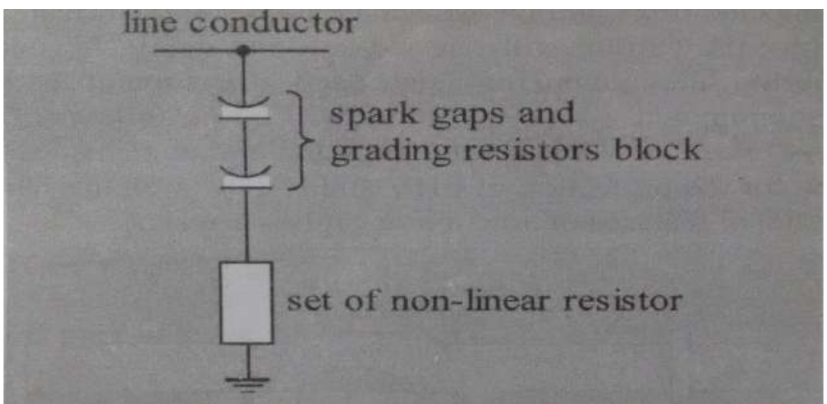


Fig. 9.8 schematic diagram of valve type arrester

Under normal operating conditions, the normal system voltage is insufficient to Cause the breakdown of air gap assembly. On the occurrence of an over voltage surge, the breakdown the series spark gap takes place and the surge current is conducted to earth via the non-linear resistors. As the magnitude of surge current is very high, the non linear elements will offer a low resistance to the passage of surge. As a result the surge will rapidly move to earth instead of being sent back over the line. When the surge is over. the non linear resistor assume high resistance and flow of the current ceases.

Advantages

- It provides very effective protection against surges
- It operates very rapidly, taking less than a second
- It's impulse ratio is practically unity Eventhough it has very superior characteristics,

but suffers the following disadvantages.

- Its performance characteristic is adversely affected by the ingress of moisture into the enclosure
- It may fail to check the surges of very steep wave front from reaching the terminal apparatus
- It is more costly

Zinc Oxide Gapless Arrester:

Zinc oxide gapless arrester is a type of metal oxide surge arrester. It works on the principle that certain elements have the property to change from a good conductor to almost ideal insulator, when slightly heated. As the name itself indicates that it is gapless arrester. Due to the non-linear characteristics of zinc oxide elements it is possible to construct surge arresters without series connected spark gaps. They operate in such a way that at normal power frequency system voltage they offer high resistance for discharge currents of higher magnitudes they offer a very low resistance path to ground. The construction and working of zinc oxide gapless arrester resembles. to that of valve type arrester except instead of spark gaps, zinc oxide elements having a highly non-linear resistance are connected. As the main constituent of this ceramic material is zinc oxide. The non-linear resistors made of this material are commonly known as Line oxide elements and surge arresters are called as metal

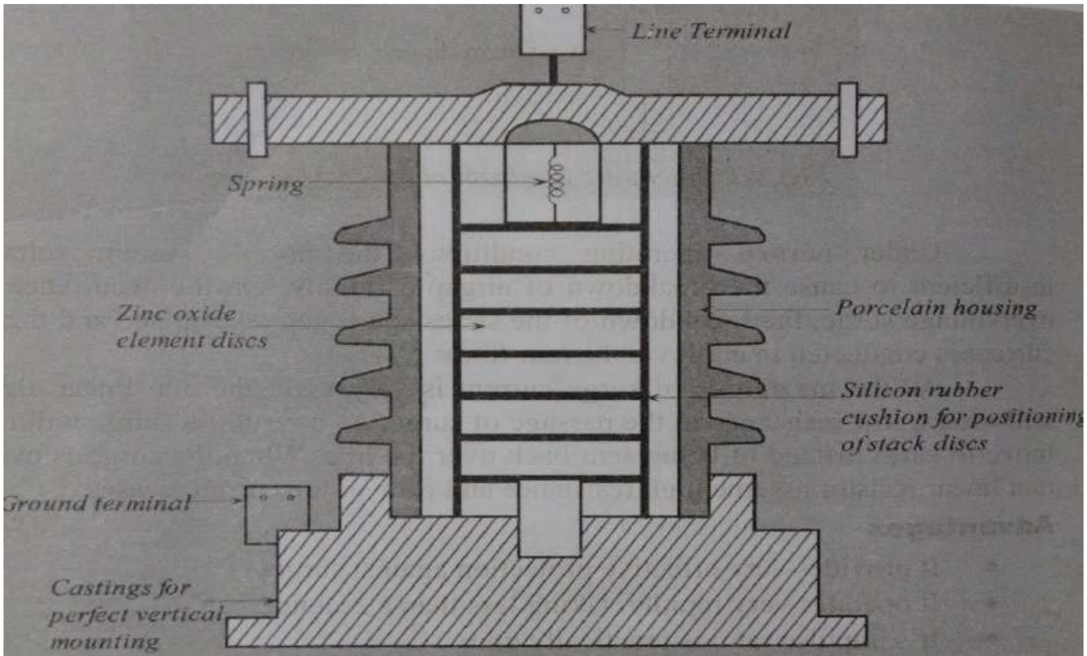


Fig. 9.9 : Zinc Oxide Gapless Arrester

star surge arresters. The zinc oxide surge arresters consist of series connected stacks of zinc oxide elements. It is constructed in such a way that under normal crating conditions the peak value is always less than the sum of the rated voltagesin series connected discs and the resistance losses in the arrester are less under high voltage surges, the current will rise without any delay. A continuous transition is observed during the conducting state and the cement is decreased after the transition is completed. Moreover, there will he no follow up current. Zinc oxide arrL ters have excellent V-I characteristics and higher energy absorption level. They are preferred for the protection of EHV and HVDC systems. The fig. 9.9 represents the constructional features of zinc oxide gapless arrester.

INSULATION COORDINATION:

Insulation levels of EHV system are determined from considerations of switching and power frequency over voltages. Switching over voltages are caused by switching off, lines with no load, low inductive current, short circuits, etc. The uver voltages called dynamic over voltages are caused by line dropping Ferranti effect, over speeding of generators, increase in emf due to leading power factor currents etc. The insulation characteristics of various equipment are defined for rated voltage, switching impulse, lightning impulse, power frequency voltage withstand. These are correlated with characteristic of surge arresters. IEC and IS on insulation co-ordination recommend the values of the following for each voltage level :

i. Normal power frequency rated voltage. ii. Highest power frequency rated voltage.

iii. One-minute power frequency withstands voltage.

iv. Basic Lightning Impulse withstand level for 1 /50,us standard impulse voltage wave.

v. Basic Switching impulse withstand level 250 / 2500 us standard impulse voltage waves.

For each voltage level, there may be one or more of recommended values of insulation levels.

Basic Impulse insulation level is commonly called BIL. The switching impulse level is commonly termed as SIL.

For EHV range the surge arresteres are selected for both lightning surge and switching surge duty. The recommended values of BIL and SIL are for guidance. The final choice is based on the insulation co-ordination studies for transmission lines, substations and associated equipment.

Selection of Basic Insulation Level

Proper selection of insulation focuses not only on the insulating equipment but also on ensuring that it is not damaged. Standard insulation levels are recommended for the coordination of insulation. Basic insulation level are the reference levels expressed in impulse crest voltage with a standard wave. The insulation level decided for substation and power plant equipments should be equal to or greater than the BIL. The number of arresters at different locations on line and in substation depends on the severity of the steep-fronted lightning waves at substations and at different points on lines. Moreover, the voltages at substations may exceed the protective level, depending on the distances involved and the arrester locations. The LA is located on the terminal side of the PT and the associated breaker. The closeness of the arrester location to the transformer provides the greatest protection as it reduces the effect of overvoltage created because of current chopping. On the other hand, by locating the arrester right on the terminal of the transformer, some other substation equipment may fall outside the protective zone, which is decided from the voltage withstand level of the equipment, discharge voltage of the LAs, and the distance between the equipment and the LA. Thus, the BIL is often determined by giving a margin of 30% to the protective level of the surge arrester and selecting the next nearest standard BIL. When a surge arrester is used to provide switching surge protection, the margin given is only 15%. The insulation levels for lines and other equipment are to be selected separately. The atmospheric conditions, lightning activities, insulation pollution, numbers of line outage, and failure rates of the line play a vital role in deciding the insulation level for lines. The protective level of the substation depends on the location of the station, the arrester protective level, and the line shielding used. The line insulation in the end, which spans close to the substation, is normally reduced to limit the lightning overvoltages reaching the substation. In a substation, the busbar insulation level is the highest to ensure continuity supply. The circuit breakers, isolators, and instrument transformers are given the next lower level. Since the power transformer is an expensive, and sensitive device its insulation level is the lowest.Thus, in general, the insulation level of substation equipment, such as circuit breakers, switches, busbars, and instrument transformers, is assumed to be 10% higher than the transformer BIL. The insulation level across the open poles of isolator switches may be kept 10-15% higher than that provided between the poles and earth.

Impulse Ratio

The breakdown of insulation in any equipment depends on the peak magnitude of voltage, shape of the .waveform, and the time for which it is applied to the equipment. The larger will be the magnitude of the voltage required to cause the breakdown the sharper the shape of the voltage wave. Thus, an appreciable time and energy expend are involved in the rupture of any dielectric material. The impulse ratio is related to the energy expenditure and the voltages withstand level. The impulse ratio is defined as the ratio of the breakdown voltage due to an impulse of a specified shape to the breakdown voltage at the power frequency. The insulators should have a high impulse ratio for an economic design, whereas the LAs should have a low impulse ratio so that a surge incident on the LA may be passed to the ground instead of to the apparatus.

Standard Impulse Test Voltage:

Transient over voltages due to lightning and switching surges cause steep build-up of voltage on transmission lines and other electrical apparatus. Experimental investigations showed that the peak rise time of these waves varies from 0.5 to 10 us and decay time to 50% of the peak value, of the order of 30-200 us. The wave shapes are random, but mostly unidirectional. It is to be observed that the wave shape of lightning over voltage can be represented as a double exponential wave, which usually has a rapid rise to the peak value and slowly falls to zero value. The general impulse wave shape of 160 kV is given in Fig. 1.

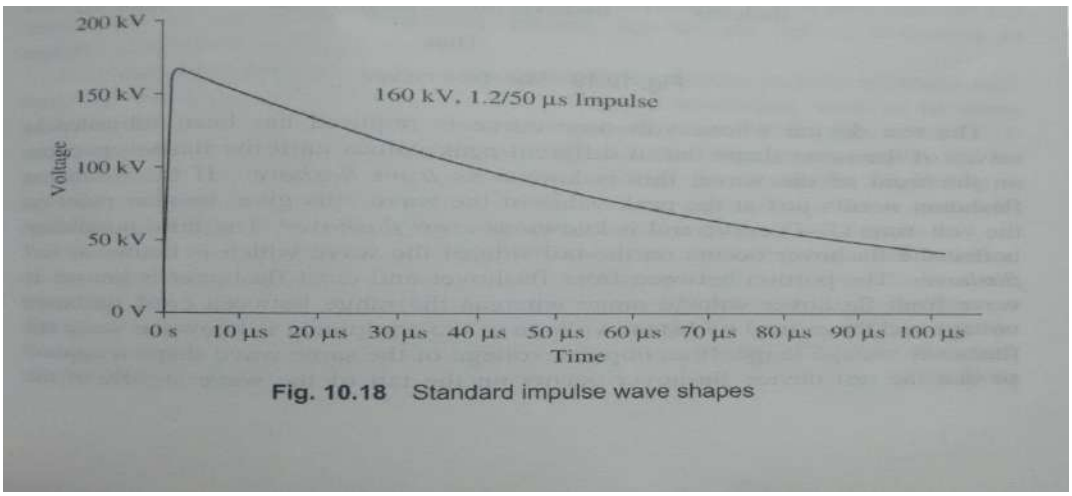


Fig. 10.18 Standard impulse wave shapes

Impulse waves are specified by defining their rise time (or front time) and fall time (or tail time to 50%peak value, and the value of the peak voltage. Thus the 1.2/50 us,750 kV wave represents an impulse voltage wave with a front time of 1.2 ms, fall time to 50% of the peak value of 50 ?is, and a peak value of 750 kV. Indian standard specifications define the 1.2/50 us wave to be the standard lightning impulse. The tolerance allowed in the peak value is +3%, and the tolerances th; can be allowed in the front time and tail time are +30% and +20%, respectively.

Volt—Time Characteristic:

The breakdown voltage of a particular insulation or flash over voltage is a function of both magnitude of voltage and time of application of the voltage. The volt—time curve is a graph showing the relation between the crest flashover voltages and the time to flashover for a series of impulse applications of a given wave shape. The construction of volt—time curve and the related terms are illustrated in Fig.

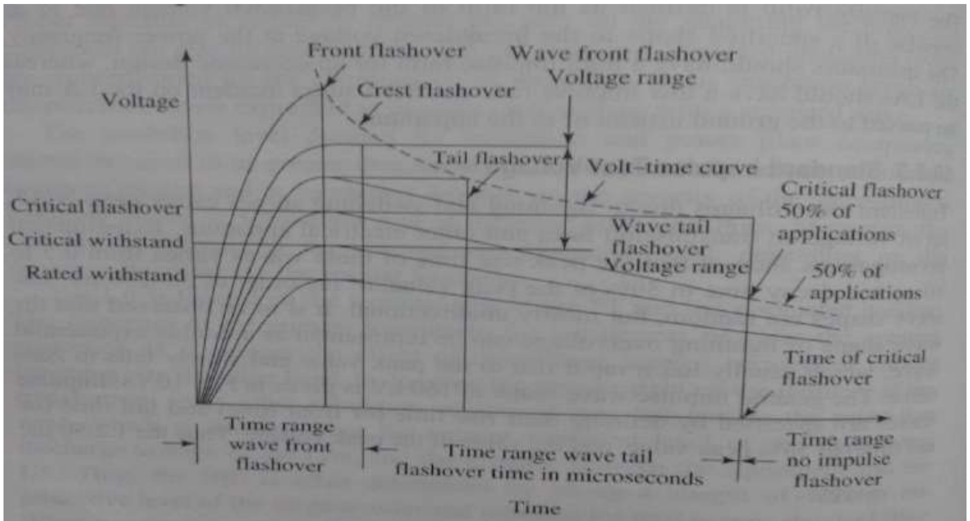


Fig. 10.19 Volt–time curves

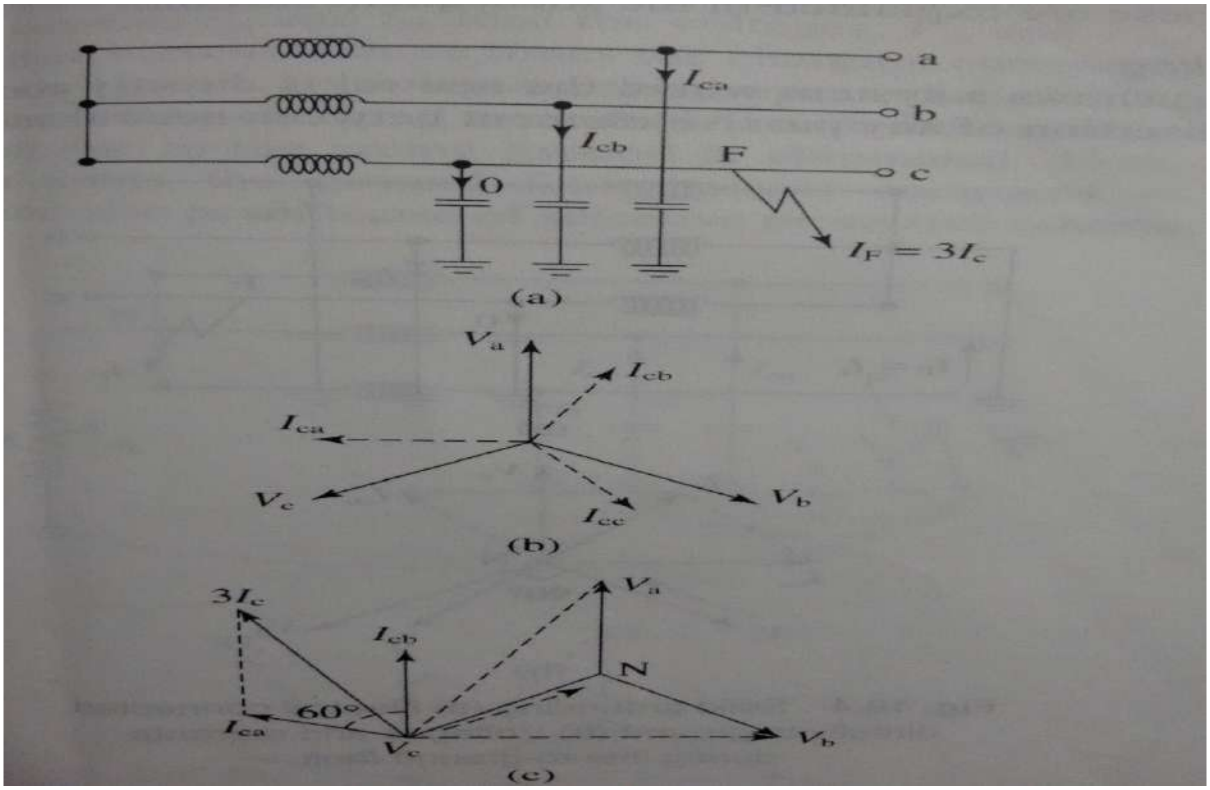
The test device whose volt—time curve is required has been subjected to waves of the same shape but of different peak values until the flash overs occur on the front of the wave; this is known as front flash over. If the insulation flash over occurs just at the peak value of the wave, this gives another point on the volt—time (V—T) curve and is known as crest flashover. The third possibility is that the flash over occurs on the tail side of the wave which is known as tail .flash over. The portion between front flashover and crest flash over is known as wave front flash over voltage range whereas the range between crest flash over voltage and the critical withstand voltage of the equipment is known as wave tail flashover voltage range. If an impulse voltage of the same wave shape is applied so that the test device flash over occurs on the tail of the wave at 50% of theapplication and tails to flashover occurs on the other 50% of the application, the crest value of this wave is called critical flashover voltage. To find the point on V—T curve, draw a horizontal line from the peak value of this wave and also the draw a vertical line passing through the point where the flashover takes place. When the given impulse voltage is adjusted to just below the flashover voltage of the test device, it is called critical withstand voltage. The test device that can withstand the crest of the applied impulse voltage without any disruptive discharge is known as rated withstanding voltage.

Neutral Grounding:

Neutral grounding has been adopted since the beginning of power system development to maintain the phase voltages at a constant level with respect to ground. The grounding of many systems is based on past experience invention of the grounding methods in existing installations. The neutral has no effect on the operation of the three-phase system if it is under a balanced condition. On the other hand, the performance of the system during fault condition is directly affected by the methods of neutral grounding. Moreover, considering the stability of the system and its protection, neutral grounding provides several benefits to the power system. Hence, in a high Voltage system, the neutral is solidly grounded to the earth to limit the over voltage phenomenon.

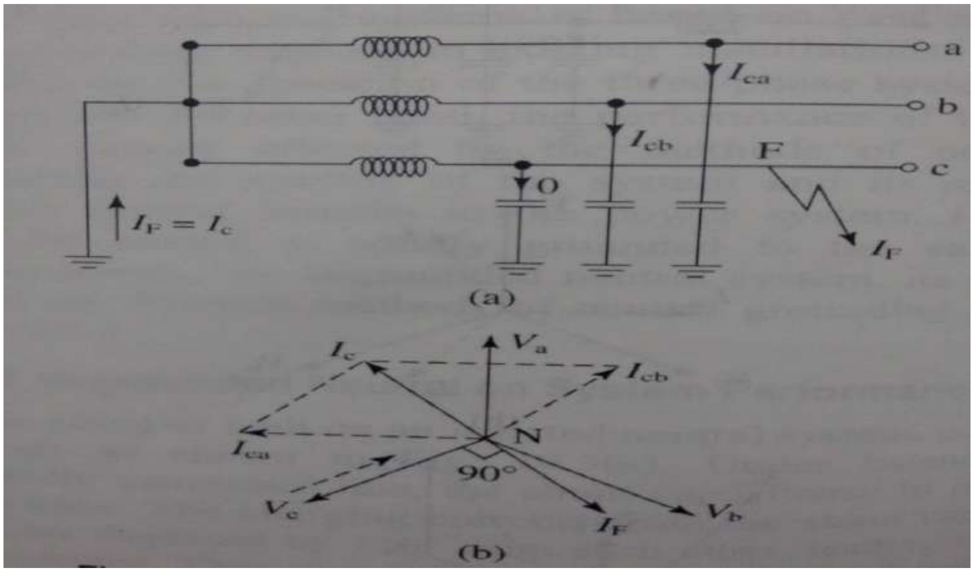
Effects of Ungrounded Neutral on System Performance:

To understand the effect of fault on an isolated neutral system, consider a simple three-phase system as shown in Fig. 10.3(a). Under balanced conditions assuming a perfectly transposed line, the shunt capacitance to ground for each' conductor is the same. The charging currents from the shunt capacitance in all the three phases are displaced by 120° from each other, leading by 90° with the corresponding voltages. Thus, the net sum of these three charging currents is zero as the system is under a balanced condition and the neutral is at approximately ground potential. Figure 10.3(b) shows the balanced set of voltage and current, in which phasors Va, Vh, and Vc denote the phase value of the voltage (Vph), and the currents through the individual phases ./ca, AG, and 4, denote the charging current (./c) through the shunt capacitor. Consider a line-to-ground fault occurring at the point F on phase c; the voltage across the shunt capacitor of that phase reduces to zero. The voltage of the other two healthy phases raise to line-to-line value, and the shunt capacitor charging currents of that phase are displaced by 60° as against its previous value of 1200. Thus, the net charging current is the vector sum of the charging current through the healthy phase, and it is three times the phase current under balanced condition. Figure 10.3(c) shows the vector representation of voltages and currents during line-to-ground fault in an ungrounded system. The net charging current flows through the fault path into the winding of the alternator and is capable of maintaining the arc in the faulty path; this condition is known as arcing ground. During arcing ground, the inductance of the generator winding and the systemcapacitance establish a cycle of charging and discharging, which results in high frequency oscillations. This oscillation builds up a very high voltage and the arc reignites, which results in supplementary transient disturbances. The consequence of such disturbance is the breakdown of insulators. Hence, the ungrounded system is not adopted in the power system because the failure of insulation causes serious phase-to-phase fault conditions.



Solid Grounding:

Figure shows a system where the neutral is directly connected to ground without insertion of any passive elements between neutral and ground. During line-to-ground fault, say on phase c, the potential of the terminal c is grounded. In addition, the neutral voltage is at earth potential. Hence, the voltage of the healthy terminal remains at phase voltage, and charging current will be fully eliminated as shown in Fig. In case of a solidly grounded system, the phase voltage of healthy phases does not exceed 80% of the line voltage and is comparatively very less. Thus, the insulation level required is less, and lower voltage class and less expensive protective equipments are required for solid grounding systems.



Reactance grounding:

Reactive grounding means grounding through impedance which is highly I in and is shown in fig if resistance is used, fault current is limited and system reactance provides the necessary phase opposition between capacitive gr. ound current and fault current. The reactance grounding provides additional reactance which provides a lagging current that neutralizes the capacitive ground current. Hence for circuits where high charging currents are involved such as transmission lines, underground cables, etc. reactance grounding is provided.

The main characteristics of reactance grounding:

• Ground to current is reduced, but it is much larger than capacitive fault current.

• The voltage across healthy phase is between 0.8 to 1 per unit of line-to-line voltage.

• Arcing grounds are avoided.

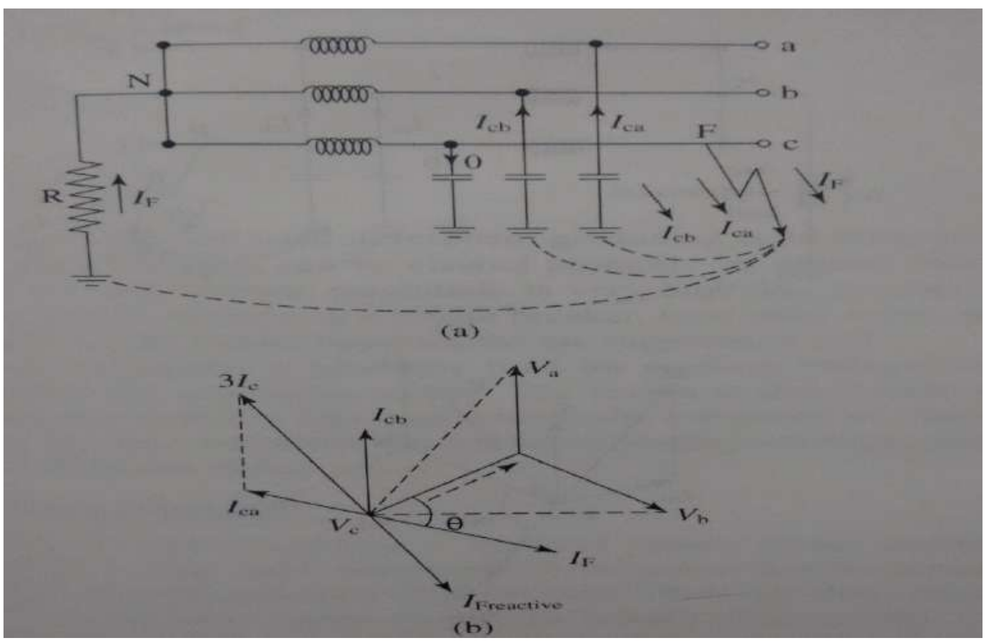
• Transient ground faults are converted into controlled current faults.

• Ground faults relaying is simple and satisfactory.

• Since ground fault current is reduced inductive interference with parallel communication circuits is also reduced.

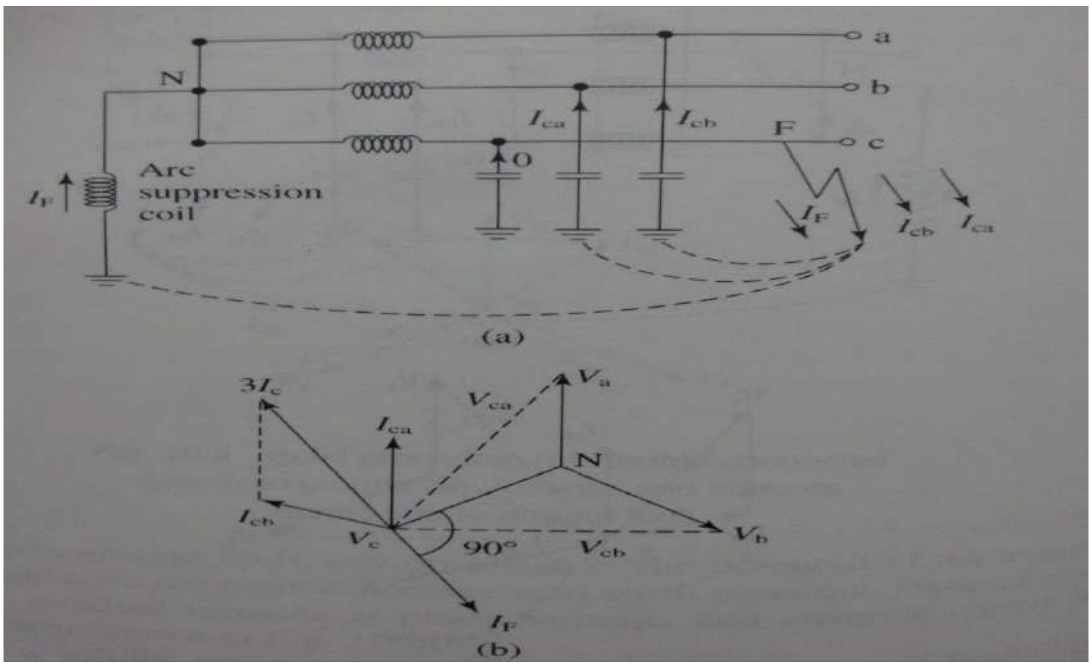
Resistance Grounding

In resistance grounding a high ohmic resistor is inserted between neutral and ground. Current practice is to use resistance loaded distribution transformers in the neutral circuit. This type of grounding is used for generator neutral as it is required to reduce the ground fault current and its destructive effects. Figure 10.5(a) shows that the system neutral is grounded through resistor R. During line-to-ground fault on phase c, fault current IF lags behind the phase voltage of the faulted phase by an angle 9, which depends on resistance R and reactance of the system upto the fault point. Figure 10.5(b) shows the vector diagram in which currents /ca and /ci, lead the voltages, Vca and rch, respectively, by 90°. Their resultant current is three times the charging current (J) through the shunt capacitor of each phase. By selecting the proper value of R, it is possible to compensate the effect of the charging current (31c) with fault current IF so that the transient oscillation due to the arcing ground is eliminated. Thus, a resistance grounding system limits the ground fault current compared to the solidly grounded system and also permits use of selective protective scheme.



Resonant Grounding

The resonant grounding system includes an arc suppression coil (iron cored reactor) inserted between the neutral and ground. The main function of this arc suppression coil is to limit the earth fault current as also to extinguish the arc sustained during the ground fault by balancing the fault current exactly with the charging current. The arc suppression coil is also known as a Petersen coil or ground fault neutralizer. Figure 10.6(a) shows the neutral of the system grounded through the arc suppression coil. Figure 10.6(b) shows the corresponding vector diagram of the earth fault on phase c at point F.



During the fault, the resultant capacitive current is three times the charging current (Ic) of one phase. If the desired value of inductance (L) is inserted in the neutral circuit such that $I_F = 3I_c$, then theoretically there is no current in the fault to sustain the arc. However, the voltage of healthy phases will be $\sqrt{3}V_{ph}$ during line to ground fault, where. Vph is the line-to-ground voltage of the system. If the inductive reactance of coil is XL, then the fault current through it is given by

If the capacitance of each phase is considered to be C, then the charging current during the fault is given by $3I_c$=3.Vph.W.C

where W = 2.(pi) f= angular frequency

f= system frequency

Hence, the inductance of the coil can be found by I_f = 3Ic

Vph/ X_L = 3 Vph W .

$$L = \frac{1}{3\omega^2 C}$$

The arc suppression coil used in resonant grounding is 10 minutes time-rated for a system where the fault can be cleared promptly by ground relays. On the other hand, if the fault current magnitude is very high and persists for a long time, a parallel circuit comprising a circuit breaker, time delay relay, and resistor is arranged such that the circuit bypasses the arc suppression coil. The resonant grounding is .generally used for medium voltage transmission lines connected to the generating source. The reason is that it reduces the line line-to-ground fault into interruption against transient line-to-ground faults compared to other forms of grounding. It also does not allow the spread of double-line or triple-line faults.

Grounding Practices:

The grounding of neutral results in a balanced system under normal working conditions of the system. Each equipment of the power system network should be grounded for the safe operation of the system. There are some practices/rules to be followed by the field engineer to gain the benefit of grounding.

1. Starting from generating station up to distribution, each voltage level should be provided with one grounding system.

2. Resistance grounding is normally used for generators and reactance grounding for synchronous motors and capacitors.

3. Grounding is to be provided to each single power source or multiple power sources as well as to each transformer substation.

4. If multiple power sources are working in parallel in a plant, they all are connected to a common neutral bus connected to the ground through a common resistor. However, neutral switching equipment can be used to connect a particular generator neutral to the neutral bus.

5. If a number of generators are operating in parallel, at least one generator should be grounded properly.

6. For low tension supply, that is, 220 V and 440 V, solid grounding is used whereas for medium voltage, that is, 3.3 kV, 6.6 kV, and 11 kV, resistance or reactance grounding is used. However, for voltage rating of 33 kV and above, solidly grounded neutral system is the right choice.