Why protection needed in a power system?

•It is important to be prepared for any possible effects or failures that may cause long-term shutdown of a system, which in turn may take longer time to bring back the system to its normal course.

•The main idea is to restrict the disturbances during such failures to a limited area and continue power distribution in the balance areas.

•Special equipment is normally installed to detect such kind of failures (also called 'faults') that can possibly happen in various sections of a system, and to isolate faulty sections so that the interruption is limited to a localized area in the total system covering various areas.

The element that detects such possible faults is referred to as 'protective relay' and the assembly of equipment that responds to the signal from the detector is termed as 'circuit breaker or interrupter '.

•The fundamental objective of system protection is to provide isolation of a problem area in the power system quickly, so that the shock to the rest of the system is minimized and as much as possible is left intact.

•Thus protection does not mean prevention, but rather, minimizing the duration of the trouble and limiting the damage, outage time, and related problems that may result otherwise.

Causes of Electrical Faults

• **Weather conditions:** It includes lighting strikes, heavy rains, heavy winds, salt deposition on overhead lines and conductors, snow and ice accumulation on transmission lines, etc. These environmental conditions interrupt the power supply and also damage electrical installations.

• **Equipment failures:** Various electrical equipment like generators, motors, transformers, reactors, switching devices, etc. causes short circuit faults due to malfunctioning, ageing, insulation failure of cables and winding. These failures result in high current to flow through the devices or equipment which further damages it.

• **Human errors:** Electrical faults are also caused due to human errors such as selecting improper rating of equipment or devices, forgetting metallic or electrical conducting parts after servicing or maintenance, etc.

• **Smoke of fires:** Ionization of air, due to smoke particles, surrounding the overhead lines results in spark between the lines or between conductors to insulator. This flashover causes insulators to lose their insulting capacity due to high voltages.

Effects of electrical faults

• **Over current flow:** When fault occurs, it creates a very low impedance path for the current flow. This results in a very high current being drawn from the supply, causing tripping of relays, damaging insulation and components of the equipment.

• **Danger to operating personnel:** Fault occurrence can also cause shocks to individuals. Severity of the shock depends on the current and voltage at fault location and even may lead to death.

• **Loss of equipment:** Heavy current due to short circuit faults result in the components being burnt completely which leads to improper working of equipment or device. Sometimes heavy fire causes complete burnout of the equipment.

• **Disturbs interconnected active circuits:** Faults not only affect the location at which they occur but also disturbs the active interconnected circuits to the faulted line.

• **Electrical fires:** Short circuit causes flashovers and sparks due to the ionization of air between two conducting paths which further leads to fire as we often observe in news such as building and shopping complex fires.

Faults in Electrical Power System:

A defect in a power system which causes the current to stop flowing through that system is known as fault. In other words, the interruption in the normal flow of current is said to be a fault. American institute of Electrical engineers defines the fault in a cable or a wire as:

"The failure of insulation of a conductor partially or completely or the discontinuity of a conductor is known as a fault."

1. **Over current:**

This occurs due to leakage current caused by short-circuit or corona discharge and sometimes due to the overloading of a supply system. Over current relays are used to overcome this fault.

2. **Under Voltage:**

This occurs on the line if the alternator field fails or the voltage drop across the machines is greatly increased. Under voltage relays are used to overcome this fault.

3. **Unbalance:**

This occurs when two phases are earthed, or they are short circuited or when one conductor breaks. In such a condition, different currents flow through different parts of the system.

4. **Reversed power:**

This only occurs in an interconnected system. When the generator's field fails, it starts working as a motor and instead of giving power, it starts drawing it, that is, the power flow reverses due to which the generator might burn up. To prevent this from happening, reverse power relays are used.

5. **Surges:**

When lightning occurs, a severe fault takes place in the adjacent systems due to which short-lived waves of high currents and voltages are produced. Such a fault is known as surges. Lightning arrestors and over voltage relays are used to overcome this fault.

6. **Open circuit:**

This occurs in a system when a conductor breaks, due to which the reliability of a system is affected.

7. **Short circuit:**

This occurs due to failure of insulation, accidents, incorrect usage of system, human errors, internal or external errors or the shorting of overhead conductors.

When such a fault occurs, as a result, heavy currents flow through one or more conductors, such a condition is known as short circuit. The resistance of the circuit is greatly decreased and heavy currents flow, these currents are known as short circuit currents. These currents are highly dangerous for the equipment. To prevent the equipment's from damaging, protective gears, for example, fuses and circuit breakers are used to isolate the faulty section.

Mostly short circuit faults occur in an electrical power system. By improving the design of the system, the possibility of faults can be reduced, however, faults cannot be completely removed.

We further divide the faults in a power system as:

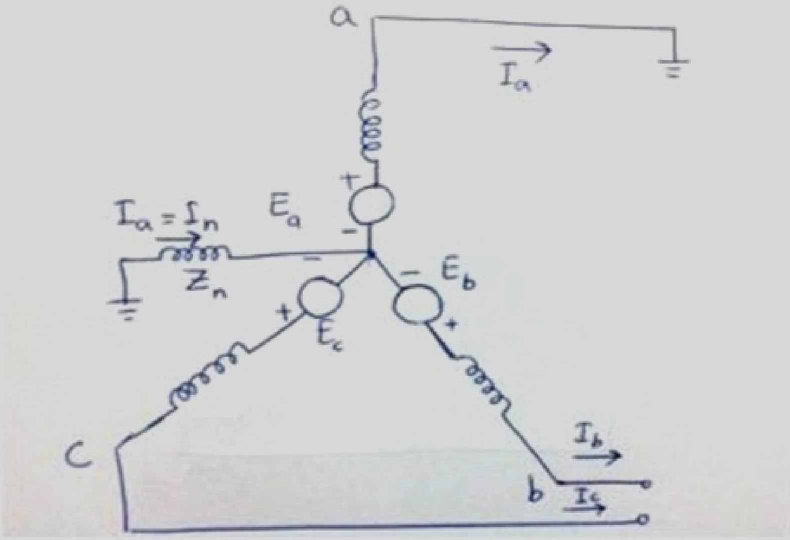
A. Faults on unloaded generators.
B. Faults on transmission lines.

A. FAULTS ON UNLOADED GENERATORS:

Following faults can occur on an unloaded generator:

1. **Single line to ground fault:**

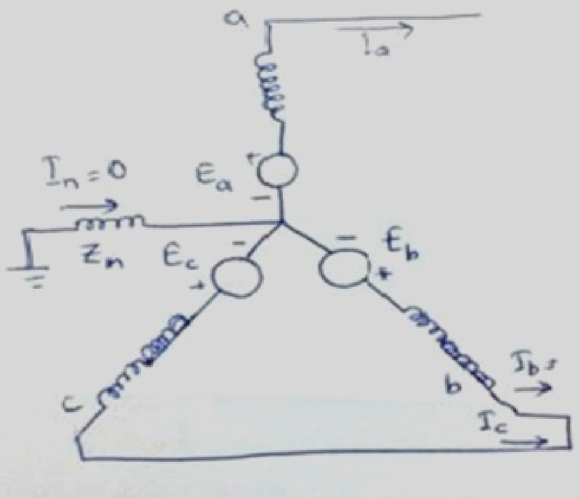
This occurs when one of the three phases is grounded or earthed. The fault on an unloaded star connected generator has been shown in the figure below, with its neutral grounded through a reactance. The fault has occurred on phase a:



single line to ground fault

2. **<u>Line to line fault:</u>**

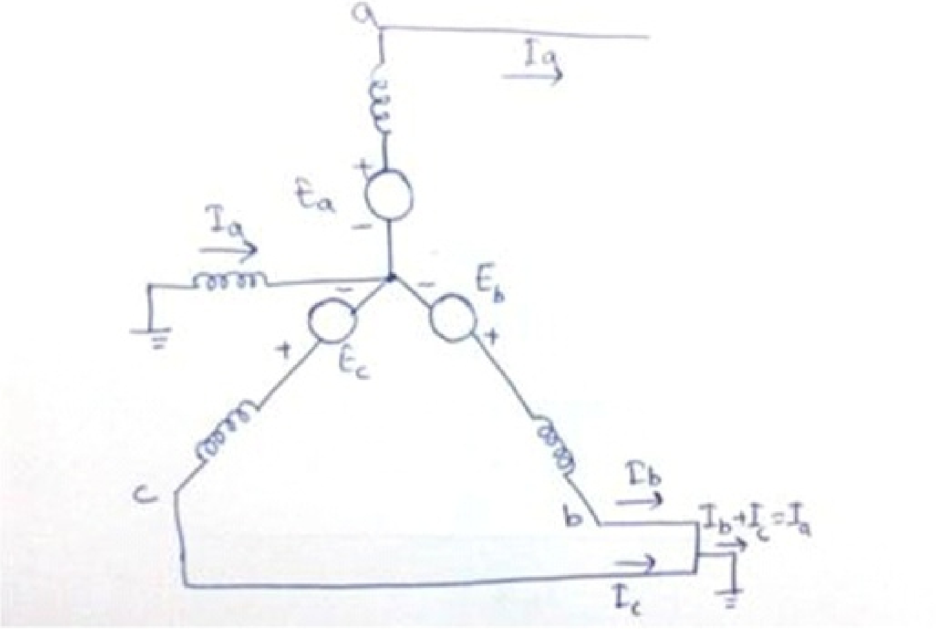
This occurs when two of the three conductors are short circuited. The figure below shows the line to line fault in an unloaded star connected generator. The fault has occurred on phases b and c:



line to line fault

3. **<u>Double line to ground fault:</u>**

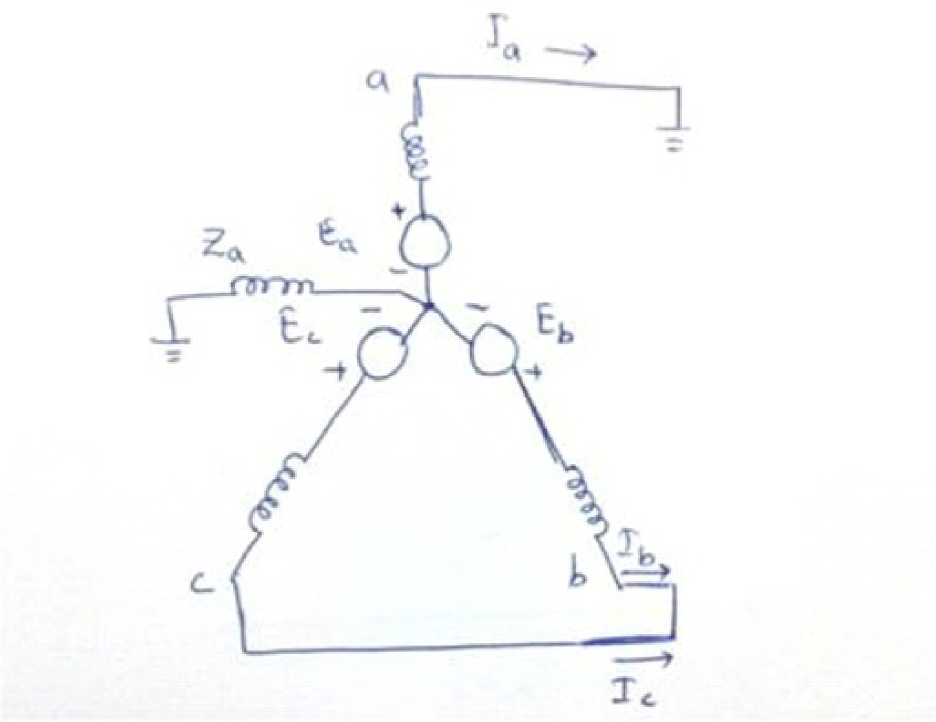
This fault occurs when the two conductors are short circuited as well as grounded. The figure shows this fault on an unloaded generator with faults on phases b and c:



double line to ground fault

4. **Line to line and third line to ground fault:**

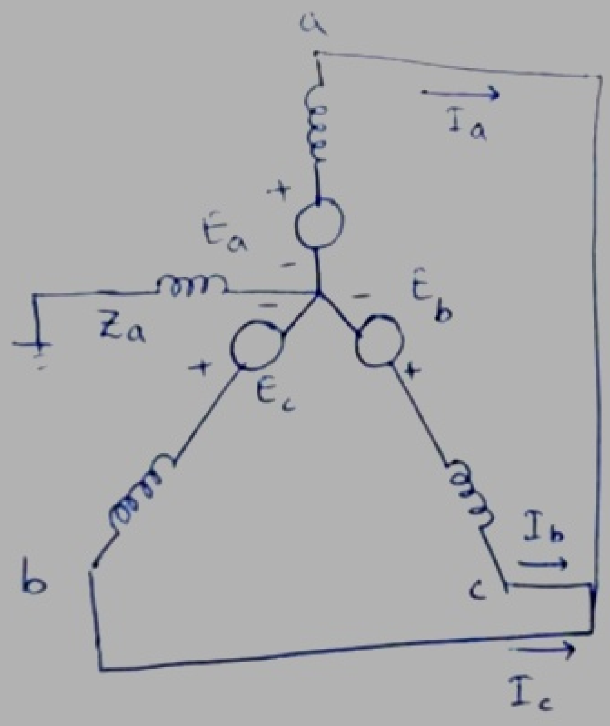
This fault occurs when any of the two phases are short circuited and the third phase is grounded. The figure shows that phases b and c are short circuited together and the phase a is grounded:



Line to line and third line to ground fault

5. **All the three lines short circuited:**

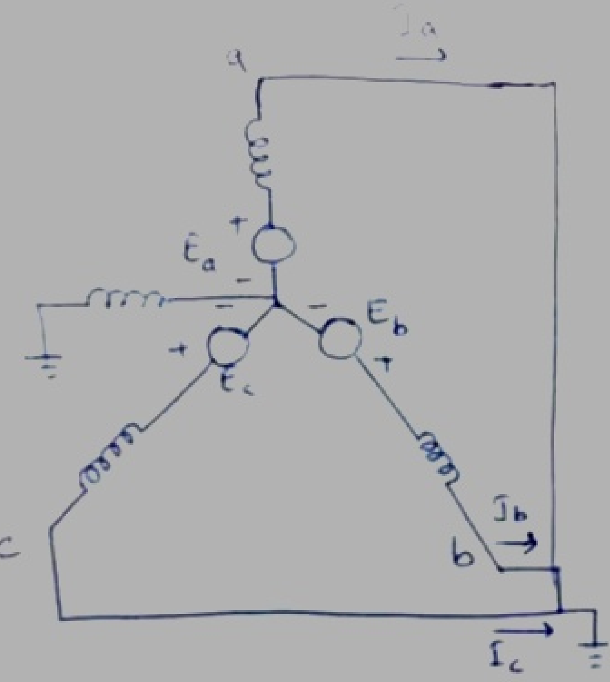
In this fault, all the three lines of the generator are short circuited as shown in the following figure:



All three lines short circuited

6. **All the three lines to ground:**

This fault occurs when all the three phases of the generator are grounded at the same time as shown in the diagram:



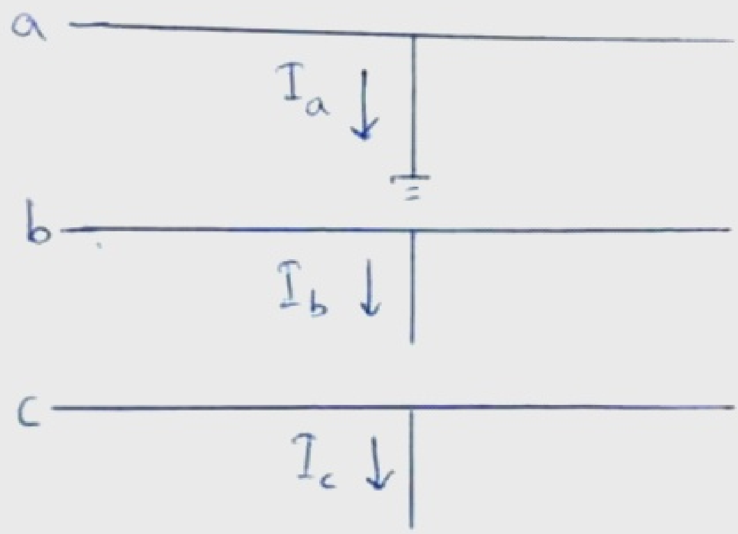
all three lines to ground

1. **FAULTS ON TRANSMISSION LINE:**

The following faults can occur in a transmission line:

1. **Single line to ground fault:**

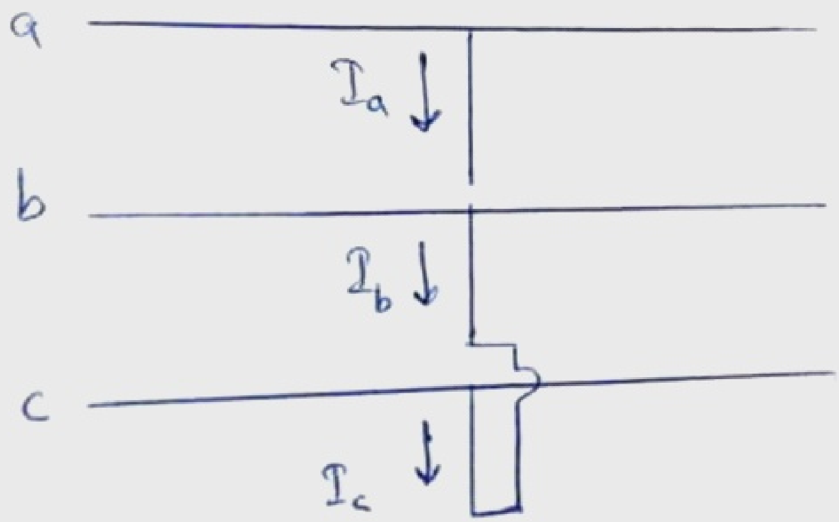
This fault occurs when one of the conductors breaks and falls as shown in the figure:



single line to ground fault on transmission

2. **<u>Line to line fault:</u>**

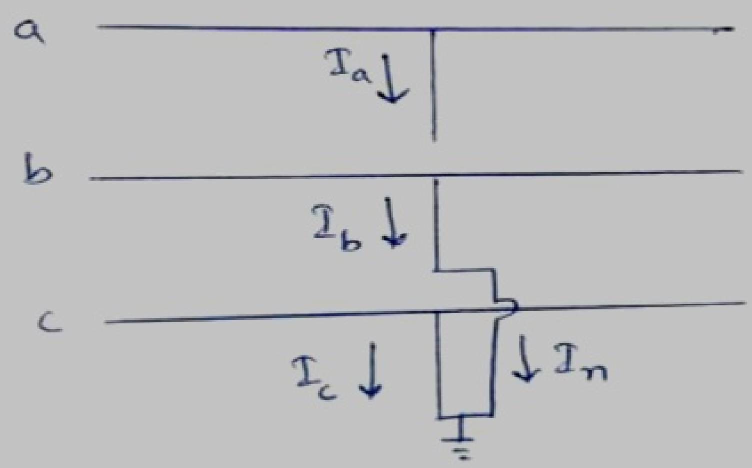
This fault occurs when one conductor breaks and falls on the other conductor as shown in the figure:



line to line fault on transmission

3. **<u>Double line to ground fault:</u>**

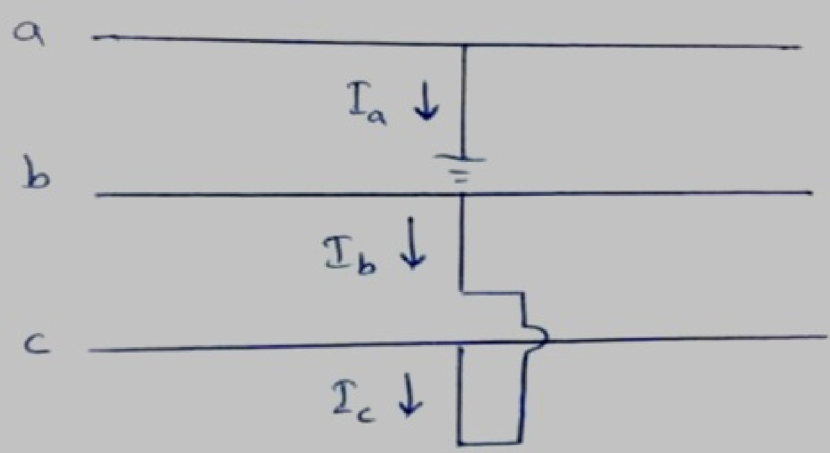
This fault occurs when two of the three lines are short circuited and fall on the ground as shown on the figure:



double line to ground fault on transmission

4. **Line to line and third line to ground fault:**

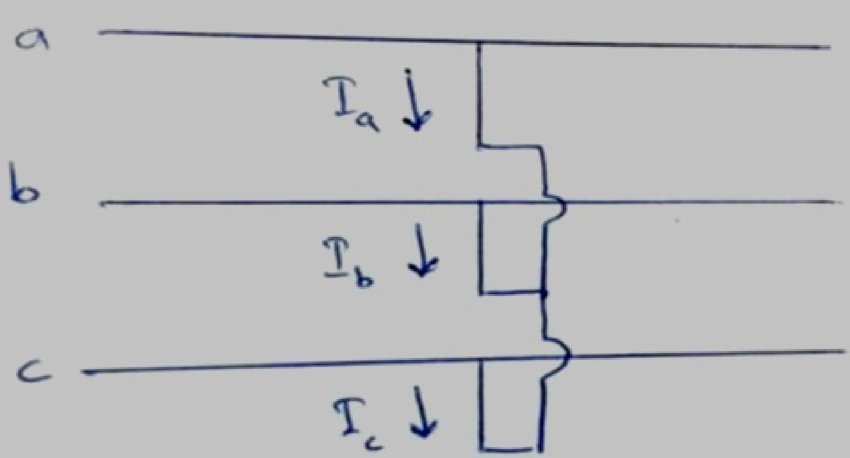
This fault occurs when two conductors are shorted, and the third conductor falls to the ground as shown in the figure:



line to line and third line to ground fault on transmission

5. **All the three lines short circuited:**

This fault occurs when two conductors break and fall on the third conductor as shown in the figure:



All three lines short circuited on transmission

6. **<u>All the three lines to ground:</u>**

This fault occurs when all the three conductors break and fall to the ground as shown in

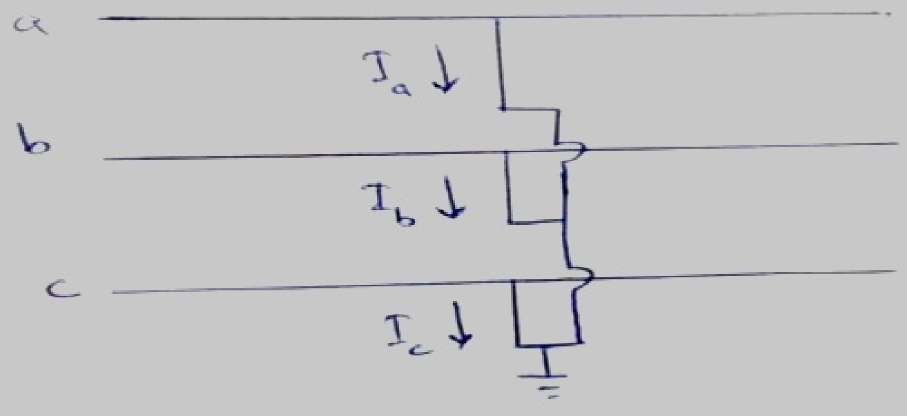


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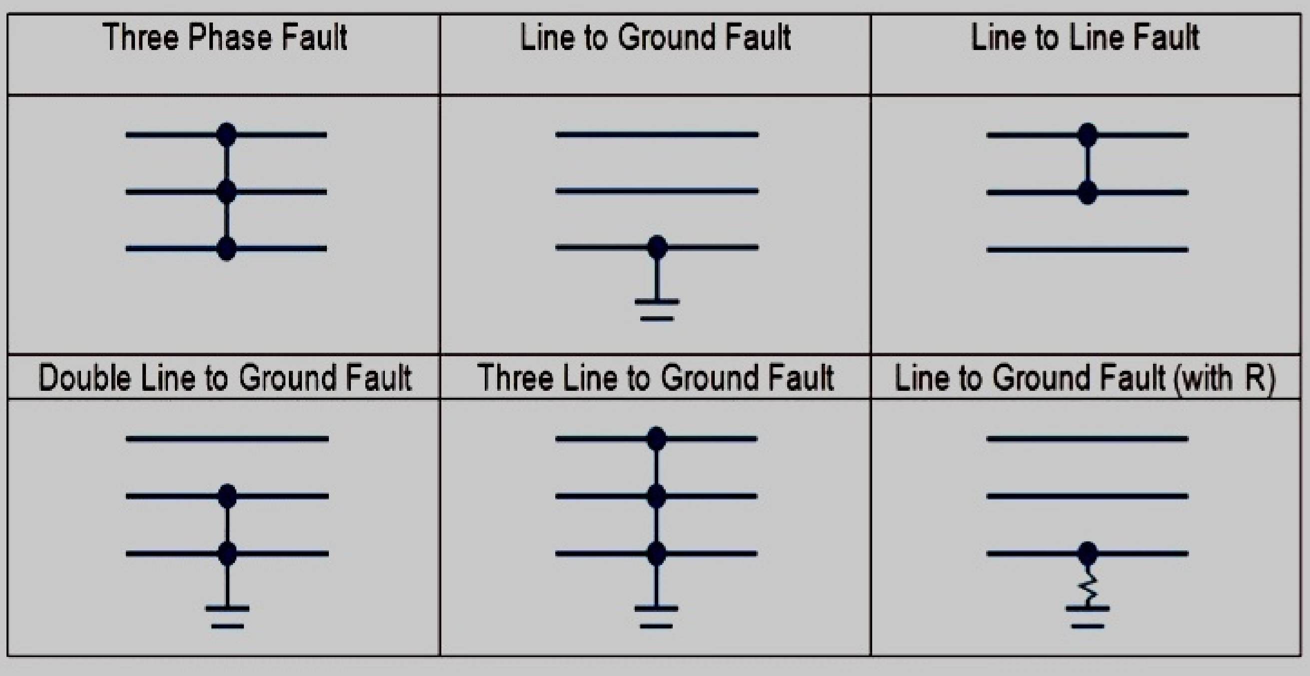
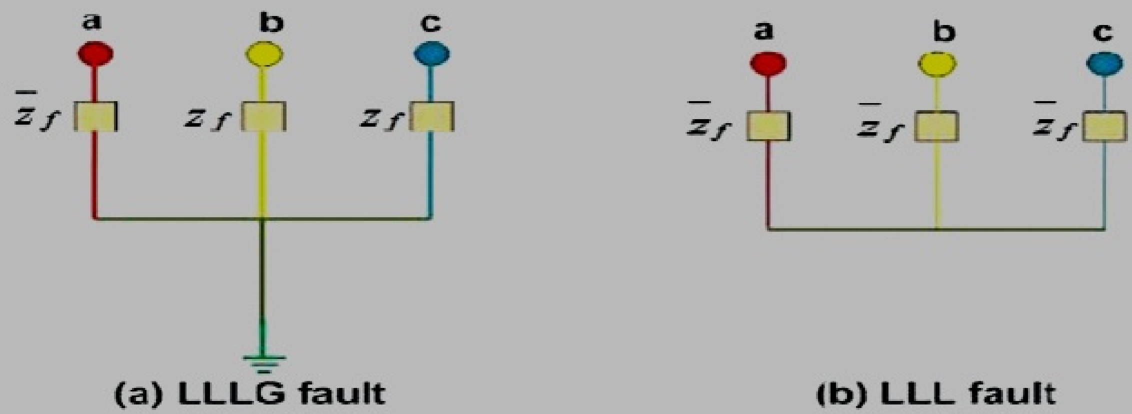
Figure: all three lines to ground on transmission

There are mainly two types of faults in the electrical power system. Those are symmetrical and unsymmetrical faults.



1.Symmetrical faults

These are very severe faults and occur infrequently in the power systems. These are also called as balanced faults and are of two types namely **line to line to line to ground** (L-L-L-G) and **line to line to line** (L-L-L).



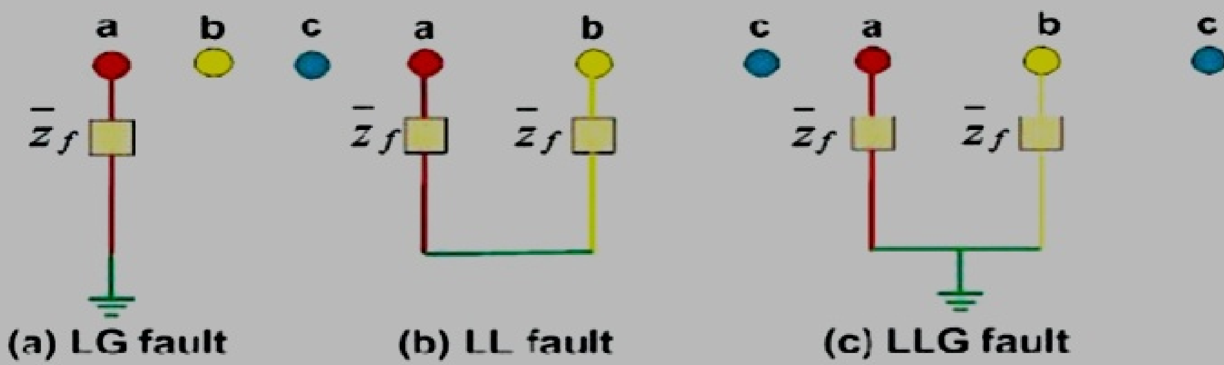
Symmetrical faults

Only 2-5 percent of system faults are symmetrical faults. If these faults occur, system remains balanced but results in severe damage to the electrical power system equipment.

Above figure shows two types of three phase symmetrical faults. Analysis of these fault is easy and usually carried by per phase basis. Three phase fault analysis or information is required for selecting set-phase relays, rupturing capacity of the circuit breakers and rating of the protective switchgear.

2.Unsymmetrical faults

These are very common and less severe than symmetrical faults. There are mainly three types namely **line to ground** (L-G), **line to line** (L-L) and **double line to ground** (LL-G) faults.



Unsymmetrical faults

Line to ground fault (L-G) is most common fault and 65-70 percent of faults are of this type

The first four faults of generator and transmission lines produce unsymmetrical short-circuit currents whereas the last two produces symmetrical short-circuit currents. Unsymmetrical means the amount of current flowing through each conductor will be different whereas symmetrical means the amount will be the same.

Fault types

Faults can be broadly classified into two main areas, which have been designated 'active' and 'passive'.

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.

The solid fault occurs as a result of an immediate complete breakdown of insulation as would happen if, say,

a pick struck an underground cable, bridging conductors, etc.

or the cable was dug up by a bulldozer.

or in mining, a rockfall could crush a cable, as would a shuttle car.

The 'incipient' fault, on the other hand, is a fault that starts as a small thing and gets developed into catastrophic failure.

As for example some partial discharge (excessive discharge activity often referred to as Corona) in a void in the insulation over an extended period can burn away adjacent insulation, eventually spreading further and developing into a 'solid' 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 over heating of insulation (deteriorating quality, reduced life and ultimate failure).

- *Overvoltage: Stressing the insulation beyond its withstand capacities.*

- *Under frequency: Causing plant to behave incorrectly.*

- *Power swings: Generators going out-of-step or out-of-synchronism with each* other.

It is therefore very necessary to monitor these conditions to protect the system against these conditions.