Chapter 01: Faults on transmission line generality

1. Introduction

The Electric Power System is divided into many different sections. One of which is the transmission system, where power is transmitted from generating stations and substations via transmission lines into consumers. Both methods could encounter various types of malfunctions is usually referred to as a “Fault”.

Fault is simply defined as a number of undesirable but unavoidable incidents can temporarily disturb the stable condition of the power system that occurs when the insulation of the system fails at any point.

The causes of faults are many, they include lighting, wind damage, trees falling across transmission lines, vehicles or aircraft colliding with the transmission towers or poles, birds shorting lines or vandalism.

2. Requirement of Transmission Lines

Transmission lines should transmit power over the required distance economically and satisfy the electrical and mechanical requirements prescribed in particular cases.

The lines should stand the weather conditions of the locality in which they are laid. This would involve wind pressures and temperature variation at the places and the lines should be designed for the corresponding mechanical loading.

The regulation would give the voltage drop between the sending-end and the receiving-end.

As far as the general requirements of transmission lines are concerned, the lines should have enough capacity to transmit the required power, should maintain three

continuous supplies without failure, and should be mechanically strong so that there are no failures due to mechanical breakdowns also.

3. Voltage for High-Voltage Transmission Lines selection

A choice could be made out of the standard voltages that are used in the country. The voltage selected has to be economical and depends on the cost of the lines, cost of apparatus such as transformers, circuit breakers, insulators, etc. This cost increases rapidly for voltages in the range of 230 kV and above

The voltages used as standards in many countries 11 kV, 22 kV, and 33 kV for short lines, 66 kV and 110 kV for medium lines and 132 kV, 166 kV, 230 kV and above for long lines.

As regards to the distance of transmission, 11 kV and 33 kV lines are used for short distances, while the other lines may be used for the appropriate distances.

4. Selection of Conductors

The size of the conductor selected depends on the length of the transmission line, load on the line, the voltage of the line and for a given loss of energy that expressed as percentage of the energy to be transmitted.

The conductors available are hard-drawn copper or stranded conductors, or ACSR (**A**luminum **C**onductor **S**teel **R**einforced) conductors that highly suitable for overhead power transmission. For short lines with comparatively low voltages up to 33 kV, copper conductors are used if available.

ACSR is the type of conductor most used worldwide and it is composed of a steel core and one or more hard drawn aluminum layers.

Fig.1.1 ACSR conductor

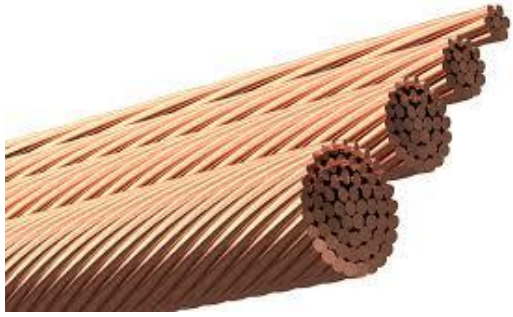

Fig.1.2 Hard down copper

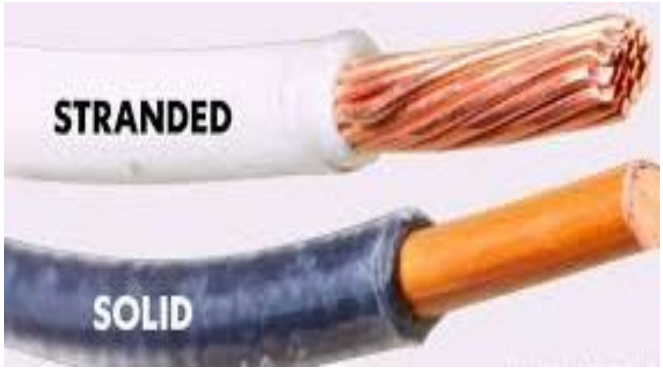

Fig.1.3 Stranded and solid copper cable

5. The Nature and Causes of Faults:

The nature of a fault is simply defined as any abnormal condition, which causes a reduction in the basic insulation strength between phase conductors, or between phase conductors and earth or any earthed screens surrounding the conductors.

1. Weather Condition

Extreme weather conditions affect the power lines in many ways that lead to electrical faults. These causes include

1. Lightning

More than half of the electrical faults occurring on overhead power transmission lines are caused by lightning (see Figure 2.1). The main conventional approaches for reduction of the lightning flashover faults on power lines are lowering of the footing resistance and employing of multiple shielding wires, and differential insulation.

A newly developed suspension-type line arrester has been developed by incorporating ZnO elements into the shed of a conventional suspension insulator

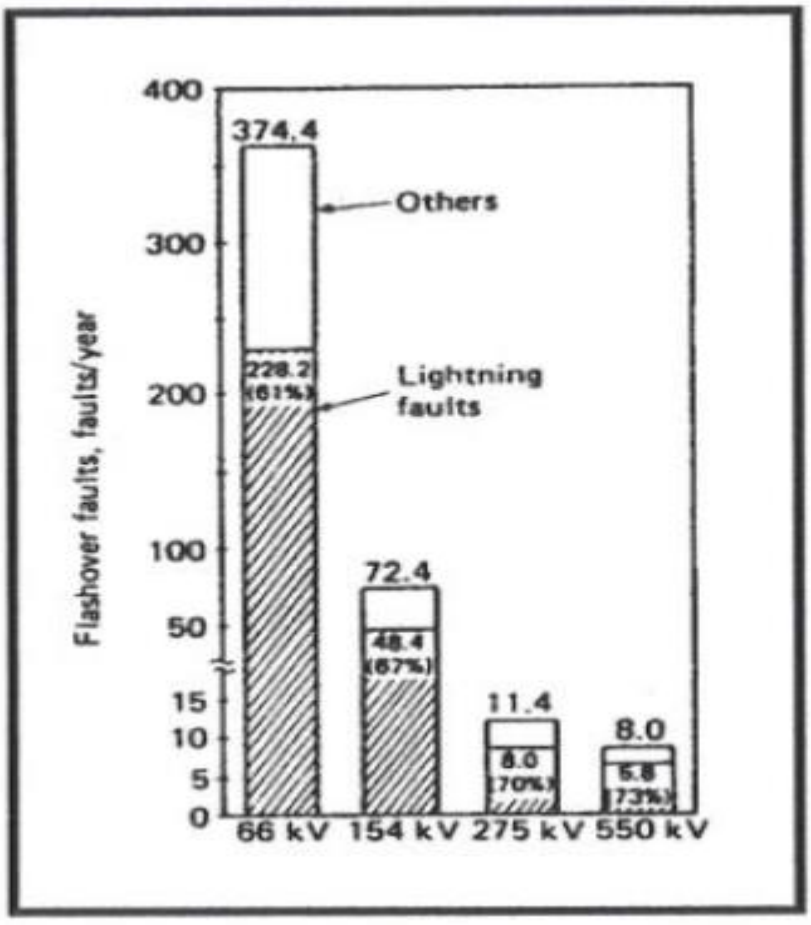

Fig.1.4 Flash over on transmission line statistic

Fig.1.5 Lightning arrester

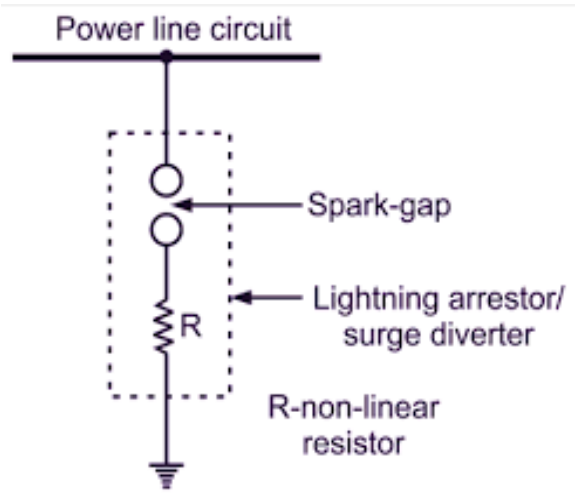

Fig.1.6 lightning arrester diagram

Fig.1.7 Lightning arrester for building

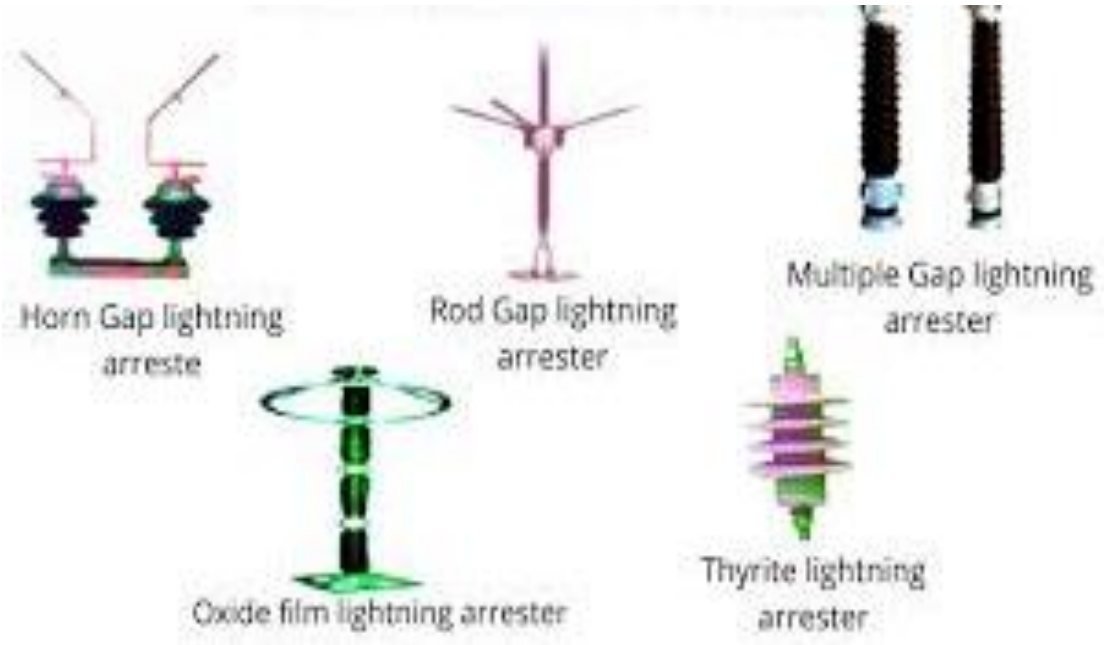

Fig.1.8 Different types of lightning arrester

2. Pollution

Pollution is commonly caused by deposited soot or cement dust in industrial areas, and by salt deposited by wind-borne sea-spray in coastal areas. A high degree of pollution on an insulator string, although it reduces the insulation strength of the affected phase, does not become a fault until it causes a flashover across the string.

Fig.1.9 Process flashover on polluted insulator

3. Fires

The occurrence of fire under transmission lines is responsible for a great number of line outages in many countries. Faults are mainly due to conductor to ground short circuit at mid-span or phase-to-phase short circuit depending on line configuration and voltage level.

Another problem arising from burning is the contamination of the insulators due to the accumulation of particles (soot, dust) on its surfaces. In this case, the line insulation requirements should be determined in such a way that the outages under fire could be reduced to a minimum

Other causes of faults on overhead lines are

- fog, ice
- Heavy rain in the monsoon season
- Storm, heavy wind and trees falling on the power lines
- Earthquake
- Flood
- Snowfall forms ice over the power lines.

Such weather conditions can damage the generation, transmission, and appliances connected to a power system.

2. Equipment Failure

Any kind of abnormality in any equipment, transmission cables, generation station, appliances, or loads connected in an electrical system can cause an electrical fault due to the following reasons.

- Insulation failure of cables and windings in the motor

- Aging and degradation of conductor
- Malfunctioning
- Physical damage

3. Human Error

There are certain safety rules and regulations that must be followed when installing any power system. However human error can still cause faults due to.

- Installing devices and components of improper ratings.
- Improper maintenance
- Switching circuit during its maintenance

Human error can be reduced to a great extent by following electrical codes and allowing professionals to do their job.

4. Miscellaneous

Here are some miscellaneous causes for the electrical fault

- Stress on power lines: the mechanical stress such as bending, flexing, and thermal stress acting on power lines causes electrical failure.
- Switching surges: Due to sudden switching of a circuit breaker, voltage surges are created in the circuit that causes overvoltage
- Accidents: any accidents involving vehicles hitting the utility pole
- Birds shorting the power lines
- Strings and snakes shorting the power lines

6. Electrical Fault types

The faults in electrical power systems can be briefly classified into two types

- Open Circuit Fault
- Closed Circuit Fault

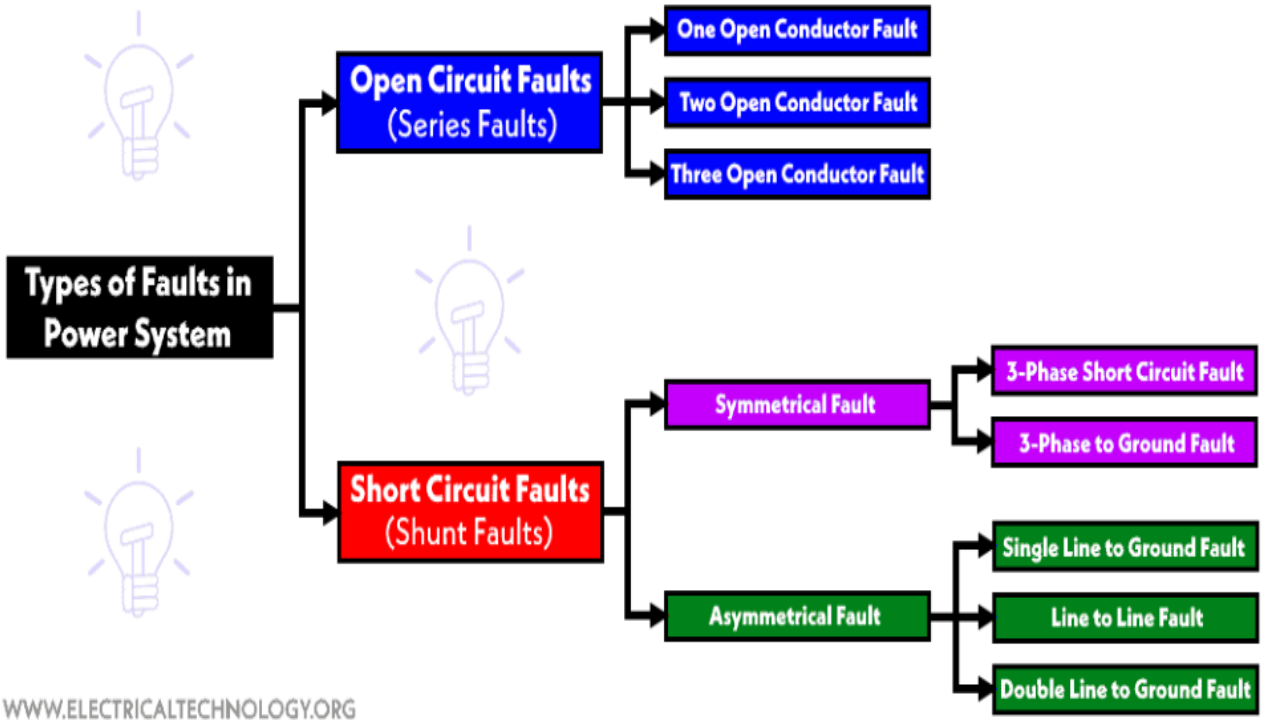

Fig.1.10 Fault types

7. Severity and Occurrence of Faults

The severity and occurrence are described in the table below

S.No	Fault Type	Fault Name	Short Name	Occurrence of fault	Severity of fault
1	Asymmetrical	Line to Ground	L – G	70 – 80%	Lowest
2	Asymmetrical	Line to Line	L – L	15 – 20%	>>
3	Asymmetrical	Line to Line to Ground	L – L – G	10%	>>
4	Symmetrical	Line to Line to Line	L – L – L	1%	>>
5	Symmetrical	Line to Line to Line to Ground	L – L – L – G	2 – 3%	Highest

8. Effects of Electrical Faults

Different kinds of faults, their duration, and location affect the electrical system differently.

1. Effects of Short Circuit Fault

Over-current: short circuit fault creates very low impedance causing a huge fault current (over-current) that can damage the insulation and equipment connected to the circuit.

Under voltage: In a short circuit fault, the large current flow also causes the reduction in the supply voltage.

Danger to personnel: Electrical fault can pose danger to personnel working at the site of fault. It can even become fatal depending on the level and duration of the fault.

Electrical fire: short circuit fault can lead to electrical fire caused by the arcing and sparks at the fault location that can spread to any adjacent objects and eventually the whole building.

2. Effect of Open Circuit Fault

The Open Circuit faults are less severe and it causes in reduction of load at the alternator. In turn, it results in the acceleration of the alternator causing over frequency.

It also causes an imbalance in the load. The intact phases take the load current of the broken phases. This affects the life span of the connected load.

Reference:

[01] William Patrick Davis, analysis of faults in overhead transmission lines, FALL 2012
[02] Furukawa, Shuji, Usada, Osamu, Isozaki, Tashaki, and Irie, Tashaki (October 1989). Development and Application of Lightning Arresters for Transmission Lines. IEEE Transactions on Power Delivery, 4(4), 2121-2127
[03] https://www.electricaltechnology.org/2022/09/faults-in-electrical-power-system.html