

## Chapter-3

# Transient Over Voltages & Insulation Coordination in High Voltage Network

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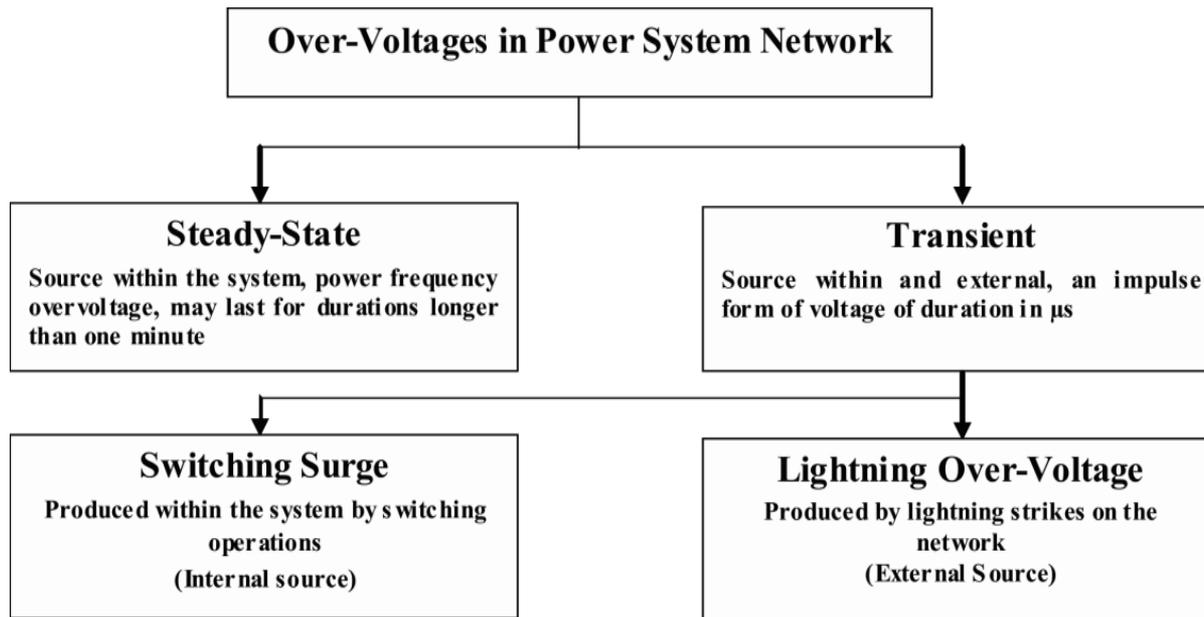
# Objective

In this chapter you will learn the following:

- Types of overvoltage's, their cause, and source
- Standard shapes of transient overvoltage's
- Mechanisms of the production of overvoltage's
- Transient overvoltage protection
- System 'Basic Insulation Level' (BIL)
- Principles of insulation coordination design

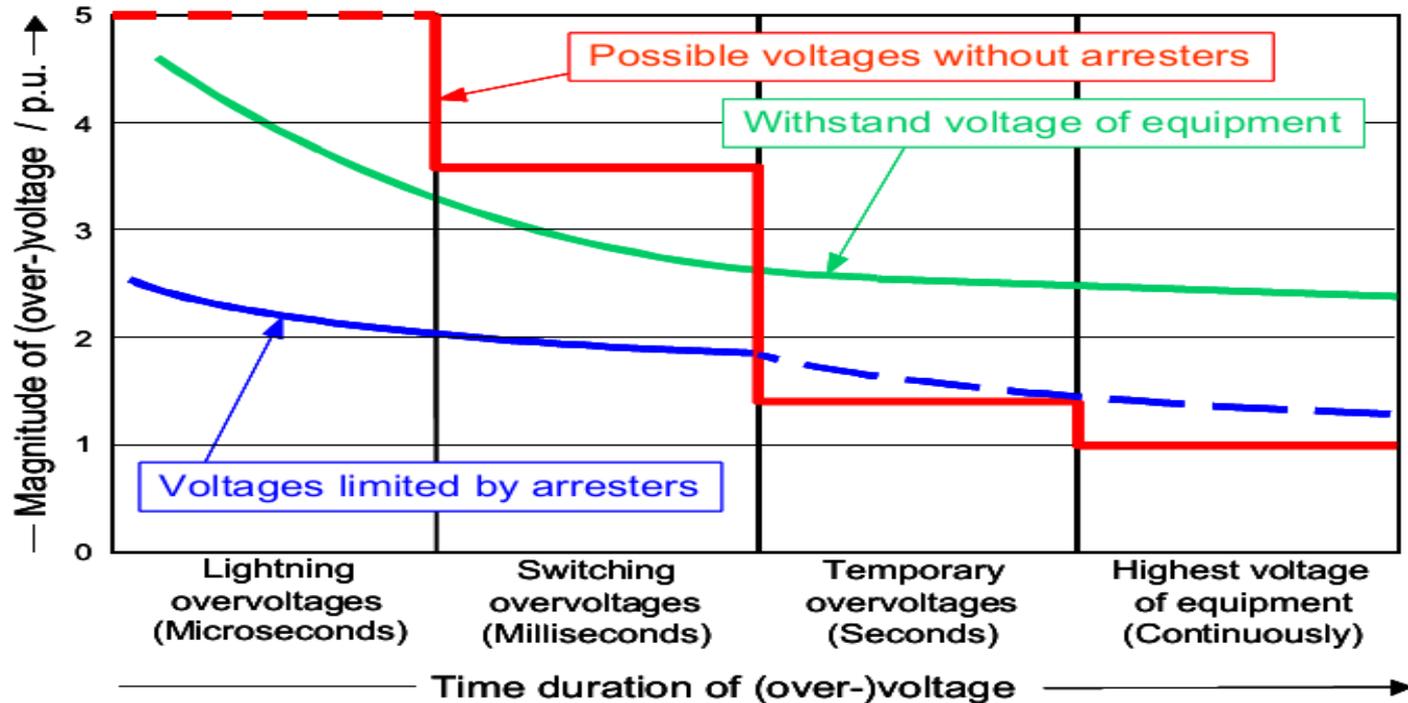
# Introduction

- ❑ OVERVOLTAGES in electric power network is temporary (or) transient in nature.
- ❑ The insulation system all over the power network must be designed to sustain over voltage and not let cause any damages in system.



# Introduction (Continued..)

- Estimation of magnitudes of over voltages in per unit and their durations.



# Steady State Overvoltage Problems

## Load disconnection

- This could happen due to (a) the outage of a long/important high voltage transmission line carrying large amount of power, (b) an electrical fault, or (c) a mechanical breakdown.

## Unbalanced load distribution

- A sudden interruption of power supplied by one of the three phases, as in the case of a fault condition, could lead to a severe situation of unbalanced load distribution giving rise to overvoltage in the other two phases.

# Transient Overvoltages In Power Systems

- The impulse overvoltages generated at a single point in the high voltage network, are spread in every direction from the point of generation in the form of a travelling wave.
- The high voltage circuit breaker operations within the system give rise to 'switching overvoltages'.

# Lightning Overvoltage, 'Li'-surge

## Reasons

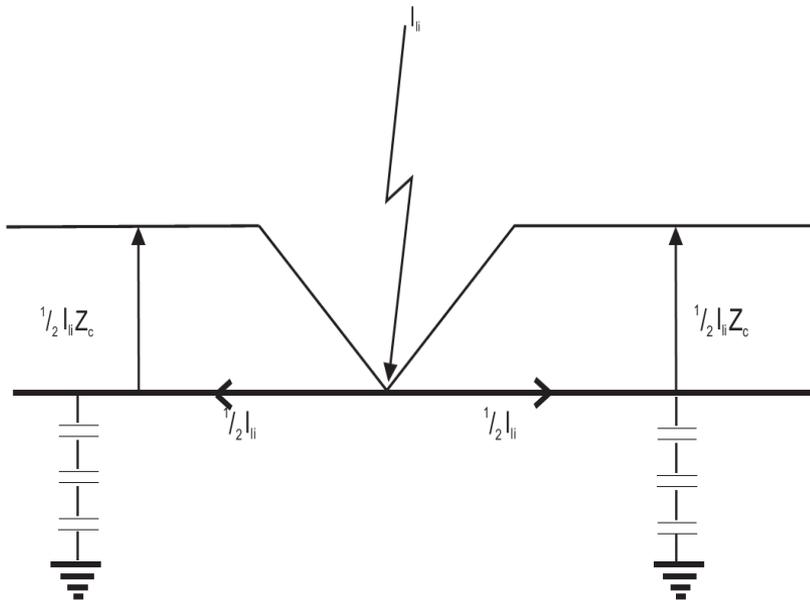
- Presence of metallic conductors.
- Presence of streamer corona.

## The pre-ionized zone:

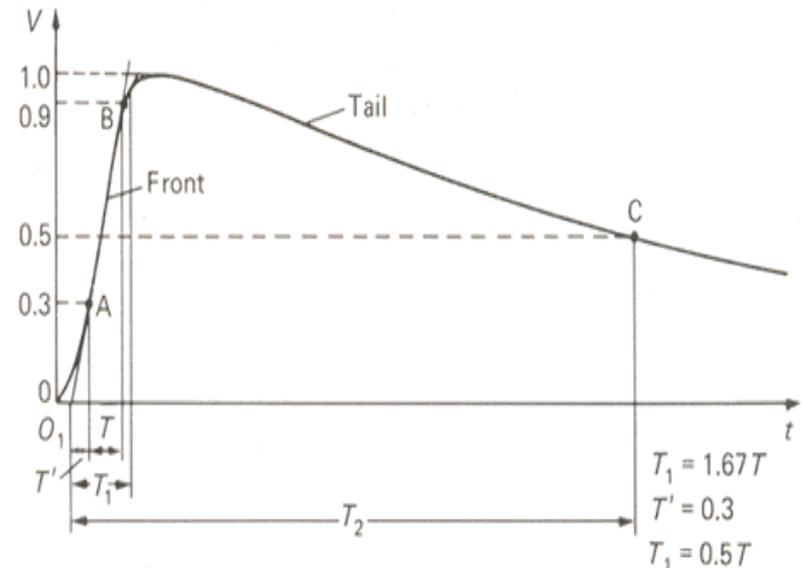
- Corona or Partial Breakdown (PB) in air is a continuous process on the whole power system network, that is, power generation, transmission, and distribution.

# Lightning Overvoltage(continued..)

Lightning strike and the overvoltage on a transmission line



Standard lightning impulse wave shape



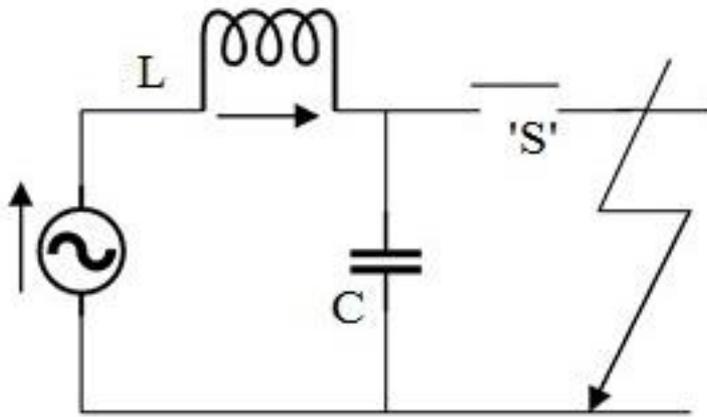
# Switching Overvoltage, 'Si'-surge

## Major reasons

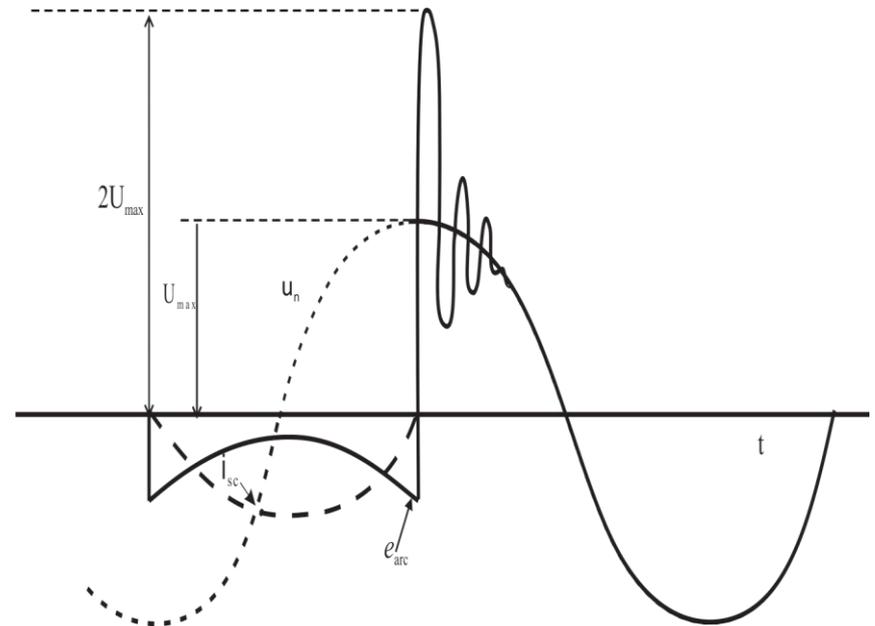
- Making and breaking operation at circuit breakers in the circuits having large inductances and capacitances,
- De-energising of unloaded transformers, reactors, etc.,
- Fault initiation and clearing,
- Sudden load rejection.

# Switching Overvoltage, 'Si'-surge(continued...)

Basic circuit



The current and voltage waveforms

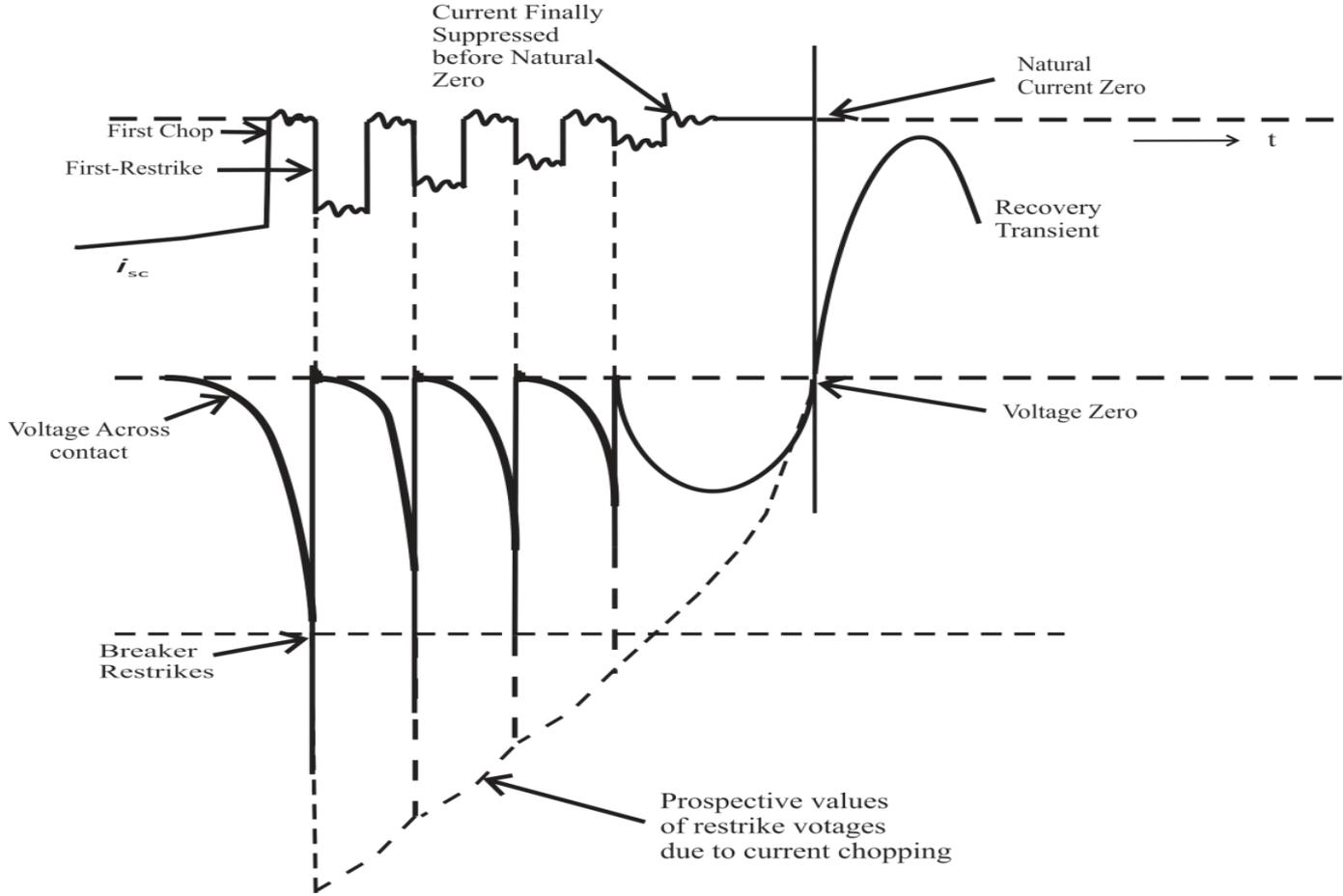


# Very Fast Switching Transient Overvoltages In Power System

## Factors

- The speed of switching operation or the electrode separation in the circuit breakers.
- The arc quenching characteristics/properties of the circuit breaker.
- Restoration of the dielectric strength of the circuit breaker electrode gap.
- The instant at which the arc across the electrodes is actually extinguished, which represents the magnitude of the instant current and hence the energy stored in the circuit inductance being interrupted.

# Overvoltages due to current chopping giving rise to VFTO



# Overvoltage Protection In Power System Network

- All overhead transmission lines above 33 kV are provided with a grounded wire on their topmost position continuously along the length to prevent the phase conductors below from getting struck by lightning.
- The overvoltages produced by the circuit-breaker operations in the network also travel over the line conductors and spread in every direction.
- The overvoltage protective device 'surge diverter' was initially very commonly known as 'lightning arrester' (LA).
- Every insulator string on transmission lines is provided with a 'rod gap' to protect it from overvoltage
- The insulator string from dangerous over voltages but also attenuates the peak intensity of the over voltage travelling wave.

## A rod-gap installed over an insulator

- ❖ lightning in Japan causes more than 50% failures of high voltage transmission lines. Malfunctioning of the 'surge diverters', a crucial device, could be one of the reasons.



# Insulation Coordination In High Voltage Power Network

- The term 'insulation coordination' is defined as the correlation of electrical equipment insulation level with respect to the characteristic of protective devices, if provided, such that the equipment is protected from excessive overvoltages.
- lightning and switching overvoltages occurring together is possible but the probability is quite low, and hence such a situation can be neglected.
- Providing the 'basic insulation level' to the system so that it could withstand the severest of lightning overvoltage.
- Transmission voltages beyond 400 kV, the requirement of the system insulation level itself became quite strong which could perform in a better way against the known highest magnitudes of lightning overvoltages.
- System voltages of 800 kV and above, the switching overvoltages become the main criterion for insulation design, which may have a range of variation from 2.0 to 3.3 pu.

# Basic Insulation Level And Switching Impulse Level

- The basic insulation level (or BIL) for lightning impulse is defined as the electrical withstand voltage of insulation expressed in terms of the crest value of the 'standard lightning impulse', as per IEC-71.
- BIL if chosen correctly relative to the prevailing protective level, the equipment will have an adequate insulation level to withstand the prevailing switching surges also.

# Practices Adopted For Insulation Coordination

- A system designer must have clear knowledge about this aspect while dimensioning the system insulation for the 400 kV and above transmission network.
- Below 400 kV, all the three techniques of protection, earth wires, rod gaps, as well as lightning arresters, are provided on the transmission lines and sub-stations.
- Newly developed metal oxide 'surge diverters' or commonly known as 'lightning arresters' are installed at the sub-stations, which cater to the need for both switching as well as lightning overvoltage transients.

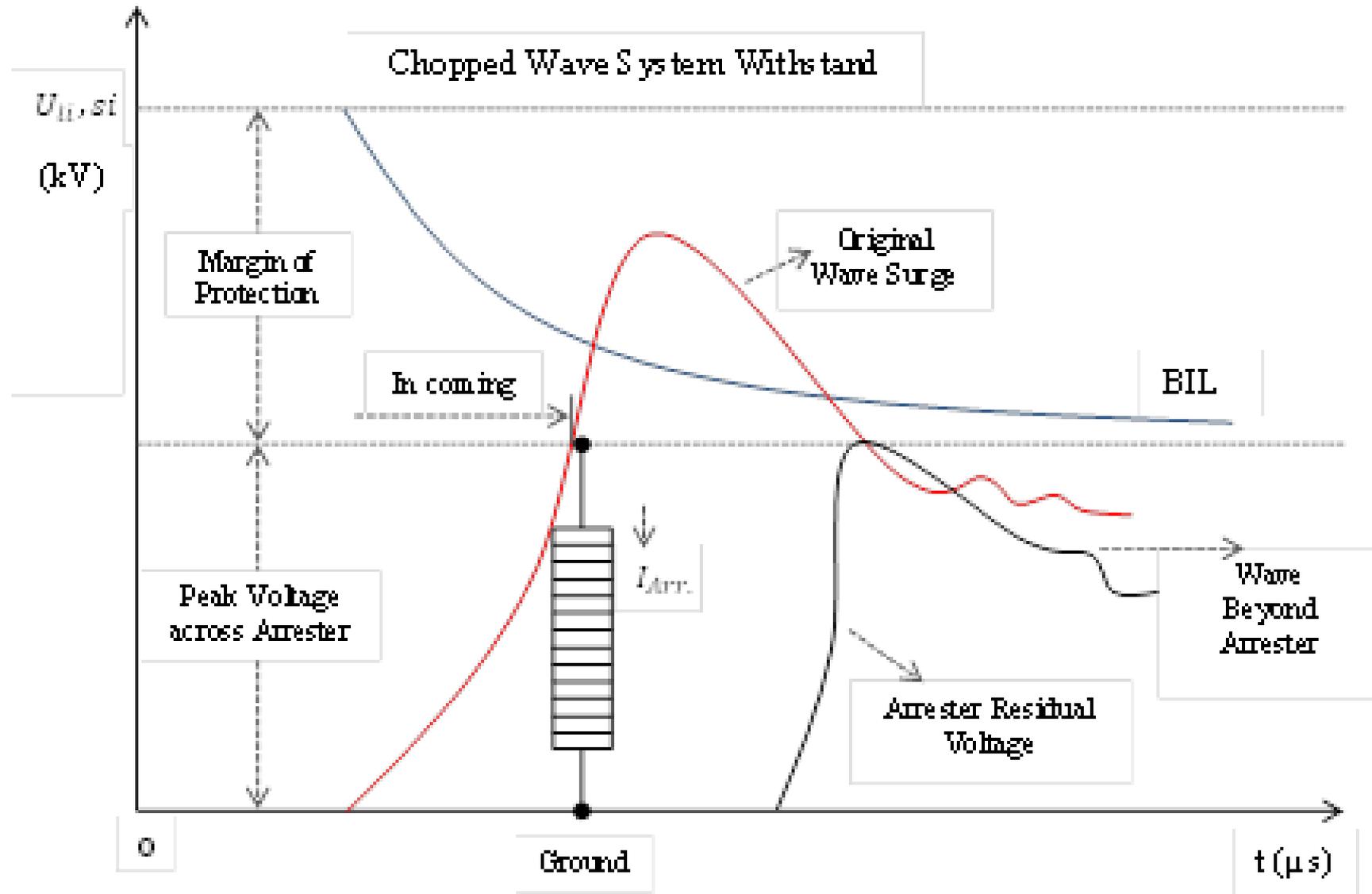
# Role Of Surge Diverters In Insulation Coordination(continued...)

- Surge diverters, also called surge arrestors, play an extremely important role in the implementation of insulation coordination schemes.
- The surge diverters protect the equipment in transmission and the distribution network from the incoming li and si surges in the form of travelling waves.
- Provide low impedance path or an alternate low resistance path to ground for the transient impulse type, the so called high frequency transient overvoltages produced by lightning strikes and the opening of the circuit breakers

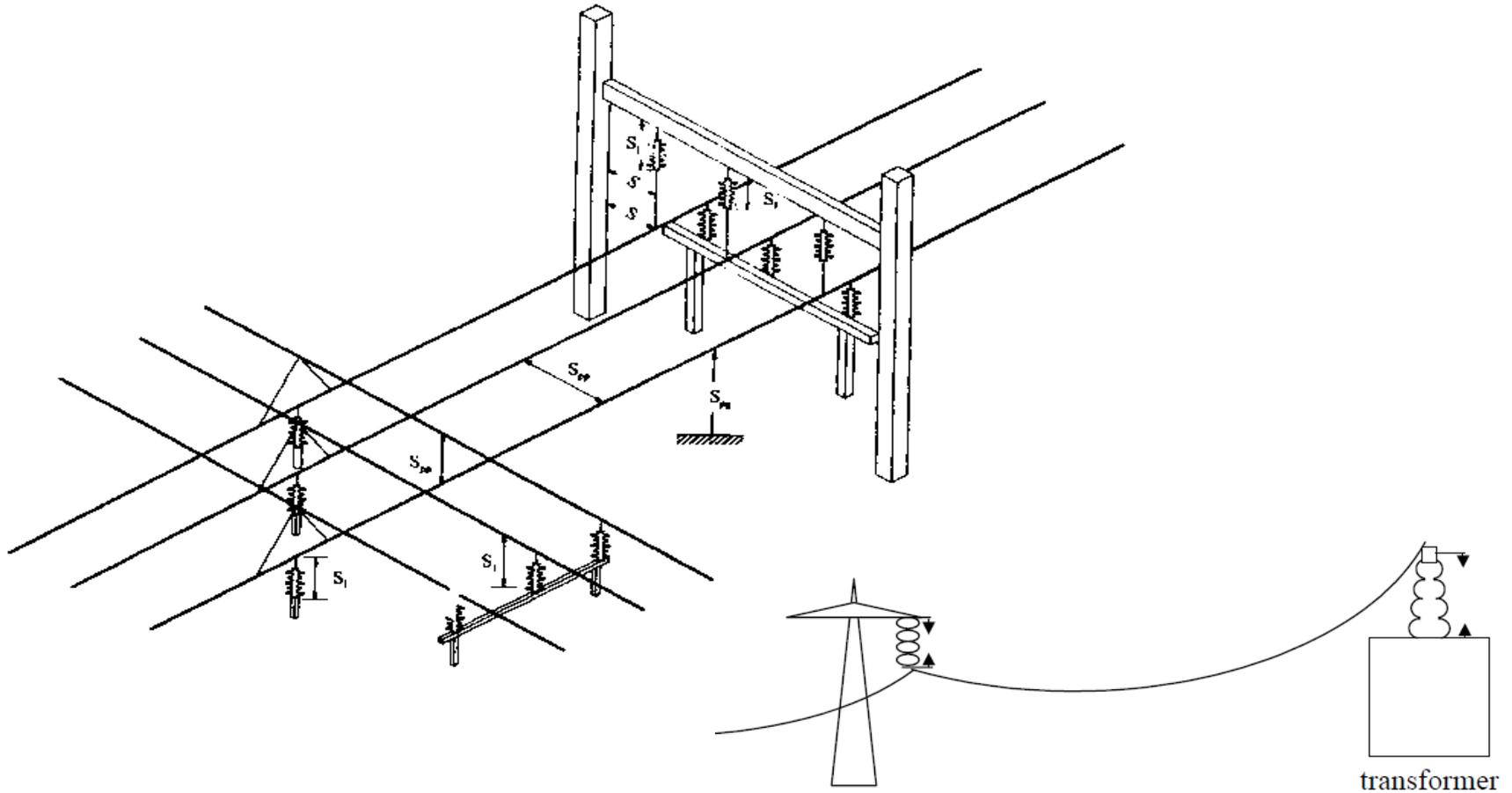
# Role Of Surge Diverters In Insulation Coordination

- It should not conduct for power frequency overvoltage.
- The volt–time characteristic of the device must lie below the withstand voltage of the protected apparatus.
- It should be capable of conducting high voltage, high frequency impulse surge currents and recover its dielectric strength quickly.
- It should not allow power frequency follow on current to flow.

# Schematic representation of the operations of a surge diverter in Power Systems



# Station Insulation Coordination



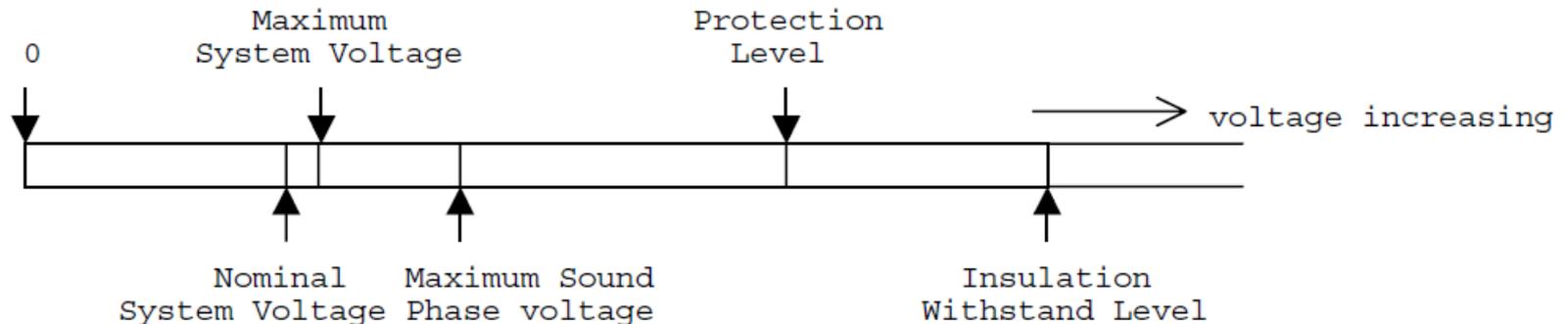
# Methods Of Insulation Co-ordination

- Insulation co-ordination can be achieved by adopting two different methods, viz,
  1. **Conventional or deterministic method:** Mostly applied to lower system voltages.
  2. **Statistical approach:** It is a probability based method used for higher system voltages.

# Conventional Method Of Insulation

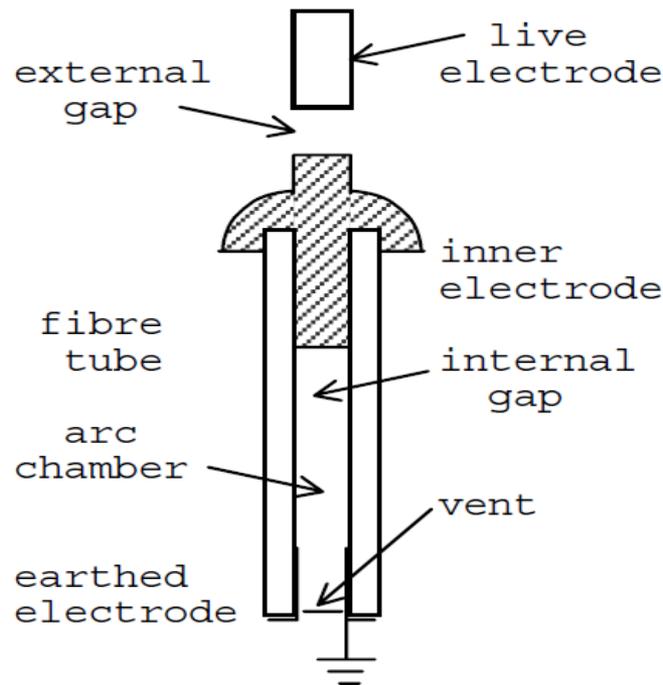
## Co-ordination:

- In order to avoid insulation failure, the insulation level of different types of equipment connected to the system has to be higher than the magnitude of transient over-voltages that appear on the system.
- The magnitude of transient over-voltages are usually limited to a protective level by protective devices. Thus the insulation level has to be above the protective level by a safe margin.



# Expulsion type

- It essentially consists of a rod gap in series with a second gap enclosed within the fiber tube. The gap in the fiber tube is formed by two electrodes. The upper electrode is connected to rod gap and the lower electrode to the earth.



# Summary

- In this chapter, overvoltages in power system network have been discussed.
- Their intensity is also brought down with the help of protective devices before they could reach the costly equipment at the sub-stations and at the consumer end.
- The whole network is also needed to be provided with protective devices/systems to prevent any damage to the insulation system
- The principles of protection and insulation coordination design have been introduced.

# Thank You & References

- Ravindra Arora and Bharat Singh Rajpurohit, "Fundamentals of High-Voltage Engineering" Wiley India, 2019.
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- High Voltage Insulation Engineering: Behaviour of Dielectrics ; Their Properties and Applications by R. Arora, W. Mosch, New Age International, 1995