Substation Engineering
Lecture 15: Surge Arrestors (Part 1 of 2)

Milav Dabgar

Surge Arrestors in Power Systems

- Substation Engineering (DI04009011)
- Lecture 15: Surge Arrestors (Part 1 of 2)
- Overvoltages and Basic Principles

Agenda

- What is an Overvoltage?
- Causes of Overvoltages
- Lightning Surges (External)
- Switching Surges (Internal)
- The Role of a Surge Arrestor
- Operating Principle
- The Ideal Surge Arrestor

What is an Overvoltage?

- An overvoltage is any voltage condition exceeding the normal operating limits of a power system.
- They manifest as 'transient surges'—rapid spikes in voltage that last for microseconds or milliseconds.
- These high voltages can break down the insulation of expensive equipment like transformers, leading to catastrophic failure.
- They are broadly classified into External and Internal overvoltages.

External Overvoltages: Lightning

- Caused by atmospheric electrical discharges (Lightning).
- Direct Strike: Lightning hits the phase conductor directly. Causes massive voltage spikes (millions of volts).
- Indirect Strike: Lightning hits nearby ground or structures. Electromagnetic induction creates a surge on the line.
- Characteristics: Extremely high magnitude, extremely fast rise time (measured in microseconds, e.g., 1.2/50 μs wave).

Internal Overvoltages: Switching Surges

- Caused by changes in the operating state of the power network.
- Examples:
- - Opening or closing circuit breakers.
- - Energizing or de-energizing long transmission lines or capacitor banks.
- - Earth faults on one phase causing voltage to rise on healthy phases.
- Characteristics: Lower magnitude than lightning, but longer duration (slower rise time, e.g., 250/2500 μs wave).

Impact of Overvoltages on Equipment

- Insulation Breakdown: The primary mode of failure. Solid, liquid, or gaseous insulation is punctured.
- Transformer Damage: Surges can cause internal winding flashovers, destroying the transformer.
- Bushing Flashovers: Arcs jumping across the external porcelain insulators of equipment.
- Without protection, the grid would be destroyed during every thunderstorm.

What is a Surge Arrestor?

- A surge arrestor (or lightning arrestor) is a protective device connected in parallel with the equipment it protects (usually from phase to ground).
- Under normal operating voltage, it acts as an OPEN circuit (an insulator).
- When an overvoltage surge arrives, it instantly becomes a SHORT circuit (a conductor).
- It safely shunts the high-voltage surge energy to ground, protecting the equipment behind it.

Operating Principle

- Surge arrestors rely on highly NON-LINEAR resistive materials.
- Non-linear means its electrical resistance changes drastically depending on the voltage applied.
- Low Voltage (Normal Operation) $\rightarrow$ High Resistance (Stops current flow to ground).
- High Voltage (Surge Condition) $\rightarrow$ Low Resistance (Allows surge current to flow to ground).
- Once the surge passes and voltage normalizes, it instantly reverts to high resistance.

The Concept of 'Follow Current'

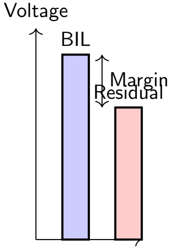
- When an arrestor conducts a surge to ground, the normal system AC voltage tries to 'follow' the surge current down the same path.
- This is called 'Power Frequency Follow Current'.
- If the arrestor cannot stop this follow current, it creates a permanent line-to-ground fault, tripping the system breaker.
- A critical function of an arrestor is to quickly extinguish this follow current and seal itself off.

Characteristics of an Ideal Surge Arrestor

- 1. Draw zero current during normal system operating voltage.
- 2. React instantaneously to overvoltages (zero delay).
- 3. Provide a very low impedance path to ground during a surge to limit the voltage on the equipment.
- 4. Safely absorb or dissipate the massive thermal energy of the surge.
- 5. Completely suppress power frequency follow current immediately after the surge passes.

Protective Margin

- The arrestor determines the maximum voltage the equipment will ever 'see'. This is called the 'Residual Voltage'.
- Equipment has a 'Basic Insulation Level' (BIL) - the maximum voltage it can withstand without damage.
- Protective Margin = BIL - Residual Voltage.
- A proper design ensures a large protective margin (typically 20% or more).



Location of Surge Arrestors

- Location is critical. A surge arrestor must be placed as CLOSE as electrically possible to the equipment it is protecting.
- Most commonly mounted directly adjacent to power transformer bushings.
- Also placed at line entrances (where overhead lines enter the substation) to catch surges before they travel through the busbars.
- Lead lengths (connecting cables to the arrestor and to ground) must be kept as short and straight as possible.

Summary

- Overvoltages come from lightning (external) or switching operations (internal).
- Surge arrestors act as pressure relief valves, shunting high voltages to ground.
- They rely on non-linear materials to act as insulators at normal voltage and conductors at high voltage.
- An ideal arrestor reacts instantly, handles massive energy, and stops follow current.
- They must be located as close as possible to the protected equipment.