Substation Engineering - Insulator, strings, Clamps and Connectors, Spacers (Part 2 of 2)

Milav Dabgar

Insulator, strings, Clamps and Connectors, Spacers (Part 2)

- Substation Hardware Fittings
- Corona and Grading Rings
- Clamps, Connectors, and Spacer Dampers

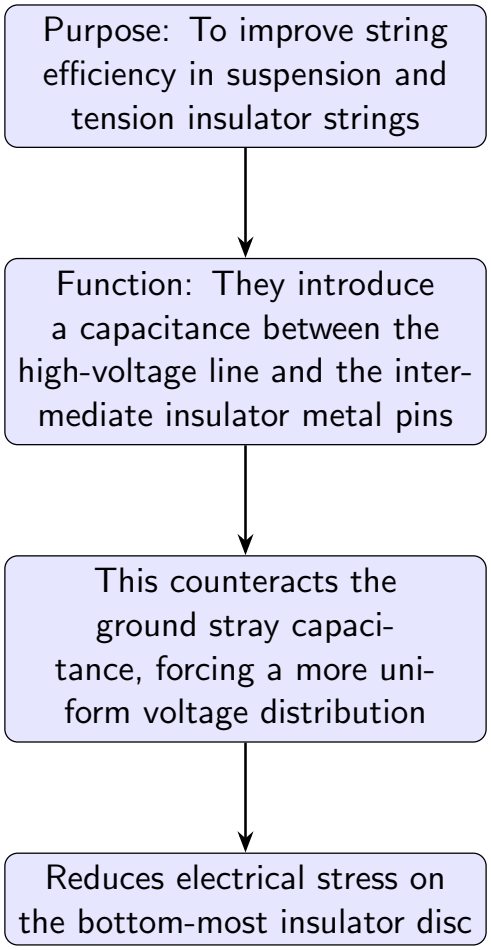
Agenda

- Recap of String Efficiency
- Grading Rings vs. Corona Rings
- Substation Clamps (Suspension, Strain)
- Electrical Connectors (Bimetallic, PG)
- Bundle Conductors overview
- Spacers and Spacer Dampers
- Maintenance of Hardware Fittings

Recap: The Need for Hardware Interfacing

- Insulators alone cannot hold conductors; they require mechanical fittings
- Fittings must transfer massive physical loads safely
- Fittings must also manage electrical stress (sharp edges cause high electric fields)
- Dissimilar metals (e.g., aluminum conductors and copper terminals) require special care to prevent corrosion

Grading Rings



Corona Rings

- Purpose: To control and distribute the electric field at the ends of insulators and equipment bushings
- Sharp edges on hardware clamps cause high localized electric fields
- If the field exceeds air breakdown strength (approx 30 kV/cm), corona discharge occurs
- Corona rings are smooth, large-radius toroids that encompass the sharp hardware, smoothing out the electric field

Substation Clamps

- Hardware used to mechanically attach the conductor to the insulator string
- Must have high mechanical strength (usually made of forged steel, malleable iron, or aluminum alloy)
- Must not damage the conductor strands through excessive pinching
- Types: Suspension Clamps and Strain (Dead-end) Clamps

Suspension Clamps

- Used at intermediate support points (e.g., I-strings or V-strings)
- Conductor rests in a grooved 'boat' and is clamped down with a keeper piece and U-bolts
- Designed to allow a limited amount of conductor slippage in case of unbalanced tension (e.g., if a wire breaks in the next span)
- Reduces catastrophic cascade failures

Strain / Dead-end Clamps

- Used to terminate conductors at dead-end gantries
- Bolted Type: Relies on heavy bolting friction; easy to install but bulky
- Compression Type: A metallic sleeve is hydraulically crimped permanently onto the conductor
- Compression clamps provide the best electrical continuity and mechanical strength for EHV systems

Substation Connectors

- Unlike clamps (which carry mechanical load), connectors primarily carry electrical current
- Used for tapping off busbars, connecting to equipment terminals (transformers, breakers)
- Must provide low contact resistance to prevent overheating
- Types: T-connectors, L-connectors, straight splices, flexible expansion connectors

Bimetallic Connectors

Problem: Connecting an Aluminum conductor to a Copper equipment terminal
Galvanic Corrosion: Moisture acts as an electrolyte; the less noble metal (Aluminum) rapidly corrodes away Solution: Bimetallic Connectors Design: Manufactured with Copper on one side and Aluminum on the other, friction-welded together in a vacuum Usage: Prevents direct contact between dissimilar metals on site

PG (Parallel Groove) Clamps

- Used for non-tension electrical connections (e.g., jumper wires)
- Two parallel grooves enclose the two conductors being clamped
- Bolts apply pressure to maintain low electrical resistance
- Requires contact grease to prevent oxidation of aluminum strands before tightening

Bundle Conductors in Substations

- EHV systems (220kV and above) use multiple parallel wires (2, 4, 6, 8) per phase
- Increases the effective radius of the conductor
- Reduces electric field gradient at the surface, thereby reducing Corona loss and Radio Interference
- Increases current carrying capacity (ampacity) due to better heat dissipation

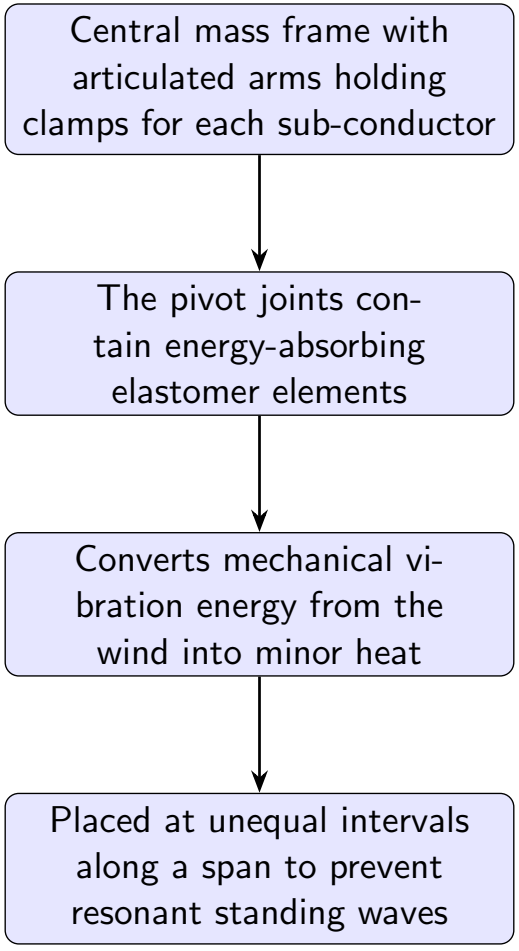
The Need for Spacers

- Bundle conductors carry current in the same direction
- This creates strong electromagnetic attractive forces (Lorentz force) pulling the sub-conductors together
- During short-circuit faults, these forces multiply, causing wires to clash violently
- Spacers hold the sub-conductors at a fixed distance to maintain the bundle geometry

Types of Spacers

- Rigid Spacers: Solid metal links. Cheap but offer no damping. Used on short jumpers.
- Flexible Spacers: Incorporate a spring or steel wire rope to absorb minor shocks.
- Spacer Dampers: The most advanced type, incorporating rubber or elastomeric hinges to absorb aeolian vibrations and wake-induced galloping.

Spacer Dampers in Detail



Summary

- Rings: Grading rings improve string efficiency; Corona rings control high electric fields
- Clamps: Suspension clamps hold weight; Strain clamps hold tension
- Connectors: Must provide low-resistance electrical paths and prevent galvanic corrosion (Bimetallic)
- Spacers: Maintain bundle geometry against electromagnetic forces and dampen wind-induced vibrations

Key Takeaways

- Smooth hardware and corona rings are essential to prevent air breakdown at EHV levels
- Bimetallic interfaces are strictly required when joining aluminum and copper
- Spacer dampers serve the dual purpose of geometric separation and vibration energy absorption

Next Lecture Preview

- Topic: Power Line Carrier Communication (PLCC) - Part 1
- Substation Control and Communication
- How Power Lines are used to transmit data
- Key Components: Wave Traps, Coupling Capacitors, and LMUs