Substation Engineering: Gas Insulated Substations (GIS) & Hybrid GIS Substations (Part 2 of 4)

Milav Dabgar

Gas Insulated Substations (GIS) & Hybrid GIS Substations (Part 2 of 4)

- Substation Engineering
- Lecture 34
- Unit 6: Gas Insulated and Hybrid Substations

Agenda

- GIS Architecture and Modular Design
- Conductors and Enclosures
- Cast Resin Spacers (Cone Insulators)
- Gas Compartmentalization Strategy
- GIS Circuit Breakers
- Disconnectors (Isolators)
- Earthing Switches (Standard and Fast-Acting)
- Instrument Transformers in GIS

GIS Architecture and Modular Design

- GIS is designed as a series of interconnected, standardized modules
- Modules are flanged and bolted together with O-ring seals
- Allows for flexible layouts (linear, stacked, double bus, etc.)
- Factory assembled and tested, reducing on-site erection time
- Enclosures are typically made of cast aluminum alloy

Conductors and Enclosures

- Inner Conductor: Made of high-conductivity aluminum or copper tubing
- Outer Enclosure: Grounded aluminum pipe that contains the SF6 gas
- Aluminum is preferred for enclosures to prevent magnetic heating (eddy currents)
- Enclosure acts as a continuous shield, confining electric fields entirely inside
- GIS surface is safe to touch while energized (zero electric field outside)

Cast Resin Spacers (Cone Insulators)

- Solid insulators that support the inner conductor within the enclosure
- Made of epoxy resin cast with alumina or silica fillers
- Typically shaped like cones or discs to manage electric field stress
- Must withstand extreme mechanical forces during short circuits
- Also serve as gas-tight barriers between different compartments

Gas Compartmentalization Strategy

A GIS is not one giant continuous gas volume
Divided into isolated gas zones
using barrier cone insulators
Reasons for compartmentalization:

1. Limit the loss of SF6 if a leak occurs
2. Allow maintenance on one component without depressurizing the whole substation
3. Prevent arc byproducts from contaminating adjacent healthy sections

Gas Monitoring Systems

- Each compartment has its own gas density monitor
- Density is monitored, not just pressure, to account for temperature fluctuations
- Two-stage alarm system:
- Stage 1 Alarm: Low density (requires gas top-up)
- Stage 2 Trip: Critical density (lockout or trip to prevent catastrophic dielectric failure)
- Modern systems use continuous online digital monitoring

GIS Circuit Breakers

- The most critical and complex module in the GIS
- Almost exclusively use SF6 puffer or self-blast technology
- Typically mounted horizontally or vertically depending on space
- Requires the largest gas volume and highest operating pressure
- Fitted with powerful spring, hydraulic, or motor drives

GIS Disconnectors (Isolators)

- Used for visible isolation of circuits for maintenance
- Operate off-load (cannot break fault current)
- Driven by motor mechanisms externally mounted on the enclosure
- Must be able to break small capacitive currents (bus charging currents)
- Provide a guaranteed dielectric gap larger than the rest of the system

Maintenance Earthing Switches

- Used to ground de-energized parts for personnel safety
- Interlocked with disconnectors to prevent closing onto a live circuit
- Slow operating mechanism (motor or manual)
- Ensures no induced voltages harm maintenance workers
- Often combined with disconnectors into a 3-position switch (Closed, Open, Earthed)

Fast Acting Earthing Switches (FAES)

- Specialized grounding switches with a high-speed spring mechanism
- Located at the incoming/outgoing line terminals of the GIS
- Designed with 'making capacity'—can safely close onto an energized line!
- Used to discharge trapped charges or in case a line is accidentally energized
- Protects the GIS from damage if the switch is operated in error

Ratings of GIS Components

Component	Function	Fault Making Capacity	Fault Breaking Capacity
Circuit Breaker	Clear faults	Yes	Yes
Disconnector	Isolate circuits	No	No (Bus charging only)
Maintenance Earth	Safety grounding	No	No
Fast Earth Switch	Line grounding	Yes	No

Instrument Transformers in GIS

- Current Transformers (CT): Often ring-type, mounted over the GIS enclosure (outside the gas) or integrated inside
- Voltage Transformers (VT): Inductive types are enclosed in their own gas compartment
- VTs use SF6 as insulation instead of oil, eliminating fire risk
- Non-conventional instrument transformers (Rogowski coils, optical sensors) are becoming popular in digital GIS

Interfaces: Cable and Overhead Line Terminations

- GIS must eventually connect to the rest of the grid
- SF6-to-Air Bushings: Used to connect GIS directly to overhead transmission lines
- SF6-to-Cable Terminations: Used to connect GIS directly to underground XLPE cables
- SF6-to-Oil Bushings: Used for direct connection to power transformers without exposed air connections

Summary

- GIS is built from modular enclosures that contain SF6 gas and high-voltage conductors
- Epoxy spacers support the conductors and divide the system into gas zones
- Compartmentalization ensures reliability and maintainability
- Switching components (CBs, Disconnectors, Earth Switches) are specialized for enclosed operation
- FAES provides critical safety at line terminals by closing onto active faults

Next Lecture Preview

- GIS and Hybrid GIS (Part 3 of 4)
- GIS layout configurations (Single Bus, Double Bus)
- Space optimization and building design
- Introduction to Mixed Technology Switchgear (Hybrid GIS)
- Bridging the gap between AIS and GIS