Substation Engineering: Gas Insulated Substations (GIS) & Hybrid GIS Substations (Part 1 of 4)

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Gas Insulated Substations (GIS) & Hybrid GIS Substations (Part 1 of 4)

- Substation Engineering
- Lecture 33
- Unit 6: Gas Insulated and Hybrid Substations

Agenda

- Introduction to Gas Insulated Substations
- Evolution and History of GIS
- Comparison: AIS vs. GIS
- Why Choose GIS? (Advantages & Disadvantages)
- Introduction to SF6 Gas
- Physical, Chemical, and Dielectric Properties of SF6
- Environmental Impact and Alternatives

What is a Gas Insulated Substation (GIS)?

- A compact, metal-enclosed switchgear consisting of high-voltage components
- Uses compressed gas (typically SF6) as the primary insulating medium
- Phase conductors are enclosed in grounded metallic pipes
- Replaces the large air clearances required in conventional AIS
- Can be installed indoors or outdoors, even in dense urban areas

Evolution and History of GIS

- First developed in the 1960s to solve space constraints in cities
- Initially operated at lower transmission voltages (110kV)
- Technology rapidly scaled to 400kV, 500kV, and eventually 800kV+
- Modern GIS designs are highly modular and compact
- Ongoing evolution focuses on reducing SF6 usage due to environmental concerns

AIS vs. GIS: Space Requirements

Air Insulated Substation
(AIS) requires large land area
GIS requires 10% to 25% of
the space of a comparable AIS
Volume reduction is up to 90%
Allows installation in basements,
high-rises, or offshore platforms

Comparison: AIS vs GIS

Feature	Air Insulated (AIS)	Gas Insulated (GIS)
Insulating Medium	Air at atmospheric pressure	SF6 gas at 3-6 bar
Space Requirement	Large (100%)	Very Small (10-25%)
Maintenance	High (exposed to weather)	Low (sealed system)
Initial Cost	Lower	Higher
Reliability	Moderate	Very High
Erection Time	Longer	Shorter (factory assembled modules)

Why Choose GIS?

- High land costs or unavailable land (urban areas, mountainous terrain)
- Severe environmental conditions (heavy pollution, salt spray, sandstorms)
- High reliability requirements (completely immune to external faults like lightning strikes or animal contact)
- Visual aesthetics and noise reduction (can be hidden inside a standard building)
- Offshore wind farms where platform space is extremely expensive

Introduction to SF6 Gas

- Sulfur Hexafluoride (SF6) is a synthetic, fluorinated compound
- It is the lifeblood of modern GIS technology
- Chemically stable and inert under normal conditions
- Non-toxic, non-flammable, and colorless
- Has extraordinary electrical insulating and arc-quenching properties

Physical and Chemical Properties of SF6

- High density: About 5 times heavier than air
- Liquefaction point: Must be monitored to ensure it remains a gas at high pressures and low temperatures
- Highly electronegative: Readily captures free electrons
- Recombines quickly after an arc is extinguished (self-healing)
- Does not degrade insulation materials like solid cast resin

Dielectric Strength of SF6

- At atmospheric pressure, SF6 has 2.5 to 3 times the dielectric strength of air
- At 3 to 5 bar pressure (typical GIS), strength increases significantly
- Allows for very small clearance distances between the live conductor and grounded enclosure
- Follows Paschen's Law: Breakdown voltage is a function of pressure and gap distance
- Highly sensitive to local electric field enhancements (e.g., sharp edges or metallic particles)

Arc-Quenching Capabilities

- Used not just for insulation, but for breaking current in Circuit Breakers
- SF6 cools the arc 100 times faster than air
- During an arc, SF6 dissociates into lower-order fluorides (SF4, SF2)
- After current zero, these compounds quickly recombine back into SF6
- Maintains dielectric strength immediately after current interruption

Byproducts of Arcing in SF6

- While SF6 is non-toxic, arc byproducts are highly toxic and corrosive
- Includes compounds like SOF2, SO2F2, and HF (Hydrofluoric acid)
- Moisture in the gas exacerbates the creation of corrosive byproducts
- GIS compartments contain desiccants (absorbers) to trap moisture and byproducts
- Maintenance personnel require special PPE when opening arced compartments

Environmental Impact of SF6

- SF6 is the most potent greenhouse gas known to science
- Global Warming Potential (GWP): 23,500 times that of CO2
- Atmospheric lifetime: 3,200 years
- Strict regulations mandate gas accounting, leak detection, and recovery
- Venting SF6 into the atmosphere is strictly prohibited globally

The Push for SF6 Alternatives

Gas Mix	GWP	Characteristics
Pure SF6	23,500	Industry standard, excellent performance
g3 (Green Gas)	¡ 400	Fluoronitrile mixture, 98% less environmental impact
AirPlus	¡ 10	Fluoroketone mixture, used up to 145kV
Clean Air / N2	0	Requires larger dimensions, used for lower voltages

Summary

- GIS reduces substation footprint by up to 90% and offers high reliability
- SF6 is an electronegative gas with incredible dielectric and thermal properties
- By pressurizing SF6, clearance distances are massively reduced
- Arcing creates toxic byproducts that must be managed
- Due to its massive Global Warming Potential, the industry is shifting to eco-friendly gas alternatives

Next Lecture Preview

- GIS and Hybrid GIS (Part 2 of 4)
- Internal architecture of a GIS module
- Detailed look at GIS Components:
- Busbars and Insulators
- Circuit Breakers and Disconnectors
- Fast Acting Earthing Switches (FAES)