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Department of EEE

UNIT-IV

Gas Insulated Substations

Subject: Power systems - I

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1. Introduction

A **Gas Insulated Substation (GIS)** is a high-voltage substation where the primary switching, interrupting, and conducting equipment (circuit breakers, disconnectors, busbars, current/voltage transformers) are enclosed in grounded metallic chambers filled with sulfur hexafluoride (SF6) gas under pressure for insulation and arc-quenching.

Advantages of GIS over Conventional Air Insulated Substations (AIS)

- **Compact Footprint (Space Requirement):**
  GIS requires only **10% to 15%** of the space occupied by a conventional AIS of equivalent voltage rating. The high dielectric strength of SF6 permits significantly reduced phase-to-phase and phase-to-ground clearances.
- **Immunity to Environmental Conditions:**
  Because all active components are completely enclosed inside grounded metal enclosures, GIS is immune to atmospheric pollution, industrial pollutants, salt spray (coastal regions), moisture, snow, and extreme temperatures.
- **Enhanced Safety:**
  The outer metallic enclosure is solidly grounded, eliminating electric shock hazards for operation and maintenance personnel.

- **High Reliability & Low Maintenance:**

  Enclosed components experience zero contact oxidation, atmospheric degradation, or external pollution flashovers. Maintenance intervals are significantly longer (often 10–15 years or more).

- **Aesthetic and Urban Integration:**

  GIS can easily be housed indoors or underground, making it ideal for metropolitan areas, architectural sensitive zones, and congested industrial hubs.

- **Minimal Noise Level:**

  Breaker switching and operation noise are fully contained inside the metallic housing and building structure.

2. Types of Gas Insulated Substations

GIS can be classified based on structural design, enclosure configuration, and installation environment.

A. Based on Enclosure / Housing Configuration

1. **Isolated Phase (Phase-Segregated) GIS:**
    - Each three-phase circuit has three separate metal enclosures—one for each phase.
    - **Application:** Common at higher transmission voltages (generally 220 kV) to avoid inter-phase short circuits and handle higher thermal/electromagnetic stresses.
2. **Three-Phase Enclosed (Integrated) GIS:**
    - All three phases are housed inside a single common cylindrical metallic enclosure.
    - **Application:** Typically used at medium-to-high voltage levels (up to 145kV or 170kV to achieve maximum compact size and lower material costs.
3. **Hybrid GIS:**
    - Combines conventional AIS outdoor components (e.g., air-insulated outdoor busbars) with GIS bay modules (breaker, disconnectors, CT/PT enclosed in SF6.
    - Useful for brownfield station retrofits and capacity expansions where space is partially constrained.

B. Based on Installation Environment

- **Indoor GIS:** Installed inside a dedicated concrete or steel building. Protects equipment completely from weather extremes and maintains ambient working conditions.
- **Outdoor GIS:** Specially designed enclosures with weather-resistant coatings, heaters, and sealing suited for direct outdoor installation.
- **Underground GIS:** Installed in subterranean chambers in highly populated city centers, hilly regions, or hydro-power station caverns.

Key Components in the Single line diagram:

- **Busbars:** Transmit power from incoming sources to outgoing bays.
- **Disconnector Switches (DS):** Provide visual electrical isolation during maintenance.
- **Earth Switches (ES):** Standard earth switches discharge residual capacitive charges on de-energized sections.
- **Fast-Acting Earth Switches (FES):** Designed to safely close against active line voltages/trapped charges during switching errors or short circuits.
- **Circuit Breaker (CB):** Interrupts normal load currents and fault currents using SF6 as the arc-extinguishing medium.
- **Instrument Transformers (CT & VT):** Provide scaled-down currents and voltages for protection relays and metering instruments.
- **SF6-to-Air Bushing / SF6-to-Cable Termination:** Interfaces the enclosed gas system to outdoor overhead transmission lines or underground power cables.

4. Busbar & Construction Aspects of GIS

A. Busbar Design in GIS

- **Conductor Material:** Aluminum or copper tubes with high electrical conductivity and structural rigidity.
- **Insulating Support:** Cast-resin epoxy insulators (discs or conical spacers) support the central conductor coaxially within the enclosure tube.
- **Gas Compartmentalization:** Barrier insulators divide the GIS busbar into distinct, gastight compartments. This limits SF6 gas loss during maintenance or accidental leaks to a single localized compartment.

B. Structural & Constructional Features

1. **Enclosure Material:**
    - **Aluminum Alloy:** Lightweight, corrosion-resistant, high electrical conductivity, eliminates induced eddy current losses in three-phase/single-phase enclosures.
    - **Stainless Steel:** Sometimes used for high structural strength, though non-magnetic aluminum remains standard.
2. **Dielectric Gas (**SF_6 **Properties):**
    - Electronegative gas (captures free electrons rapidly).
    - Dielectric strength is approximately **2.5 to 3 times** higher than air at atmospheric pressure.
    - At working pressure, dielectric strength rivals transformer oil.
3. **Expansion Joints (Bellows):**
    - Stainless steel flexible expansion bellows absorb thermal expansion/contraction of metal pipes and structural tolerances during installation.
4. **Particle Traps:**
    - Metallic dust or microscopic conducting particles drastically reduce SF6 breakdown voltage. Low-field zones (particle traps) are provided at the bottom of enclosures to safely capture free metallic debris.

5. Installation and Maintenance of GIS

A. Installation Considerations

1. **Cleanliness & Environment:**
   - High-voltage GIS bays must be assembled under cleanroom conditions. Moisture, dust, and particulate contamination must be strictly avoided during site installation.
2. **Foundation & Civil Work:**
   - Requires a flat, reinforced concrete floor rated for static and dynamic mechanical shock loads caused by circuit breaker operation.
3. **Gas Filling & Vacuuming:**
   - Pre-evacuation to high vacuum (< 1 mbar) to evacuate air and moisture prior to filling with technical-grade SF6 gas to operating pressure.
4. **Site Testing & Commissioning:**
   - **High Voltage (HV) With**
   - **stand Test:** Variable frequency resonant testing at site.
   - **Partial Discharge (PD) Measurement:** UHF sensors detect internal partial discharges before energization.
   - **Gas Quality Checks:** Moisture content, purity percentage, and leakage checks.

B. Maintenance Practices

- **Routine Monitoring:** Continuous gas density monitoring using temperature-compensated pressure switches/gauges.
- **Condition Monitoring:** Periodic partial discharge testing (UHF/Acoustic), IR thermography on outdoor joints, and chemical purity testing of gas.
- **Gas Handling:** Specialized SF6 gas service carts are used for gas evacuation, filtering, storage, and re-filling without releasing gas into the atmosphere (since SF6 is a potent greenhouse gas).

Comparison of Air insulated substations and Gas insulated substations

Parameter	Air Insulated Substation (AIS)	Gas Insulated Substation (GIS)
Insulation Medium	Atmospheric Air	Sulfur Hexafluoride (SF6) Gas
Space Footprint	Large area required	Very compact (10% to 15%of AIS)
Capital Cost	Lower initial equipment cost	Higher initial equipment cost
Civil & Land Cost	High (due to large land requirements)	Significantly lower land/site development cost
Environmental Effect	Susceptible to pollution, salt spray, moisture	Fully immune to ambient environment
Maintenance Needs	Frequent (cleaning, corrosion control)	Minimal (long intervals, enclosed parts)
Safety Level	Exposed live conductors	Fully grounded metallic enclosures
Installation Time	Long (multiple outdoor structures)	Short (pre-fabricated modular units)
Environmental Impact	Minimal greenhouse effect	SF6 has high Global Warming Potential (requires strict gas handling)

THANK YOU