

# COMPREHENSIVE ANALYSIS OF 400/220 kV AIS & GIS SUBSTATION SYSTEMS

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**Abstract:** Substations are critical components of modern power systems, enabling voltage transformation, switching, and system protection. This paper presents a comprehensive analysis of 400/220 kV substations, focusing on Air Insulated Substations (AIS) and Gas Insulated Substations (GIS). The study compares their design, operation, reliability, cost, environmental impact, and suitability for different applications. Key components such as transformers, circuit breakers, busbars, protection systems, and insulation methods are discussed in detail. The paper also highlights recent technological advancements and the future scope of hybrid substations. The analysis shows that while AIS remains cost-effective and easier to maintain, GIS offers compactness, higher reliability, and better performance in constrained environments.

**Keywords:** AIS, GIS, 400/220 kV Substation, Power System, Switchgear, Insulation, High Voltage Engineering

## 1. INTRODUCTION

Electrical substations play a vital role in the transmission and distribution of electrical power. A 400/220 kV substation is typically used in high-voltage transmission systems to step down voltage levels for further distribution.

Two primary types of substations are widely used:

- Air Insulated Substations (AIS)
- Gas Insulated Substations (GIS)

With increasing urbanization and demand for reliable power supply, the choice between AIS and GIS has become crucial. This paper aims to provide a detailed comparison and technical evaluation of both systems.

## 2. OVERVIEW OF 400/220 KV SUBSTATIONS

### 2.1 Function

A 400/220 kV substation performs:

- Voltage transformation (400 kV to 220 kV)
- Power flow control
- Fault isolation
- System protection and monitoring

### 2.2 Major Components

- Power Transformers
- Circuit Breakers
- Isolators and Earth Switches

- Busbars
- Instrument Transformers (CTs and PTs)
- Protection and Control Systems
- Surge Arresters

### 3. AIR INSULATED SUBSTATION (AIS)

#### 3.1 Definition

AIS uses atmospheric air as the primary insulation medium between energized components.

#### 3.2 Design Characteristics

- Open-air installation
- Large physical spacing between conductors
- Requires significant land area

#### 3.3 Advantages

- Lower initial cost
- Simple design and construction
- Easy maintenance and fault detection
- No special gas handling required

#### 3.4 Disadvantages

- Requires large land area
- Susceptible to environmental conditions (pollution, humidity)
- Higher maintenance frequency
- Lower reliability in harsh environments

### 4. GAS INSULATED SUBSTATION (GIS)

#### 4.1 Definition

GIS uses sulphur hexafluoride (SF<sub>6</sub>) gas as an insulating medium, enclosed in metal compartments.

#### 4.2 Design Characteristics

- Compact and enclosed system
- High dielectric strength
- Modular construction

#### 4.3 Advantages

- Requires 70–90% less space than AIS
- High reliability and safety

- Minimal maintenance
- Suitable for urban and industrial areas

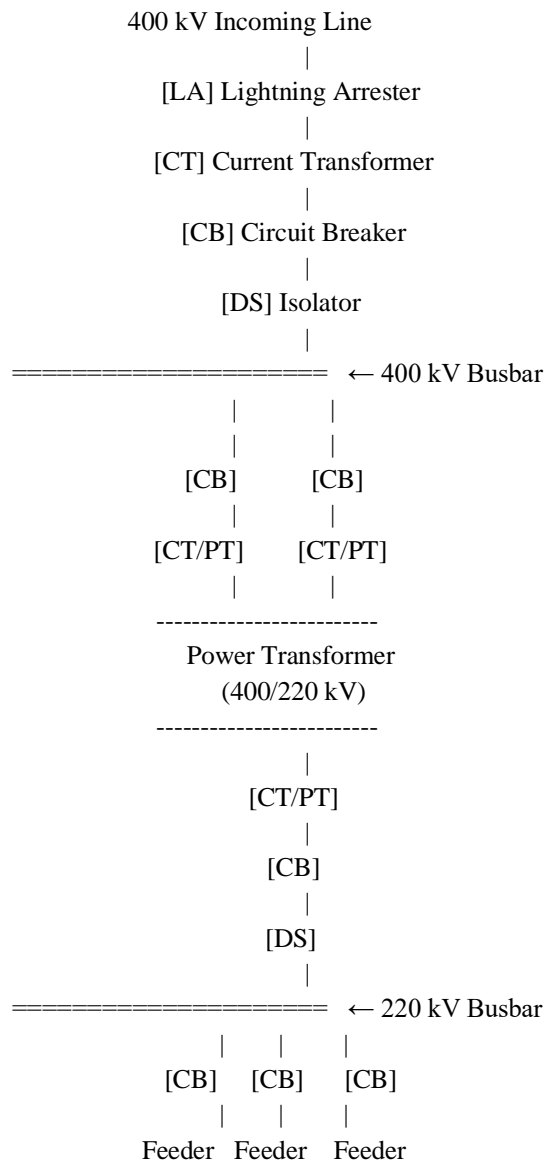
#### 4.4 Disadvantages

- High initial cost
- Complex installation
- SF<sub>6</sub> gas handling and environmental concerns
- Difficult fault detection and repair

#### 5. COMPARATIVE ANALYSIS OF AIS AND GIS.

1. Parameter	2. AIS	3. GIS
4. Space Requirement	5. High	6. Very Low
7. Initial Cost	8. Low	9. High
10. Maintenance	11. Frequent	12. Minimal
13. Reliability	14. Moderate	15. High
16. Installation Time	17. Longer	18. Shorter
19. Environmental Impact	20. Less harmful	21. SF <sub>6</sub> gas concerns
22. Safety	23. Moderate	24. High

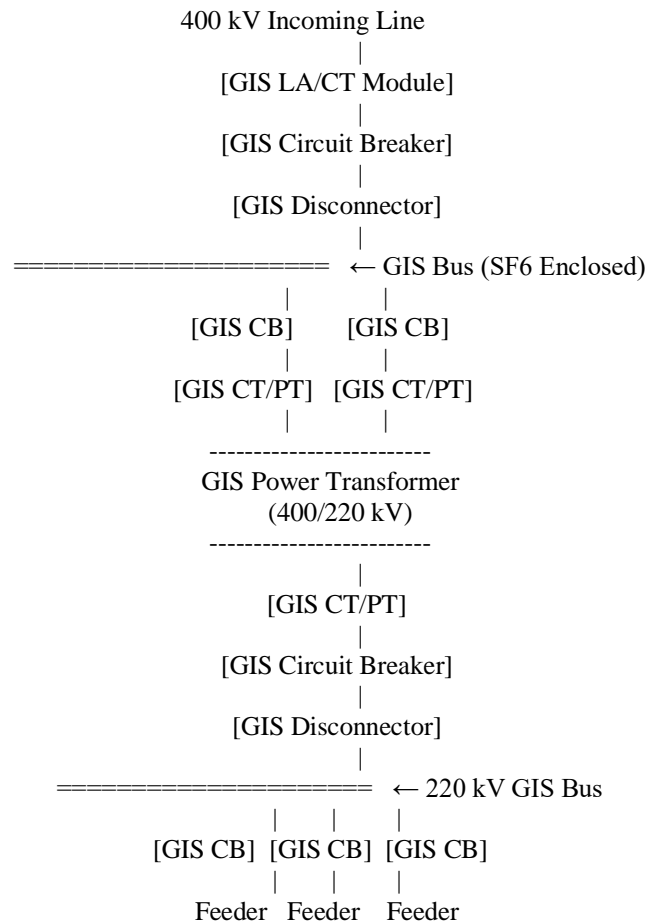
## 5.1 Single-Line Diagram of 400/220 kV AIS Substation



### Explanation

- Air acts as insulation between all components.
- Equipment is spaced widely in an open yard.
- Each component is separately mounted and visible.
- Maintenance and fault identification are straightforward.

## 5.2 Single-Line Diagram of 400/220 kV GIS Substation



### Explanation

- All components are enclosed in grounded metal chambers filled with SF<sub>6</sub> gas.
- Compact modular structure replaces open-air spacing.
- Reduced exposure to environmental conditions.
- Requires specialized monitoring systems.

## 6. KEY EQUIPMENT ANALYSIS

### 6.1 Power Transformers

- Step down voltage from 400 kV to 220 kV
- Equipped with cooling systems (ONAN, ONAF)

### 6.2 Circuit Breakers

- AIS: Air or SF<sub>6</sub> breakers
- GIS: SF<sub>6</sub> breakers integrated within sealed chambers

### 6.3 Busbar Configuration

- Single bus

- Double bus
- Ring bus
- Breaker-and-a-half scheme

#### **6.4 Protection Systems**

- Distance protection
- Differential protection
- Overcurrent protection
- SCADA integration for monitoring

### **7. ENVIRONMENTAL AND SAFETY CONSIDERATIONS**

#### **7.1 AIS**

- Exposure to weather conditions
- Risk of flashovers due to pollution

#### **7.2 GIS**

- SF<sub>6</sub> gas has high global warming potential
- Requires strict handling and recycling protocols

### **8. APPLICATIONS**

#### **8.1 AIS Applications**

- Rural and semi-urban areas
- Areas with abundant land availability

#### **8.2 GIS Applications**

- Urban cities
- Underground substations
- Industrial zones
- Coastal and polluted environments

### **9. RECENT DEVELOPMENTS**

- Hybrid substations combining AIS and GIS
- Digital substations using IEC 61850
- Smart monitoring and predictive maintenance
- Eco-friendly alternatives to SF<sub>6</sub> gas

## 10. CONCLUSION

Both AIS and GIS substations play significant roles in modern power systems. AIS remains a preferred choice for cost-sensitive and land-available regions, while GIS is ideal for compact, high-reliability applications. The future lies in hybrid solutions and environmentally sustainable technologies that combine the advantages of both systems.

## 11. FUTURE SCOPE OF 400/220 kV AIS & GIS SUBSTATIONS

The evolution of power systems, driven by increasing electricity demand, urbanization, and renewable energy integration, is shaping the future of 400/220 kV substations. Both AIS and GIS technologies are expected to undergo significant advancements in the coming years.

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