

Comparative Study of Civil Engineering Methodology for GIS and AIS Type 220/132/33 KV Substations in Dehradun, Uttarakhand

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Abstract: *The increasing demand for reliable power transmission and the growing constraints on land availability have accelerated the adoption of Gas Insulated Substations (GIS) as an alternative to conventional Air Insulated Substations (AIS). Civil engineering plays a fundamental role in the successful implementation of both substation technologies through proper site development, foundation design, structural planning, drainage systems, and infrastructure construction. This study presents a comparative evaluation of the civil engineering methodology employed in 220/132/33 kV GIS and AIS substations with reference to substation development practices in Dehradun, Uttarakhand. The research investigates key civil engineering aspects including site selection, geotechnical investigations, earthwork operations, equipment foundations, control building construction, cable trench systems, drainage networks, and surface development works. The findings demonstrate that GIS substations provide significant advantages in land optimization and compact infrastructure development, whereas AIS substations remain cost-effective in areas with adequate land availability.*

Keywords: GIS, AIS, Substation Construction, Civil Engineering, Foundation Design, Power Infrastructure

1. Introduction

Electrical substations are critical components of power transmission and distribution systems. They facilitate voltage transformation, power control, protection, and switching operations. The rapid urbanization of Indian cities has increased the requirement for compact and efficient substations, resulting in a transition from conventional Air Insulated Substations (AIS) to Gas Insulated Substations (GIS).

Civil engineering activities account for a significant portion of the overall substation project and include site development, foundation construction, drainage systems, control buildings, cable trenches, roads, and structural works. This study examines and compares the civil engineering methodologies associated with GIS and AIS substations at the 220/132/33 kV voltage level.

2. Objectives of the Study

The objectives of this research are:

- To study the civil engineering methodology adopted in 220/132/33 kV substations.
- To compare GIS and AIS substation construction requirements.
- To evaluate land utilization and foundation requirements.
- To assess construction challenges and mitigation measures.
- To identify the most suitable substation technology from a civil engineering perspective.

3. Literature Review

Previous studies indicate that GIS substations occupy substantially less land than AIS substations and provide improved operational reliability in densely populated areas.

Researchers have reported that:

- GIS substations require approximately 10–20% of the land required by AIS substations.
- AIS substations offer lower initial capital investment.
- GIS installations reduce environmental exposure of electrical equipment.
- Civil works for GIS projects focus more on building construction than open-yard development.

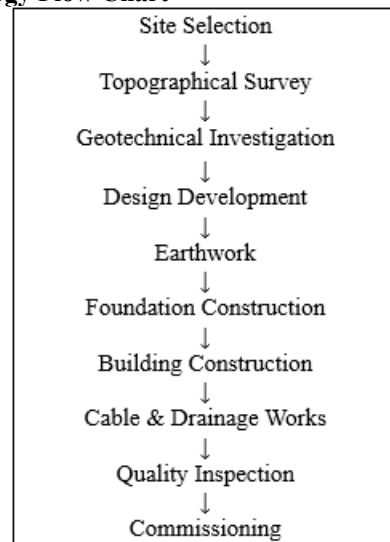
These findings establish the need for comparative civil engineering analysis.

4. Research Methodology

The methodology adopted in this study consists of:

- Collection of technical literature.
- Review of civil engineering standards.
- Analysis of GIS and AIS construction practices.
- Comparison of land requirement, foundation quantity, construction cost, and project execution.

Methodology Flow Chart



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5. Site Selection and Investigation

5.1 Site Selection

The selection of a substation site depends on:

- Proximity to transmission corridors
- Land availability
- Accessibility
- Environmental constraints
- Future expansion possibilities

5.2 Geotechnical Investigation

Geotechnical investigations include:

- Borehole drilling
- Soil classification
- Groundwater assessment
- Safe Bearing Capacity determination
- Settlement analysis

The results are used to design foundations and retaining structures.

6. Civil Engineering Methodology for AIS Substations

6.1 Site Preparation

Activities include:

- Clearing and grubbing
- Demolition of existing structures
- Site grading and levelling

6.2 Earthwork

Earthwork involves excavation, filling, and compaction. Proper compaction ensures long-term stability of equipment foundations.

6.3 Equipment Foundations

Foundations are constructed for:

- Transformers
- Circuit Breakers
- Current Transformers
- Voltage Transformers
- Gantry Structures

The construction sequence includes excavation, PCC, reinforcement, formwork, concreting, curing, and backfilling.

6.4 Cable Trenches

Reinforced concrete cable trenches are provided for power and control cables.

6.5 Drainage System

Drainage networks include:

- Surface drains
- Culverts
- Oil-water separators
- Stormwater channels

6.6 Gravel Surfacing

Crushed stone surfacing is applied to improve drainage and reduce step and touch potential.

7. Civil Engineering Methodology for GIS Substations

7.1 GIS Building Construction

Unlike AIS substations, GIS equipment is housed within enclosed structures.

Major civil works include:

- GIS Hall
- Control Room
- Relay Room
- Battery Room
- Auxiliary Buildings

7.2 Structural Design

Structural design considers:

- Equipment loads
- Wind loads
- Seismic forces
- Crane loads
- Dynamic loads

7.3 Foundations

GIS equipment requires comparatively smaller foundations because equipment is compact and integrated.

7.4 Utility Systems

Utility systems include:

- HVAC
- Fire Protection
- Cable Management Systems
- Earthing Infrastructure

8. Comparative Analysis of GIS and AIS Substations

Parameter	AIS	GIS
Land Requirement	High	Very Low
Initial Cost	Lower	Higher
Foundation Quantity	Higher	Lower
Construction Footprint	Large	Compact
Reliability	Good	Excellent
Maintenance	High	Low
Environmental Exposure	High	Low
Future Expansion	Easy	Moderate

9. Results and Discussion

The comparative analysis indicates that GIS substations provide substantial savings in land utilization and improve operational reliability. The compact layout significantly reduces earthwork, cable trench length, and external infrastructure requirements.

AIS substations remain economical where land is readily available and environmental constraints are minimal. However, in urban locations such as Dehradun, GIS technology offers significant advantages due to reduced land acquisition requirements and improved system reliability.

10. Quality Assurance and Quality Control

Quality assurance measures include:

- Material testing
- Concrete cube testing
- Reinforcement inspection
- Compaction testing
- Survey verification

Construction quality records are maintained throughout the project lifecycle.

11. Health, Safety and Environmental Considerations

Key safety measures include:

- Personal Protective Equipment (PPE)
- Safe excavation procedures
- Fire safety systems
- Electrical hazard control

Environmental management includes:

- Dust suppression
- Waste management
- Noise control
- Soil conservation

12. Challenges in Substation Construction

Major challenges include:

- Difficult geotechnical conditions
- High groundwater levels
- Limited urban land availability
- Weather-related delays
- Strict construction tolerances

Proper planning and engineering controls help mitigate these issues.

13. Conclusion

Civil engineering methodology directly influences the safety, reliability, and lifecycle performance of electrical substations. The study demonstrates that GIS substations provide significant advantages in land optimization, operational reliability, and infrastructure efficiency. AIS substations continue to be suitable for locations where land availability is not a limiting factor.

For rapidly urbanizing regions such as Dehradun, GIS technology represents a sustainable and technically superior solution despite higher initial capital costs. The selection between GIS and AIS should therefore be based on project-specific technical, economic, and environmental considerations.

14. Future Scope

Future research may focus on:

- BIM implementation in substation projects.
- Sustainable construction materials.
- Digital monitoring of foundations.
- Smart asset management systems.
- Life-cycle cost analysis of GIS and AIS substations.

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