IJARSCT
ISSN: 2581-9429
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Volume 6, Issue 11, April 2026
Impact Factor: 8.2

# Per-Unit Based 33/11 kV Hybrid GIS–AIS Substation Prototype (Yavatmal GIS)

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**Abstract:** *Electrical substations are essential components of power transmission and distribution systems, responsible for voltage transformation, switching, protection, and monitoring. Traditionally, Air Insulated Substations (AIS) have been widely implemented; however, increasing urbanization and land constraints have led to the growing adoption of Gas Insulated Substations (GIS), which offer compact design and higher reliability. This project presents a per-unit based hybrd 33/11 kV GIS–AIS substation prototype developed for educational and demonstration purposes. The proposed model applies the per-unit scaling method to convert high-voltage parameters into safe low-voltage values, enabling practical visualization of substation operation without the risks associated with high-voltage systems. The prototype demonstrates the arrangement of bays, switching operations, and basic monitoring of electrical parameters such as voltage and current. A comparative study between AIS and GIS substations is also performed to analyze differences in space requirement, insulation performance, reliability, and operational safety. The developed prototype provides an effective platform for understanding modern substation concepts and highlights the advantages of GIS technology for compact and reliable power distribution systems.*

**Keywords:** Per-Unit System, Gas Insulated Substation (GIS), Air Insulated Substation (AIS), Hybrid Substation, 33/11 kV Substation, Substation Prototype, Power System

## I. INTRODUCTION

Electrical substations are essential components of power transmission and distribution networks. They perform important functions such as voltage transformation, switching operations, protection, and control of electrical power [1],[5].

Traditionally, Air Insulated Substations (AIS) have been widely used due to their simple construction, low installation cost, and ease of maintenance [5], [10]. However, AIS systems require a large land area and are significantly affected by environmental factors such as dust, moisture, and pollution, which may reduce their reliability and efficiency.

In recent years, Gas Insulated Substations (GIS) have gained popularity due to their compact design, high reliability, and reduced maintenance requirements [1],[3],[11]. GIS uses sulfur hexafluoride ($SF_6$) gas as an insulating medium, allowing components to be enclosed in a metallic chamber. This makes GIS suitable for urban areas where space is limited. However, GIS systems are expensive and complex, making them difficult to study practically.

To overcome the limitations of both AIS and GIS, a hybrid substation approach is used. A hybrid GIS–AIS substation combines the advantages of both systems by using GIS for critical components and AIS for the remaining parts [10],[7].

In addition, the per-unit system is widely used in power system analysis to simplify calculations by expressing electrical quantities as a ratio of their base values [6]. In this project, the per-unit system is used to scale down high-voltage values into safe low-voltage levels for practical implementation.

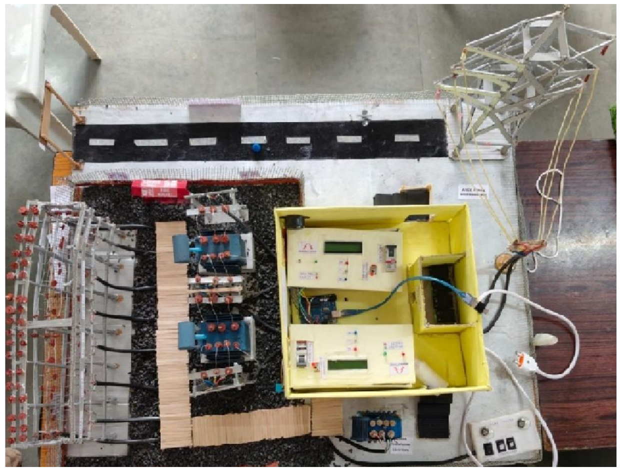

Figure 1. Prototype Model

## II. LITERATURE REVIEW

| Authors | Type | Advantages | Limitations |
|---|---|---|---|
| Jonathan et al. (2025) | AIS | Simple, reliable | Large area |
| Flores et al. (2025) | AIS & GIS | GIS compact | High cost |
| Babaei (2025) | GIS | High reliability | Expensive |
| Korotchenko et al. (2024) | GIS | Low failure rate | Complex maintenance |
| Aziz & Gamal (2024) | GIS/AIS | Better insulation | Environmental effects |
| Sreeram et al. (2022) | GIS | Fast switching | Overvoltage |
| Cuguz et al. (2022) | Hybrid | Space saving | Complex design |
| Baig et al. (2018) | GIS | Compact design | Costly |

Table 1. Literature Review

From the literature, it is observed that AIS substations are widely used due to their simplicity and cost-effectiveness, but they require large installation space and are affected by environmental conditions. GIS substations, on the other hand, provide compact design, higher reliability, and better performance in polluted environments. However, GIS systems involve high capital cost and complex maintenance.

Hybrid substations combine the advantages of AIS and GIS, offering a balanced solution in terms of cost, space, and reliability [7],[8]. Despite these advancements, there is a lack of practical and low-cost prototype models that can demonstrate the working of substations for educational purposes.

Therefore, this project focuses on developing a per-unit based hybrid GIS–AIS substation prototype to bridge the gap between theoretical knowledge and practical implementation.

## III. SYSTEM DESIGN AND METHODOLGY

### 3.1 System Architecture

The proposed system is a scaled-down model of a 33/11 kV substation. It consists of the following sections:

- Input power supply (230V AC)
- Step-down transformer (230/12V)
- GIS section (enclosed system representation)
- AIS section (open system representation)
- Switching devices (relays, MCB)

- Load section (lamp)
- Monitoring system (sensors + Arduino)

The system simulates real substation operation at a safe voltage level [4],[6].

**3.2 Per-Unit System**

The per-unit system is used to simplify power system calculations by normalizing electrical quantities.

Per Unit Value = Actual Value / Base Value

**3.3 Methodology**

The methodology of the proposed system describes the step-by-step procedure followed for the design and development of the prototype.

The steps involved are as follows:

Problem Identification:

The limitations of existing AIS and GIS substations were studied, such as space requirements and high cost.

Literature Review:

Various research papers related to substations were analyzed to understand existing technologies.

System Design:

A hybrid GIS–AIS substation model was designed and a block diagram was prepared.

Per-Unit Calculation:

The per-unit system was used to scale down high voltage levels to safe low-voltage values.

Component Selection:

Suitable components such as transformer, sensors, relays, and controller were selected.

Prototype Development:

The system was fabricated and assembled using selected components.

Testing and Validation:

The system was tested to ensure proper functioning and accuracy.

Result Analysis:

The performance of the system was observed and analysed.

**3.4 Components Used**

The main components used in the system include:

Arduino UNO: Acts as the control unit

Voltage Sensor (ZMPT101B): Measures AC voltage

Current Sensor (ACS712): Measures load current

Relay Module: Controls switching operations

LCD Display: Displays real-time values

Transformer: Steps down voltage

MCB: Provides protection

Temperature Sensor: Monitors system temperature

## IV. RESULT AND ANALYSIS

**4.1 Measured Values**

During testing, the following values were observed:

Primary Voltage = 246 V

Secondary Voltage = 12.5 V

Current = 0.46 A

### 4.2 Per-Unit Analysis

Primary Voltage = 1.07 p.u.
Secondary Voltage = 1.04 p.u.
Current = 0.153 p.u.
These values indicate that the system operates close to normal conditions.

### 4.3 Performance Analysis

The system shows stable voltage regulation
The transformer operates efficiently
Load condition is light (low current)
No abnormal fluctuations observed

## V. PROTECTION SYSTEM

### 5.1 Overload Protection

When current exceeds 0.30 p.u., the relay disconnects the load and activates the buzzer.

### 5.2 Short Circuit Protection

A sudden voltage drop and high current trigger immediate system shutdown.

### 5.3 Over-Temperature Protection

If temperature exceeds 45°C, the system disconnects power and generates an alert.

## VI. ADVANTAGES

Safe low-voltage operation
Real-time monitoring
Cost-effective design
Easy to understand and implement

## VII. LIMITATIONS

Although the project has been successfully implemented, certain limitations are observed:
The prototype operates only at low voltage and does not replicate real high-voltage conditions of actual substations. The system has limited capability for fault simulation, such as short circuits or overload conditions. The accuracy of measurements depends on the calibration of sensors used in the system.
Additionally, the project does not include advanced monitoring and control systems such as SCADA. The size and design of the prototype also limit the addition of more complex components. These limitations can be addressed in future improvements.

## IX. CONCLUSION

The project titled "Per-Unit Based 33/11 kV Hybrid GIS–AIS Substation Prototype" has been successfully designed and implemented. The main objective of this project was to develop a safe, cost-effective, and practical model that demonstrates the working of a real electrical substation using low-voltage components. This objective has been achieved through proper design, component selection, and system integration.
The developed prototype effectively combines the features of both Air Insulated Substation (AIS) and Gas Insulated Substation (GIS) [5], [10]. The AIS section provides simplicity and ease of understanding, while the GIS section represents compact and protected operation. The hybrid approach ensures that the advantages of both systems are utilized efficiently.

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The application of the per-unit system played a crucial role in scaling down high-voltage values into safe low-voltage levels. This allowed the system to operate safely without compromising the actual working concept of a substation. The use of sensors such as voltage and current sensors, along with a microcontroller, enabled real-time monitoring and control of the system parameters.

During testing, the system demonstrated proper functioning of power flow, switching operations, and parameter monitoring. The relay module successfully controlled the load, and the display unit provided accurate readings of voltage and current. The overall performance of the system was found to be stable and reliable under normal operating conditions.

## X. FUTURE SCOPE

The proposed system can be further improved and enhanced in several ways. Integration of IoT technology can enable remote monitoring and control of the system through mobile or web applications. Advanced fault detection and protection mechanisms can be added to improve system reliability.

The prototype can be expanded by including additional substation components such as protection relays and advanced switching devices. Implementation of SCADA systems can provide better control and visualization of system parameters. The accuracy of the system can also be improved by using high-precision sensors and advanced measurement techniques.

These improvements will enhance the practical applicability and performance of the system.

## REFERENCES

**[1].** Bolin, P., & Koch, H. (2005, June). Introduction and applications of gas insulated substation (GIS). In IEEE Power Engineering Society General Meeting, 2005 (pp. 920-926). IEEE.

**[2].** Vahedi, S., Banejad, M., & Assili, M. (2020). GIS-based substation expansion planning. IEEE Systems Journal, 15(1), 959-970.

**[3].** Korotchenko, E., Galiaskarov, I., Misrikhanov, M., Ryabchenko, V., & Shuntov, A. (2024). On Reliability of 110-500 kV GIS: Operational Experience. In E3S Web of Conferences (Vol. 584, p. 01018). EDP Sciences.

**[4].** Jonathan, E. O., Ewere, O. E., Ezekiel, E. E., Onogharigho, O. A., & Okieke, U. J. (2025). Analysis of Oria Abraka 33/11 kV Power Sub-Station: A Case for Sustainable Power Supply. NIPES-Journal of Science and Technology Research, 7(1), 204-218.

**[5].** Nagarsheth, R., & Singh, S. (2014). Study of gas insulated substation and its comparison with air insulated substation. International Journal of Electrical Power & Energy Systems, 55, 481-485.

**[6].** Okereafor, F. C., Idoniboyeobu, D. C., & Bala, T. K. (2017). Analysis of 33/11KV RSU injection substation for improved performance with distributed generation (DG) units. American Journal of Engineering Research (AJER), 6(9), 301-316.

**[7].** Aziz, M. A., & Gamal, A. (2024). Insulation Coordination and Reliability in Modern Substations: Case Study of AIS and GIS in the Egyptian Grid. International Journal of Artificial Intelligence and Emerging Technology, 7(1), 35-43.

**[8].** Sreeram, V., Arunkumar, S., Reddy, S. S., & Gurudev, T. (2022). Comparative Analysis of Transients in AIS and GIS With Vacuum Interrupters. IEEE Transactions on Plasma Science, 50(9), 2681-2686.

**[9].** *Kim, D. E., Lee, G. Y., Kil, G. S., & Kim, S. W. (2024). Trends in Measuring Instrument Transformers for Gas-Insulated Switchgears: A Review. Energies, 17(8), 1846.*

**[10].** *Flores, L. I. R., Ocampo, L. E. M., & Castillo, B. C. (2025, November). Technology Comparison for Medium-Voltage Switchgear: AIS vs. GIS. In 2025 Mexican International Conference on Computer Science (ENC) (pp. 1-6). IEEE.*

**[11].** *Babaei, R. (2025). Main components of gas insulated switchgear (GIS) and their functional roles. PSP Company.*

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**[12].** Babaei, R. (2025). Advantages and disadvantages of gas insulated switchgear (GIS) compared to air-insulated substations (AIS). PSP Company.

**[13].** Srilekha, P. D. P., Raghu Ram, A., & Mohan Rao, M. (2022). A coupled multifield estimation for temperature rise in a gas insulated bus bar using ANSYS. International Journal of Emerging Trends in Engineering Research, 10(5), 291–294.

**[14].** Baig, M. R., Ansari, Y., Tahir, S., Ansari, S. A., & Sayeed, Y. A. (2018). Gas insulated substation. In Proceedings of the National Conference on Advances in Engineering and Applied Science (NCAEAS) (pp. 355–359).

**[15].** Shendre, Y. R., Bayskar, S. K., Thakare, C. S., & Borkhade, R. R. (2024). 33/11 kV substation Maharashtra State Electricity Distribution Co. Ltd., Lohara MIDC, Yavatmal. International Journal of Advanced Research in Science, Communication and Technology, 4(1)



DOI: 10.48175/IJARSCT-33648