
DESIGN AND PERFORMANCE ANALYSIS AT 220KV/ 132KV/ 33KV BHOOTPUR SUBSTATION

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ABSTRACT

The rapid growth in electrical power demand necessitates efficient, reliable, and well-designed transmission and distribution systems. This project focuses on the design and performance analysis of a 220/132/33 kV TRANSCO substation, which plays a crucial role in stepping down high transmission voltages to suitable levels for sub-transmission and distribution networks. The primary objective of this project is to analyze the single-line diagram of the 220/132/33 kV TRANSCO substation and evaluate its performance by examining key operational parameters. In addition, the project provides a comprehensive overview of the substation, including its major equipment and operational principles. The design aspect of the project includes detailed consideration of essential substation components such as power transformers, busbar arrangements, circuit breakers, isolators, current transformers (CTs), potential transformers (PTs), lightning arresters and earthing systems. The selection of appropriate equipment ratings is based on load requirements, system voltage levels, fault conditions, and applicable safety standards. Performance analysis is carried out to assess important factors such as load factor, demand factor and line losses of the substation. Overall, this project provides a clear understanding of the design principles, operational performance, and significance of a 220/132/33 kV TRANSCO substation in modern power systems. It highlights how proper planning and design contribute to efficient power transmission, reduced losses, and improved system reliability.

1.INTRODUCTION

1.1 INTRODUCTION OF THE PROJECT

The increasing demand for electrical energy due to rapid industrialization, urbanization, and technological advancements has placed significant pressure on power systems to ensure efficient,

reliable, and continuous electricity supply. Electrical substations play a crucial role in the power system by acting as intermediaries between generation, transmission, and distribution networks. Among various types of substations, Extra High Voltage (EHV) substations such as 220kV/132kV/33kV substations are vital for

stepping down voltage levels and maintaining system stability.

The 220kV/132kV/33kV Bhoothpur substation is an important component of the transmission network, responsible for receiving high voltage power and distributing it at lower voltage levels suitable for regional distribution systems. The primary function of this substation is to step down voltage from 220kV to 132kV and further to 33kV, thereby ensuring efficient transmission with minimal power losses. Voltage transformation is essential because electrical power is transmitted at high voltages to reduce transmission losses and then reduced to lower voltages for safe and practical use by consumers.

Substation design involves careful consideration of several technical, economic, and safety factors. The major components of a substation include power transformers, circuit breakers, isolators, busbars, current transformers (CTs), potential transformers (PTs), lightning arresters and earthing systems. Each component has a specific function and must be selected based on system requirements, load demand, and fault conditions. Proper coordination among these components ensures smooth operation and minimizes the risk of failures.

The performance analysis of a substation focuses on evaluating parameters such as load factor, demand factor and line losses. Efficient substations are designed to minimize transmission losses, maintain voltage levels within permissible limits, and ensure

uninterrupted power supply. Reliability is particularly important, as faults or failures in substations can lead to widespread power outages. Protection systems play a critical role in detecting faults and isolating faulty sections quickly to prevent damage to equipment and ensure safety.

In modern power systems, substations are increasingly integrated with digital technologies such as Supervisory Control and Data Acquisition (SCADA) systems and intelligent electronic devices (IEDs). These technologies enhance monitoring, control, and automation, thereby improving operational efficiency and reducing human intervention. Additionally, proper earthing and insulation coordination are essential for ensuring safety and protecting equipment from over voltages and lightning strikes.

The Bhoothpur substation, operating at multiple voltage levels, is designed to handle varying load conditions and provide reliable power supply to a wide area. The study of its design and performance analysis provides valuable insights into the functioning of EHV substations and highlights the importance of proper planning and engineering in power system infrastructure. This project aims to analyze the single-line diagram, design considerations, and operational performance of the 220kV/132kV/33kV substation, thereby contributing to a better understanding of modern electrical power systems.

2. LITERATURE SURVEY

The design and performance analysis of substations have been widely studied by researchers and engineers in the field of electrical power systems. Various authors have contributed to understanding the components, configurations, and operational aspects of EHV substations.

Sudipta Sen, Arindam Chatterjee, and Debanjan Sarkar (2013) presented a detailed design of a 132/33kV substation, focusing on single-line diagrams, load estimation, and equipment selection. Their work emphasized the importance of proper planning and coordination between different substation components to ensure efficient power transfer.

Yash Raju Shendre, Rohit Jarande, Sejal Thakare, and Juhi Dawale (2022) discussed the design of substations with a focus on reliability, cost-effectiveness, and efficiency. They highlighted that substations must be designed with considerations such as low capital cost, high efficiency, and reserve capacity for future expansion.

Dr. Prajwalit Shikha, Dr. J. Dubey, Amritanshu Jha, and Deepika Yadav (2022) conducted a comparative study of 132/33kV substations in India. Their research showed that substations play a key role in voltage transformation and power distribution, and their design varies depending on geographical and load conditions.

Malay, Chintan, Rahul, Vishwas, and Dr. Sweta Shah (2020) focused on the design of a 66/11kV

distribution substation. Their study emphasized the importance of selecting appropriate equipment ratings and ensuring proper protection systems to maintain system stability.

Esobinenwo, Akinwole, and Omeje (2014) studied earthing system design for substations using simulation tools. Their research highlighted the importance of grounding systems in ensuring safety and reducing fault currents.

Madhusmita (2025) discussed protection schemes for 220/132/33kV substations, emphasizing the role of relays, circuit breakers, and communication systems in fault detection and isolation. The study also highlighted modern practices such as digital relays and SCADA integration.

Dulip Madurasinghe and Ganesh Venayagamoorthy (2022) explored the use of artificial intelligence in identifying substation configurations. Their research demonstrated how AI can improve monitoring and operational efficiency in modern power systems.

Pagani and Aiello (2011) analyzed power grids as complex networks, emphasizing the importance of reliability and network topology in ensuring efficient power transmission.

Sun et al. (2015) proposed methods for load balancing in substations using energy storage systems, highlighting the importance of balancing loads to improve efficiency and reduce losses.

Blake et al. (2018) developed detailed models of high-voltage power networks, emphasizing the role of grounding and system modeling in analyzing substation performance under different conditions.

These studies collectively highlight the importance of proper design, advanced protection systems, and modern technologies in improving the efficiency and reliability of substations.

3. METHODOLOGY

The methodology adopted for the design and performance analysis of the 220kV/132kV/33kV Bhoothpur substation involves systematic steps to ensure accurate evaluation and efficient design.

Initially, the single-line diagram of the substation is developed to represent the electrical layout and interconnection of components. This diagram provides a simplified representation of the system, making it easier to analyze power flow and equipment placement.

Next, load analysis is performed to determine the total power demand and distribution requirements. Based on this analysis, suitable ratings for transformers, circuit breakers, and other equipment are selected. The transformer capacity is chosen considering present load demand and future expansion.

The design of busbar arrangements is carried out to ensure flexibility and reliability. Different configurations such as single bus, double bus, and

ring bus systems are evaluated based on cost and reliability requirements.

Performance analysis is conducted by evaluating parameters such as load factor, demand factor and line losses is also performed to determine system behavior under abnormal conditions.

Finally, earthing system design is carried out to ensure safety and proper dissipation of fault currents.

4. EXISTING METHODS

Traditional substation design methods primarily focus on manual calculations and conventional equipment selection. These methods rely on simplified assumptions and standard design practices.

In existing substations, electromechanical relays are commonly used for protection. Although reliable, these relays have limitations in terms of speed and accuracy. Similarly, manual monitoring systems are used, which require human intervention for operation and maintenance.

Conventional substations use basic busbar configurations such as single bus systems, which are cost-effective but less reliable. Fault detection and isolation are slower due to limited automation.

Another limitation of existing methods is the lack of real-time monitoring and control. This can lead to delays in identifying faults and increased downtime.

Despite these limitations, traditional methods are still widely used due to their simplicity and lower initial cost. However, they are gradually being replaced by modern techniques.

5. PROPOSED SYSTEM

The proposed system for the 220kV/132kV/33kV Bhoothpur substation incorporates modern technologies to improve efficiency, reliability, and performance.

Advanced digital relays are used for protection, providing faster and more accurate fault detection. These relays can communicate with control systems for better coordination.

The integration of SCADA systems allows real-time monitoring and control of substation operations. This reduces human intervention and improves operational efficiency.

Modern busbar configurations such as double bus or ring bus systems are proposed to enhance reliability and ensure uninterrupted power supply.

Energy-efficient transformers and equipment are selected to reduce power losses and improve overall efficiency.

The proposed system also includes improved earthing design and lightning protection to enhance safety and protect equipment.

Overall, the proposed system provides a more reliable, efficient, and automated solution compared to traditional methods.

6. OUTPUT RESULTS

6.1 LOAD FACTOR CALCUCATIONS PER 5 DAYS:

Veltoor-1:

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	232	208	220.5
2	232	208	220
3	233	205	219
4	230	206	218
5	233	206	219.5

Veltoor-2:

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	225	198	211.5
2	226	200	213
3	224	197	210.5
4	227	199	213

Thimmajipet-1 :

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	225	198	211.5
2	226	200	213
3	224	197	210.5
4	227	199	213
5	225	198	211.5

Thimmajipet-2 :

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	229	203	216
2	230	204	217
3	228	202	215
4	227	201	214
5	229	203	216

Mahabubnagar-1 :

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	120	95	107.5
2	118	94	106
3	119	96	107.5
4	121	97	109
5	120	95	107.5

Mahabubnagar-2:

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	118	93	105.5
2	117	92	104.5
3	119	94	106.5
4	118	93	105.5
5	117	92	104.5

Mahabubnagar-3:

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	122	96	109
2	121	95	108
3	120	94	107
4	122	96	109
5	121	95	108

Puttapahad-1 :

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	117	92	104.5
2	117	92	104.5
3	118	93	105.5
4	119	94	106.5
5	118	93	105.5

Puttapahad-2:

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	122	96	109
2	122	96	109
3	121	95	108
4	120	94	107
5	121	95	108

Kothakota :

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	122	96	109
2	121	95	108
3	120	94	107
4	122	96	109
5	121	95	108

Jadcherla:

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	122	96	109
2	124	91	107.5
3	123	90	106.5
4	122	95	108.5
5	121	95	108

Marikal :

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	119	96	107.5
2	121	95	108
3	123	94	108.5
4	125	96	110.5
5	123	95	109

Kotha moglara :

Day	Maximum load (MW)	Minimum load (MW)	Average load (MW)
1	39	27	33
2	38	26	32
3	39	27	33
4	38	26	32
5	39	27	33

6.2 DEMAND FACTOR:

6.2.1 DEMAND FACTOR PER DAY CALCULATION:

Parameter	Value (MW)
Connected load	250
Maximum demand	233
Demand factor(%)	93%

6.3 LINE LOSSES

6.3.1 LINE LOSSES PER DAY CALCULATION:

$$\text{Line loss (\%)} = \frac{(\text{Sending end} \times \text{Multiplication factor}) - (\text{Receiving end} \times \text{multiplication factor})}{(\text{Sending end} \times \text{Multiplication factor})}$$

$$1. \text{ Sending End Energy (Bhoothpur)} \quad 3683134-3681702=1432$$

$$\text{Multiplication Factor (M.F)} = 1000$$

$$S.E=1432 \times 1000=1,432,000 \text{ units}$$

$$2. \text{ Receiving End Energy (Veltloor)}$$

$$4921234-4919086=2148$$

$$\text{Multiplication Factor (M.F)} = 666.67$$

$$R.E=2148 \times 666.67=1,431,856 \text{ units}$$

LINE LOSSES PER DAY CALCULATION:

$$\% \text{LINE LOSS} = \frac{S.E-R.E}{S.E} \times 100$$

$$= \frac{1432000-1431856}{1432000} \times 100$$

$$= \frac{144}{1432000} \times 100$$

$$= 0.000100 \times 100$$

$$= 0.01\%$$

7. CONCLUSION

The performance analysis of the 220/132/33 kV Bhoothpur substation demonstrates that the system is operating efficiently with strong load management and minimal losses. From the calculated results, the load factor values for major substations such as Veltloor and Thimmajipet are around 93%–94%, indicating optimal utilization of installed capacity and consistent load distribution. Similarly, the 132 kV feeders show load factors close to 88%, while 33 kV feeders maintain values around 83%–85%, reflecting slightly varying but stable demand patterns at lower voltage levels.

The demand factor is observed to be approximately 93%, which signifies that the connected load is

effectively utilized without excessive overloading. Additionally, the line losses are extremely low (around 0.01%), highlighting efficient transmission and proper maintenance of the system.

These performance values clearly indicate that the substation is well-designed and operates with high efficiency, reliability, and stability. Proper equipment selection, effective earthing systems, and systematic load distribution contribute significantly to safe operation and reduced energy losses. Overall, the study confirms that the substation meets operational requirements while ensuring quality power supply and system security.

8. FUTURE SCOPE

The future scope of the 220/132/33 kV Bhootpur substation focuses on enhancing efficiency, reliability, and adaptability to modern power system requirements. With the increasing demand for electricity and the integration of renewable energy sources, substations must evolve to handle dynamic load conditions and variable power generation. The adoption of advanced technologies such as SCADA systems and smart grid infrastructure will enable real-time monitoring, improved control, and faster fault detection, thereby reducing system downtime and improving operational efficiency.

In addition, the implementation of IoT-based sensors and artificial intelligence techniques can support predictive maintenance, allowing early identification of equipment failures and minimizing

unexpected outages. Further improvements in transformer efficiency, reactive power compensation, and advanced conductor materials can help reduce transmission losses and improve overall system performance. The transition towards digital substations with modern communication protocols will enhance protection schemes, data management, and system flexibility.

Moreover, the development of simulation tools and digital twins will provide better training opportunities for engineers and assist in system planning and analysis. Overall, the future advancements will ensure that substations become more intelligent, automated, and capable of meeting the growing energy demands while maintaining safety, reliability, and efficiency

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