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A Comparative Study of Electrical System of 132/33kV Substations in India

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Abstract
According to the classification rules followed by the Government of India, EHV (Extra High Voltage) substation refers to any substation that manages power values greater than 33 kV. The aim of this paper is to provide a comparative study of the electrical system of such EHV 132/33KV substations that are there in multiple places in India. A substation is a component of a power transmission, distribution, as well as generation system. There are various important tasks performed by substations such as the voltage is switched from higher to lower levels also vice-versa at substations. Electric power is transferred between the customer and generating station by means of a variety of substations with varying voltage levels. The 132/33 KV substation transmission voltage is 132 kV, while the voltage distribution is 33 kV.A descriptive statistic helps in gaining an understanding of substation designs and how they vary from one another, within every common geographical setting.

Keywords:*132/33KV, Substation, Electrical Power, Extra High Voltage*

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I. Introduction

Electrical substations serve as a connection between the distribution grid and the transmission grid. In a substation, transformers may be used to switch levels of voltage between high transmission and lower distribution voltages, and even to connect two transmission voltages. An electrical utility may own and operate a substation, or a large industrial or commercial customer may own and operate one. The majority of substations are unmonitored, relying on SCADA for remote monitoring as well as controlling. [15].

Loss of electric power has important economic and social consequences for both the utility providing electricity and the end consumers of electricity. A large power failure that is limited to a single state can cost tons of millions of money. System failures, such as control, safety, or communication system, as well as disruptions, such as lightning, and personnel operational errors, make the power system vulnerable. As a result, maintaining a stable power supply is important for the design and operation of power systems [6]. A well-designed electrical system achieves a good balance between cost and reliability. One of the most important responsibilities of power system operators is to run their systems in a way that the facilities in their control have the possibility [7] of highest level of service reliability [7]. Therefore, the design of a substation must be such that they suit the purpose for which they are constructed.

Based on their functionalities and the role, the substations are classified as below:

*1. Step-up Substations:*These raise the voltage produced by generators (generally at power plants) to improve the efficiency of electricity transmission.

*2. Step-down Substations:*These services lower power transmission voltage to sub-transmission voltage that is commonly used in industry. Then again, the output can also be routed to a distribution substation.

*3. Distribution Substation:*With distribution transformers, when power is gradually supplied to the load, these substations reduce the voltage of sub-transmission to a level which could be used to supply most industrial, commercial, as well as residential requirements.

The following are the main tasks related to the delivery system and transmission substations [4]:

1. Security of system of transmission.
2. Ensuring that steady state and the transient stability is maintained.
3. Monitor and control of the exchange of energy.
4. Load shedding and synchronization preservation parameters.Keeping the frequency of the device within predetermined parameters.

5. Control of voltage by decreasing reactive power flow by tap-changing as well as reactive power compensation.
6. Demonstrate adequate line capabilities to meet supply.
7. For network monitoring, control, and protection, data is transmitted across a power line carrier.
8. Fault investigation as well as identification of the root cause, as along with the consequent change in that direction.
9. Consistent supply by fueling the network at multiple stages.
10. Calculating energy transfer through transmission lines.
11. Establishment of a cost-effective load distribution system, as well as a number of related functions.

Based on the voltage levels, the substations are categorized as follows:

*1. Substations with HV (High Voltage):*Voltages ranging from 11 to 66 kV are used.
*2. Substations with EHV (Extra High Voltage):*Voltages ranging from 132 and 400 kV are used.
*3. Substations with UHV (Ultra High Voltage):*The operating voltage is greater than 400 kV.

The 132/33KV Substation is an Extra High Voltage substation that implies that the transmission voltage is of 132KV, and its distribution voltage is 33KV.

II. Electrical Substation Components

The basic components of an electrical substation are discussed below with the help of pictorially representation in figure 1:

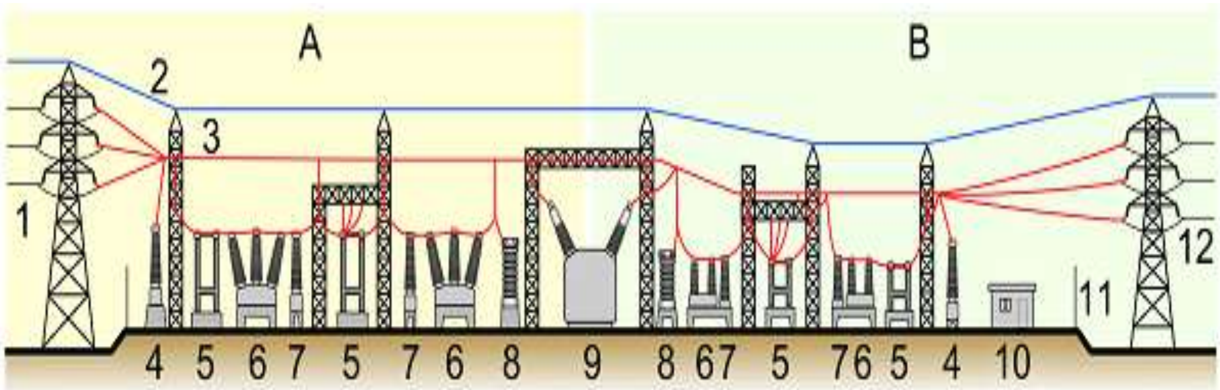

Figure 1: Substation Elements[3]

The substation shown above is divided into two sections A and B. Section A shows the primary lines of power,whereas section B is the secondary lines. The components numerically denoted are named below:

a.Ground wire
b. Overhead lines
c.Measurement of electric voltage with a transformer
d. Separate switch
e. Breaker of the circuit
f.Current transformer
g. Lightning arrester
h. Main transformer
i. Control building
j. Security fence
k. Secondary power lines

Now, looking briefly at the function of these components in a substation. The grounding network and the link to the earth are the two key components of a substation grounding device. The substation grounding network connects all equipment frameworks and metallic structures, while the link to the earth serves as the interface between both the electrical device and the environment. An overhead power line is a system that transmits electrical energy over long distances in electric power transmission and distribution. It comprises of one or more uninsulated power lines suspended by towers or poles (generally multiples of three for the purpose of three-phase power).

Power transformers are used at generating stations to step up voltage for transmission and at key step-down transformer substations to step down voltage for further delivery. Transformers with two windings and three phases, which are typically naturally cooled and oil immersed, are used for ratings up to 10 MVA. Air-cooled transformers with level greater than 10 MVA are popular. Air blast, Force oil, and water cooling can be used for extremely high ratings.

*1. Current Transformer (CT)[3]:*The prime winding of a current transformer is made up of one or more changes of heavy coil wired in sequence with current to be weighed thread.The secondary is fed by a regular 5 amp ammeter and has a significant number of fine wire turns. It can be used for calculating and securing information.Under any conditions, the secondary current transformer must not be left open.

*2. Potential Transformer (PT)[3]:*These are step-down lines of transmission with a high precision ratio that have been used in combination with a low-voltage standard (100-120V).The actual voltage on the primary side is calculated by dividing the deflection by the transformation ratio. They are also of the shell kind. For safety reasons, their rating is extremely low, and the secondary is totally isolated from the high voltage main. The load on the secondary determines the primary current.

Isolators are a kind of switch that is only used to isolate the circuit when the current has been disrupted. When there is no load on the isolator, it is known as disconnected switches. They don't have any arc-quenching machines. They don't have any potential for breaking or making current. In certain situations, it is used to interrupt the transmission line charging current.

Circuit breakers are switches that are used to close or open circuits when a fault occurs in the system. In normal circumstances, the circuit breaker two mobile contacts are turned off. If a malfunction occurs in the device, a relay sends a tripped order to the circuit breaker, which may cause the contacts to separate in order to avoid damage to the circuit.

Relays [3] are a type of electrical substation component that protects the system from abnormal situations such as faults. Relays are essentially sensing devices that are used to detect faults, determine their location, and send a tripped command interruption message to a particular point on the circuit. After receiving an order from relays, a circuit breaker is ripping its contacts apart. These safeguard equipment against a variety of threats, including fire, the threat of human life, and the removal of a fault from a specific section of the substation.

Lightning arresters may be considered the very first substation components. These have the purpose of shielding substation equipment from high voltages

as well as restricting the amplitude and length of current flow. These are linked between the earth and the line, i.e. in line with the substation equipment. These are designed to divert current to earth in the event of a current surge, thereby protecting the insulation and conductor from damage. There are many types each with its own set of responsibilities.

The Busbar [3] is a conductor that brings current to a point with several connections. It is one of the most essential elements of the substation. The Busbar is a type of electrical junction that allows current to flow in both directions. When a fault occurs in the busbar, all components linked to that section should be tripped in order to provide complete isolation in a short period of time, such as 60ms, to prevent danger rising due to conductor heat. They come in various sizes and shapes, including ring buses, double buses, and single buses.

III. 132/33KV SUBSTATION

Suppose that 132/33KV substation is designed to give 200MW of power, the substation [7] is linked to 3 load or substations such as A (3.2 MW), B (3.2MW), C (3.2MW) at 33KV, and D (36MW) at 132 KV. The 16.2 kV created is raised upto 132 kV, and transmitted to the substation at 132 kV through 2 double-circuit lines of transmission.The outdoor equipment should be feasible to support a three phase, 50Hz system with a nominal voltage value of 132KV. Figure 2 represent a single-line picture of a substation.

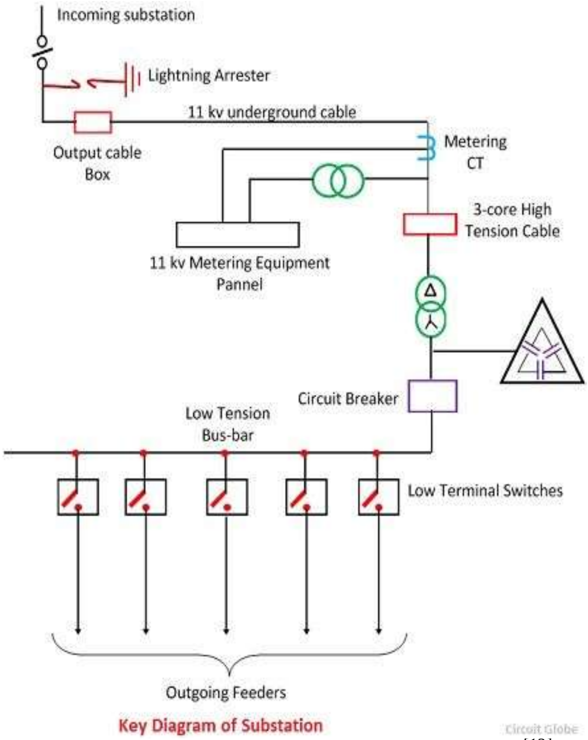

Figure 2: Single Line Diagram of a Substation[13]

The substation links are categorized as follows:

- Link to an incoming power source or a power feeder.
- Other switchgear or substations are fed from the outgoing feeder.
- Link with power transformer
- Linking voltage transformer for metering and control.

A circuit breaker can be seen between the busbar and each of circuits both incoming as well as outgoing in the single line diagram. An isolator is present on circuit breaker both sides. The potential transformer can be used for safety and measurement.They protect the circuit breaker and cover the shielded area by being installed on both sides of the circuit breaker.

On the incoming line side, the prospective transformer is attached to the busbar. To prevent switching, surge or lightning arresters are phase-connected to ground at the incoming side as the first device, along with the big motor terminal, the generator terminals and shunt reactor, and lastly the capacitor and transformer bank terminals.

The control and relay circuitry with its protection [11] for a 132/33 KV substation involves corridor form or the duplex type control panels. The front and back walls are built separately with a traditional cover in this design. The sides are opened except for the end panels that have both a door switch and doors for internal lighting. For checking and wiring, there should be enough room to turn between the front and back. Protective relays are mounted on the back board, while control and indication equipment is mounted on the front panels. Individual panels have a depth of 1983 mm, a width of 1000 mm, and a height of 2312 mm as normal. The corridor is 762mm wide, and the end panels access doors are 1900mm long.The panels are pest, dust, and moisture resistant.These are free-standing as well as floor-mounting units which are grounded with base bolts. The bottom of the panel is where the cables join.Both the cable and gland plates on the panel bottom plates can be removed.The screwed brass cable glands are suitable for PVC armored cable.

IV. 132/33KV SUBSTATIONS IN INDIA

Some of the substations in India which have the 132/33KV model is listed below[12]:

1. Geotechnical Investigation for Proposed HPPTCL Project - 22020/132/33 KV GIS at Dehan near Palampur, Himachal Pradesh - client GE T&D India Limited
2. Geotechnical Investigation for Proposed Project 132/33/0.433KV Substation Package at Talaipalli, Chhattisgarh – client Larsen & Toubro Limited
3. Electrical Resistivity Tests at RVPNL-BANAR 220/132 KVA AIS at Banar near Jodhpur, Rajasthan – client Alstom T&D India Limited

4. Geotechnical Investigation for Proposed 132/33 KV Sub-Station at Pratap Nagar, Jodhpur Rajasthan – client Larsen & Toubro Limited.
5. Geotechnical Investigation for Proposed 132/33 KV Gis Sub-Station at Kuri, Jodhpur, Rajasthan – client Larsen & Toubro Limited
6. Geotechnical Investigation for Proposed 132/33 KV Gis Sub-Station at Old Power House, Jodhpur, Rajasthan – client Larsen & Toubro Limited.
7. Geotechnical Investigation for Proposed 132 KV Terminal Bays at Existing 132 KV Sub-Station, Chopasani, Jodhpur, Rajasthan – client Larsen & Toubro Limited
8. Geotechnical Investigation for Proposed 132 KV Terminal Bays at Existing 132 KV Sub-Station Banar, Jodhpur, Rajasthan – client Larsen & Toubro Limited
9. Geotechnical Investigation for Proposed 400/220/132 KV Sub-Station at Deedwana, Rajasthan - client Larsen & Toubro Limited are a few to mention.

V. METHODOLOGY

The data collection for the purpose of this study is the research data from previous studies, along with the data that is available on the electricity department websites of respective states. Main focus in the data collection has been in the areas where 132/33 KV substations have been employed.

The aim is to perform a comparative study of 132/33 KV substations located in a similar geographical setup are chosen. In lieu of that, three 132/33 KV substations in Bettiah, Ramnagar, and Motihari in the state of Bihar as shown in figures 3,4,and 5 respectively are compared. The single line diagram is also maintained with the National Informatics Centre (NIC).

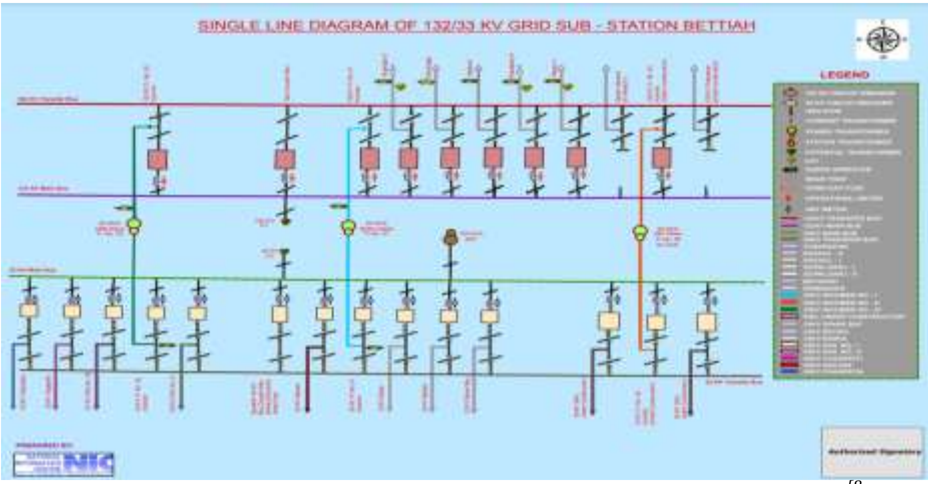

Figure 3: Single Line Diagram of the 132/33KV Grid Substations Bettiah[8

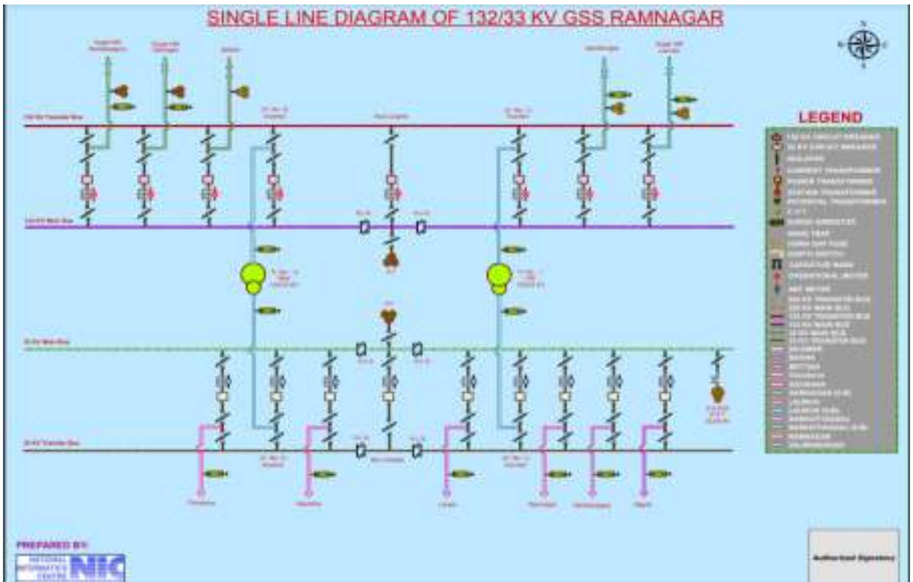

Figure 4: Single Line Diagram of the 132/33KV Grid Substation Ramnagar[10]

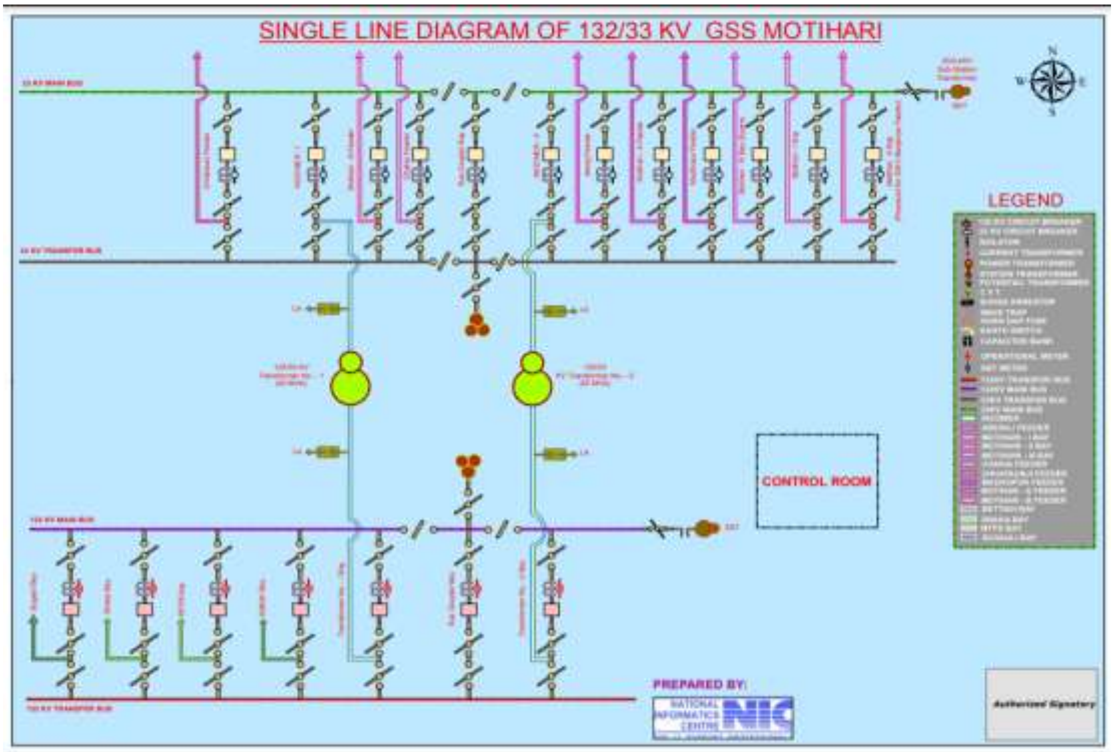

Figure 5: Single Line Diagram of the 132/33KV Grid Substation Motihari[9]

VI. RESULT

The three figures shown above depicted a detailed comparison in the three substation within a geographical location. A tabular column below shows the differences found in the number of feeders, incomers, and transformers on 132KV. It can be seen from the table that even after being in the same geographical location in the state of Bihar – Bethiah, Motihari, and Ramnagar have different electrical systems with respect to the number feeders, incomers, and transformers. Thus, the comparative study is done here.

Table 1: Comparative Study of the Three Substations

SUBSTATION NAME	NUMBER OF FEEDERS	NUMBER OF INCOMERS	NUMBER OF TRANSFORMERS ON 132KV
BETIAH	10	3	3
MOTIHARI	9	2	2
RAMNAGAR	6	2	2

VII. CONCLUSION

With the help of this paper, a detailed study has been conducted regarding the various components used in a substation. The main focus of this paper has been the 132/33KV substation. A general design of this type of substation has been discussed. Additionally, a comparative study has been conducted by choosing three 132/33kv substation, and by taking the grid system single line diagram in three different places within the same geographical boundary. It has been found that being in the same geographical area doesn't guarantee uniform designs of electrical systems and only a case –by – case analysis is required. It is also possible to do an analysis of these systems, for any issues suing simulations with an advance software called the ETAP – Electrical Transient Analyzer Program [1]. This software can be used for analysis of the load flow and determine probable areas for short circuits and so on.

Finally, an important aspect to be kept in mind is the system analysis that will look into not only the substation but also the incoming and outgoing feeders, as well as the substation effect on the system, along with the customer satisfaction [2,14].

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