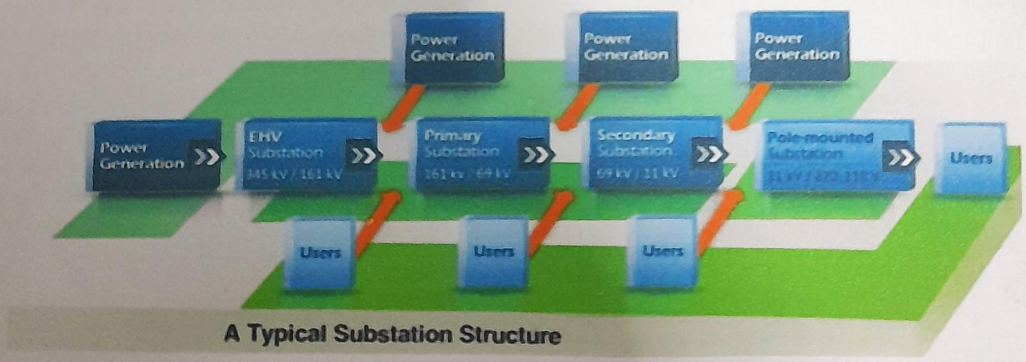
Substation

Electrical substations play a key part in effectively transmitting electricity through our national system. Find out what they do, how they work and where they fit into our electricity grid. Substations are integral features within that grid and enable electricity to be transmitted at different voltages, securely and reliably. A **substation** is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, convert electricity into different voltages or perform any of several other important functions. Between the generating station and the consumer, electric power may flow through several substations at different voltage levels. A substation may include transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages. They are a common component of the infrastructure. Substation transformers will fulfil different purposes in voltage conversion depending on where electricity is in its transmission journey. for maintenance of such voltage levels and deliverance of stability numerous switching stations and transformation stations are created amid consumer ends and electrical power generating stations. The **transformation and switching station** is generally **known as a substation** which is further elaborated below.

The **electrical substation** can be defined as a network of electrical components comprising of power transformers, busbars, auxiliaries, and switchgear etc. The components are interconnected such that creating a sequence of a circuit capable to be switched OFF while running on normal operation through manual commands while in emergency situations it can be switched OFF automatically. The emergency situations may be an earthquake, floods, or short circuit etc.

The electrical substation does not have a single circuit but is composed of numerous outgoing and incoming circuits which are connected to a busbar i.e. common entity among circuits. The **substation receives electrical energy** directly from generating stations through incoming power supply lines while it delivers electricity to the consumers through outgoing transmission lines. A substation which is near to the electrical power generation is also known as **grid substation**.



A Typical Substation Structure

Major Tasks of Substations

There are numerous tasks associated with **power substations** in the distribution and transmission system. Some of the major tasks that substations perform are as follows.

- It serves as protection hub of the transmission system.
- It maintains the frequency of system confined in targeted limits and has to deal with load shedding.
- It controls the exchange of electrical energy amid consumers and generating stations.
- It is ensuring transient stability along with steady-state stability of the system.
- It delivers sufficient line capacity hence securing supply.
- It helps in reducing the flow of reactive power, hence gaining voltage control.
- Through line carrier, it performs data transmission to ensure monitoring of network, protection, and control.
- It helps in fault analysis and pinning cause for a failure, hence improving the performance of the electrical network.
- It ensures reliable supply through feeding network at numerous points.
- It assists in determining energy transfer with help of transmission lines.

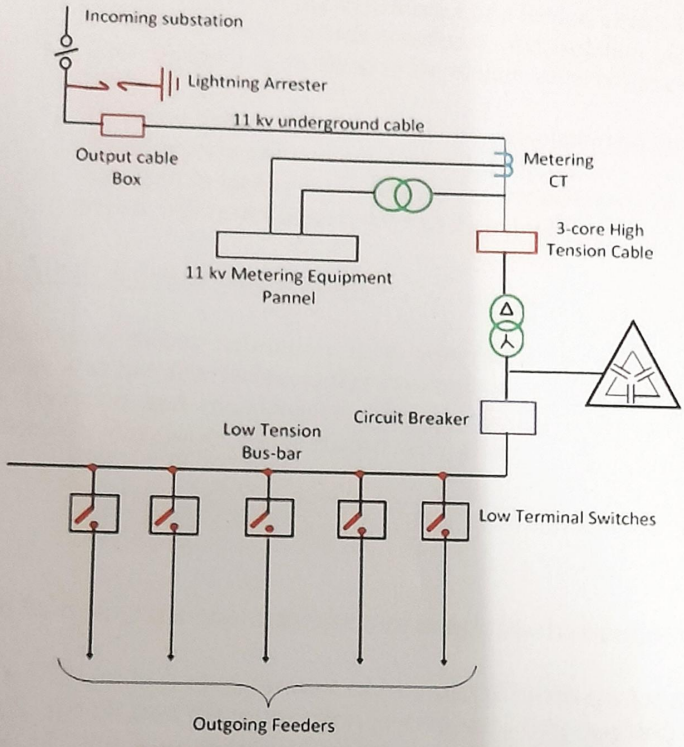
Single Line Diagram of an Electrical Substation

The single line diagram of the substation is shown in the figure below.The connection of the substation is divided as

- Incoming or power feeder connection
- Outgoing feeder for feeding the other subsequent substations or switchgear.
- Power transformer connection.
- Voltage transformer connection for control and metering.

The circuit breaker is connected between the bus-bar and each incoming and outgoing circuit. The isolator is provided on each side of the circuit breaker. The current transformer is used for measurement and protection. The current transformers are placed on both sides of circuit breaker so that the protection zone are overlapped and cover the circuit breaker.

The potential transformer is connected to the bus bar and on the incoming line side. Lightning or surge arrester are connected phase to ground at the incoming line as the first apparatus and also at the terminal of transformer and capacitor bank, the terminal of shunt reactor and a terminal of the generator, the terminal of the large motor to divert switching.



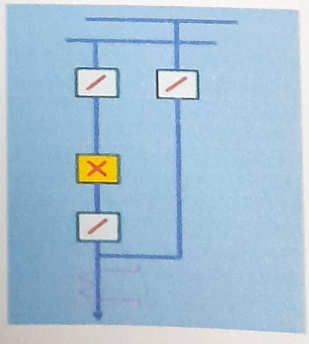
Key Diagram of Substation

Different Substation Layouts

The following are the general **substation layout diagram**. These are also referred to as **substation design**.

1) Single Busbar Substation

This design is simplest and has an ease of operation and maintenance. This design has a minimum reliance over signaling for the necessary protection of its operation. Furthermore, there is a facility for supporting economical operations of feeder bays. Following is a general schematic diagram of single busbar substation.



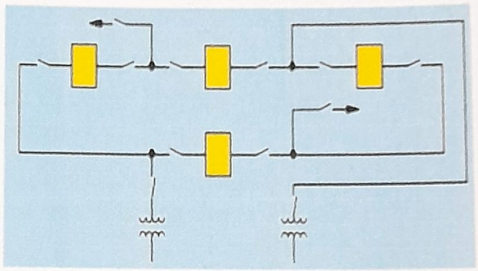
The characteristics of single busbar substation are as follows.

- There is a circuit breaker for protection of each circuit, hence there is no loss of supply in outages.

- In case of fault on the transformer of a feeder, circuit breaker results in loss of feeder or transformer circuit which is restored after isolation of faulty circuit breaker.
- Loss of circuit is involved in the maintenance of the circuit breaker of the transformer of the feeder.
- There are bypass isolators amid circuit isolator and busbar hence allowing maintenance of circuit breaker without any loss to the circuit.
- Any fault in busbar is causing loss of a transformer or feeder. Hence, maintenance of a busbar will result in an outage of 2 circuits.

2) Mesh Busbar Substation

The mesh busbar substation is a complex design and has few technicalities involved in its operation and maintenance. The generic schematic diagram of mesh busbar substation is as follows.

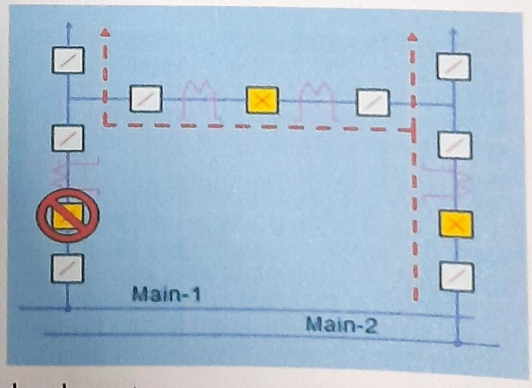


The following are characteristics of **mesh busbar substations**.

- There is a requirement of two circuit breakers for disconnecting or connecting of a circuit and disconnection is also requiring opening up of mesh.
- There is an option of maintenance of circuit breakers without loss of supply.
- One circuit breaker loss occurs when busbar is faulty while fault in breaker involves loss of two circuits.

3) One and Half Circuit Breaker Substation

The one and a half circuit breaker layout of a substation are not common because of its high cost and complex technicalities involved in its operation and maintenance. The generic schematic diagram of the mentioned substation is given below.



The following are characteristics of one and half circuit breaker layout.

- High security is involved alongside the loss of supply.
- There is a possibility of operating only one pair of circuits, a pair of circuits, or groups of circuits.
- The circuit breakers are having a complex arrangement and higher costs are involved.

The following factor is considered while making site selection for a substation.

- **Type of substation** – The category of the substation is important for its location. For example, a step-up transformer is a point where power from various sources is pooled and step up for long distance transmission should be located as cool as possible to minimise the losses. Similarly, the step-down transformer should be located nearer to the load centre to reduce transmission losses, the cost of the distribution system and better reliability of supply.
- **Availability of suitable and sufficient land** – The land selected for a substation should be level and open from all sides. It should not be waterlogged particularly in the rainy season. The site selected for substation should be such that approach of transmission lines and their take off can be easily possible without any obstruction.The places nearer to airdrome, shooting practice ground, etc. should be avoided.
- **Communication facility** – Suitable communication facility is desirable at a proposed station, both during and after its construction. It is better, therefore, to select the site alongside the existing road to facilitate an easier and cheaper transportation.
- **Atmospheric Pollution** – The atmosphere around the ground factories produces metal corroding gas, air fumes, conductive dust, etc. And the area near the sea coast may be more humid and is harmful to the proper running of the power system. Thus, the substation should not be located near the factories or sea coast.
- **Availability of Essential Facilities to the Staff** – The site should be such where staff can be provided essential facilities like school, hospital, drinking water, housing, etc.
- **Drainage Facility** – The site selected for the proposed substations should have proper drainage arrangement or the possibility of making effective drainage, avoid pollution of air and growth of micro-organism and health

Parts of an electrical substation

- Transformer: It is a static electrical machine that serves to increase or decrease electricity in an AC electrical circuit, while maintaining a constant frequency and power.
- Circuit breaker: It interrupts and reestablishes the continuity of an electric circuit. Such interruption is made with load or short-circuit current.
- Recloser: It is an electromechanical part that interrupts the current when there is an excess of electricity and acts when a fault is generated in the circuit. Reclosers are designed to operate with 3 closing operations and 4 openings with an interval between them.
- Blade fuses: They are connection and disconnection elements of electric circuits with a double function. On the one hand, as a blade disconnect, it switches on and off. On the other hand, it acts as a fuse protection element and is used when an overcurrent is registered.
- Disconnect switches and test switches: They serve to physically disconnect an electric circuit, so they usually operate without charge. These switches work mechanically and also manually.
- Lightning arresters: They are responsible for keeping ionized rays away. When there is a surge of a certain magnitude, lightning arresters form an electronic arc that makes the current discharge on the ground and not on people or equipment and installations.

- Instrument transformers: They are apparatuses responsible for measuring the electric current. There are two types: current transformers (CT), to change the value of the current, and potential transformers (PT), to transform the voltage values without taking the current into account. Both values are used in real time for measuring, control, and protection instruments that require current or voltage signals.
- Junction boxes: They are the connection terminals per phase that allow us to make derivations and to reach specific areas.
- Condensers: They allow us to conserve the electricity that is produced in an electric field. Through two conductors separated by insulating material, energy is temporarily stored.

Types of electrical substations

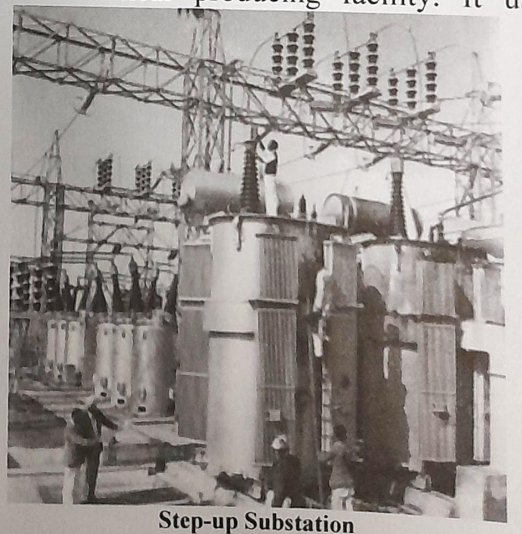
The different types of substations mainly include Step-up Type Substation, Step-down Transformer, Distribution, Underground Distribution, Switchyard, Customer Substation, and System Station. There are numerous **types of electrical substations** depending on its nature and power tackling capacities. **Classification of Substations** broadly falls under the following **4 categories** based on various aspects

1. Substation Types based on Application
2. Substation Types based on Service
3. Substation Types based on Operating Voltage Levels

Substation Types based on Location/Design

Step-up Type Substation

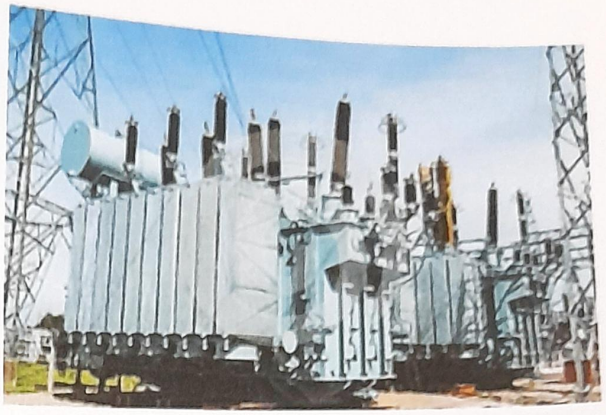
This type of substation gets the power supply from a near producing facility. It uses a large power transformer for enhancing the voltage level for transmitting to the remote locations. In is substation, the power transmission can be done by using a transmission bus to transmission lines. This substation can also be a knock on the incoming power which is received by the generation plant. The received power can be used to supply power to the operation of apparatus in the plant. A substation includes circuit breakers for switch generation as well as transmission circuits in & out of service as required.



Step-up Substation

2) Step-down Substation:

The step-down substations are linked with load centers as there is a requirement of different voltage levels for various loads. The step-down substations are capable to change the voltage levels of transmission to usually 69kv. The lines of the substation are then serving as a source to that of the distribution substation. Moreover, some of the power is tapped from the substation line to be used for industrial purposes in the way.



Step Down Substation

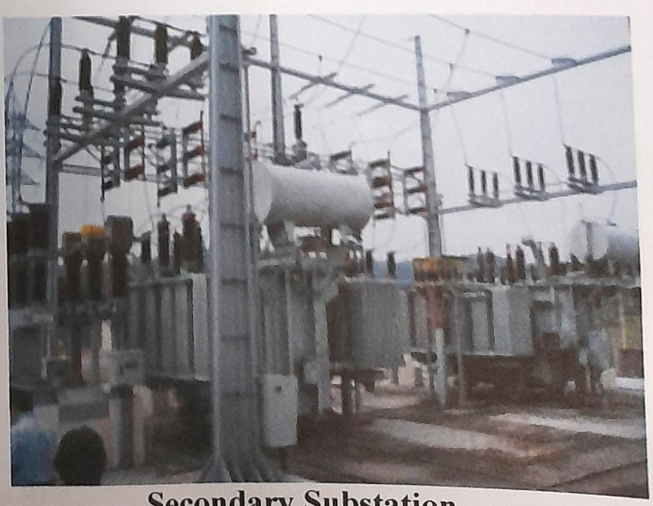
3) Primary Substation:

The primary grid substations are linked with bulk load centers alongside primary lines of transmissions. The voltages are stepped-down at various voltage ranges for purpose of secondary transmission.

Primary Substation

4) Secondary Substation:

The secondary substations are lined alongside secondary transmission lines adjacent to loads. The voltages here are further stepped-down for purpose of distribution.



Secondary Substation

Customer Substation

This type of substation works as the major source of power supply for one specific business client. The business case, as well as the requirements of technical, highly depends on necessities of customers.

System Stations

This substation includes the huge amount of power transfer across the station and it is called as a system station. These stations only offer no power transformers while others do voltage exchange as well. Typically, these stations supply the end-points to the transmission lines creating from switchyards & supply the electrical energy for circuits that supply transformer stations. They are important to long-term consistency. These stations are strategic services as well as very costly to build as well as to maintain.

Distribution Type Substation

Distribution type substations are placed where the main voltage distributions are stepped-down to supply voltages to the consumers using a distribution network. The voltage of any two phases will be 400 volts, and the voltage between neutral and any phase will be 230volts. Conventional – Outdoor type with air-insulated equipment

- Indoor type with air-insulated equipment
- SF6 Gas Insulated Substation
    - Outdoor type with gas-insulated equipment
    - Indoor type with gas-insulated equipment

Composite Substation or Hybrid Substation combination of above two

Distribution Substation

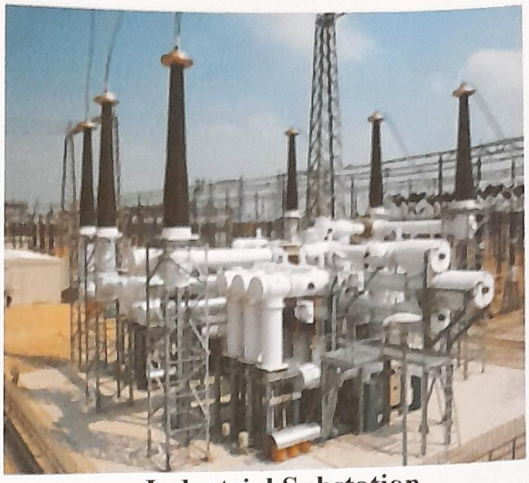
6) Mobile Substation:

The mobile substations are only for a dedicated purpose and are temporary in nature i.e. mainly for giant constructions. A mobile substation is supposed to fulfill power requirements of the under-construction structures. These substations are a source of temporary electrical supply and its maintenance is very easy. It has vibrant protection from blackouts, fires, weather disturbance, and sabotage etc.

Mobile Substation

7) Industrial Substation:

The industrial substations are also known as bulk substations and are traditionally referred to as distributive substation, however, these are for dedicated consumers only e.g. industries requiring bulk power to be supplied.



Industrial Substation

8) Mining Substation:

The mining substation is of a distinct kind and is needed to be designed carefully as an increased level of precautionary safety measures are to be taken for the operation of its electrical energy. This substation is dedicated for the control of electrical power supply from the surface to mine power station lying underground.

Types of Substations based on Service

9) Converter Substations–

As the name suggests, Converter substations contain equipment that changes the frequency of current from higher to lower and can also convert AC to DC or the reverse also.

Converter Substation

10) Switching Substations–

A key function of these switching station includes switching the power line without altering the voltages as they are placed in between the transmission lines. It also isolates the faulted portion of the systems and de-energize faulted equipment which helps the grid operate with stability.

14) Collector substations–

These substations are primarily used in distributed power generation projects like wind farms, hydroelectric projects etc where power flow from multiple power sources can be collected and distributed to the grid by stepping up the transmission voltage.

15) Step-down Type Substation

This type of substation is placed at different points in an electrical network. They can connect different parts of the network and that are a source of sub-transmission or distribution lines. This type of substation can change the transmission voltage to a sub-transmission voltage (69kV). The converted voltage lines can provide a source for distribution substations. In some cases, power is tapped from the line of -transmission line to utilize in an industrial capacity along the way. Or else, the power will supply to a distribution substation.

16) Underground Distribution Substation

Installation of a substation in urban centers requires large space, but generally, they don't have a place to install the substation. To overcome this problem, installing the substation underground decreases requirement of space and the surface area can also be used for other constructions like buildings, shopping malls, etc. The main concept of the underground substation is to offer the best conventional substation by reducing the space occupied above land.

Underground Substation

17) Switchyard

The switchyard is the mediator among the transmission as well as generation, and equal voltage can be maintained in the switchyard. The main purpose of this is to supply the generated energy from the power plant at the particular level of voltage to the nearby transmission line or power grid.

Switchyard