

**Lecture Notes**  
**for**  
**B.TECH. III yr, VI<sup>th</sup> Semester**  
**( Electrical Engg.)**  
**Subject Code: EE604**  
**Subject: Power Station Practices**



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## Unit- 3 (Substations)

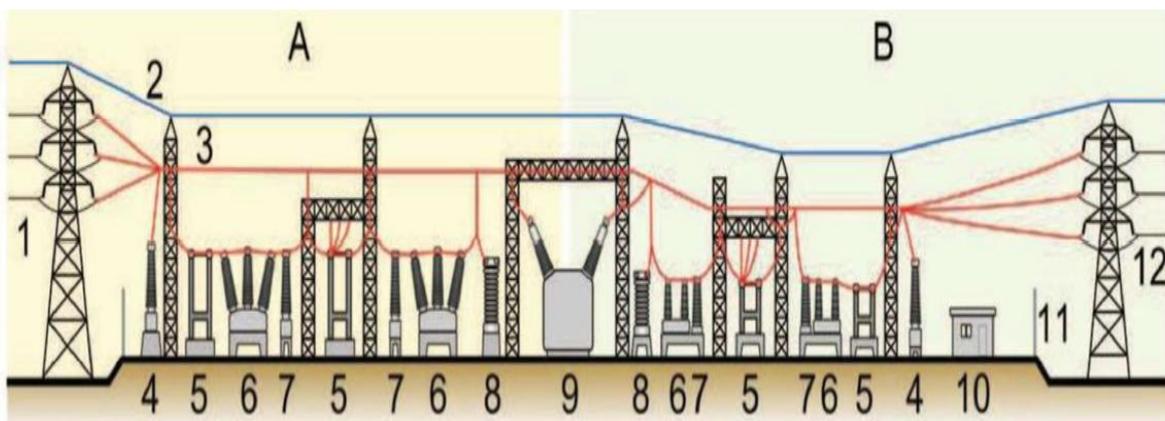
### What is a substation and why it is needed?

A substation is the intermediate means between high voltage transmission or distribution and end user including connecting generators, transmission or distribution lines, and loads to each other, and generally stepping higher voltages down to lower voltages to meet specific customer requirements. For example we cannot use electricity directly from 11 KV power line or 33 KV power line. In order to use energy from these lines we would have to get power through substation from these lines. Therefore it is required to install a substation there. Also if we want to transmit electrical energy over long distance, then it is also required to install a substation to get high voltage for transmission. Also a substation is required for the control of energy i.e. changing frequency, converting from ac into dc or inverting from dc into ac, for switching of different feeders and transmission lines etc.

### Elements of a substation:

A: Primary power lines' side B: Secondary power lines' side

1. Primary power lines
2. Ground wire
3. Overhead lines
4. Transformer for measurement of electric voltage
5. Disconnect switch
6. Circuit breaker
7. Current transformer
8. Lightning arrester
9. Main transformer
10. Control building
11. Security fence
12. Secondary power lines



To conclude, substation is an integral part of a power system. The continuity of electric energy supply system is solely depending on substation. So, enough care should be taken when designing and set upping a sub-station in a suitable place. Some points are as follows-

- The substation must have the chance of easy operation and maintenance.
- The place must be proper for setup a substation. It must be setup near the centre of load.

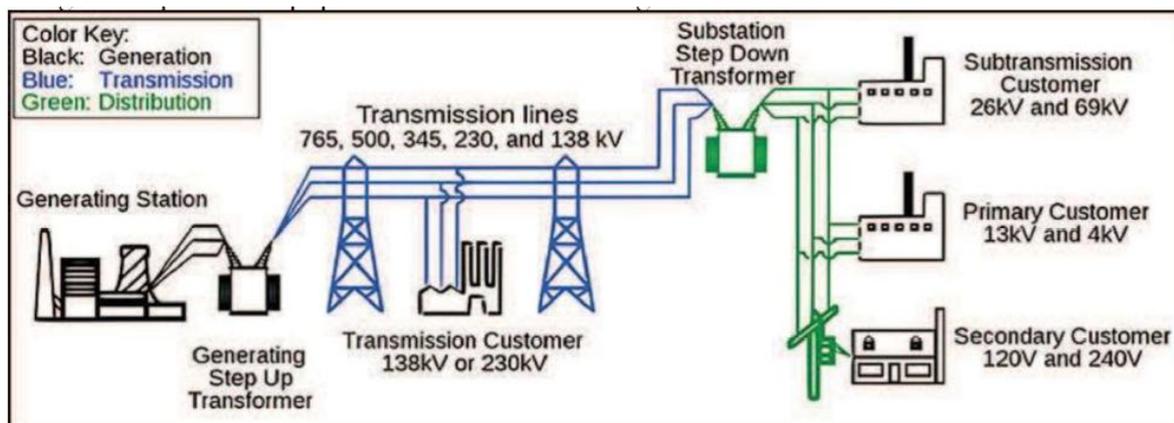
- The substation must have enough safety apparatus or safety setup. There must be enough chance for running the maintenance and clearing process. Also there should be setup for fire protection.
- The system must be reliable. When designing protected gears and other instruments must be included. The construction process also maintained properly for reliable operation.
- The capital cost must be as low as possible.

## Types of substation-

1. Transmission substation
2. Distribution substation
3. Collector substation
4. Converter substations
5. Switching station

## Transmission substation

A transmission substation connects two or more transmission lines. The simplest case is where all transmission lines have the same voltage. Transmission substations can range from simple to complex. In such cases, substation contains high-voltage switches that allow lines to be connected or isolated for fault clearance or maintenance. A transmission station may have transformers to convert between two transmission voltages, voltage control/power factor correction devices such as capacitors, reactors or static VAR compensators and equipment such as phase shifting transformers to control power flow between two adjacent power systems. The largest transmission substations can cover a large area with multiple voltage levels, many circuit breakers. Today, transmission-level voltages are usually considered to be 110 kV and above. Lower voltages, such as 66 kV and 33 kV, are usually considered sub-transmission voltages, but are occasionally used on long lines with light loads. Voltages above 765 kV are considered extra high voltage and require different designs compared to equipment used at lower voltages.



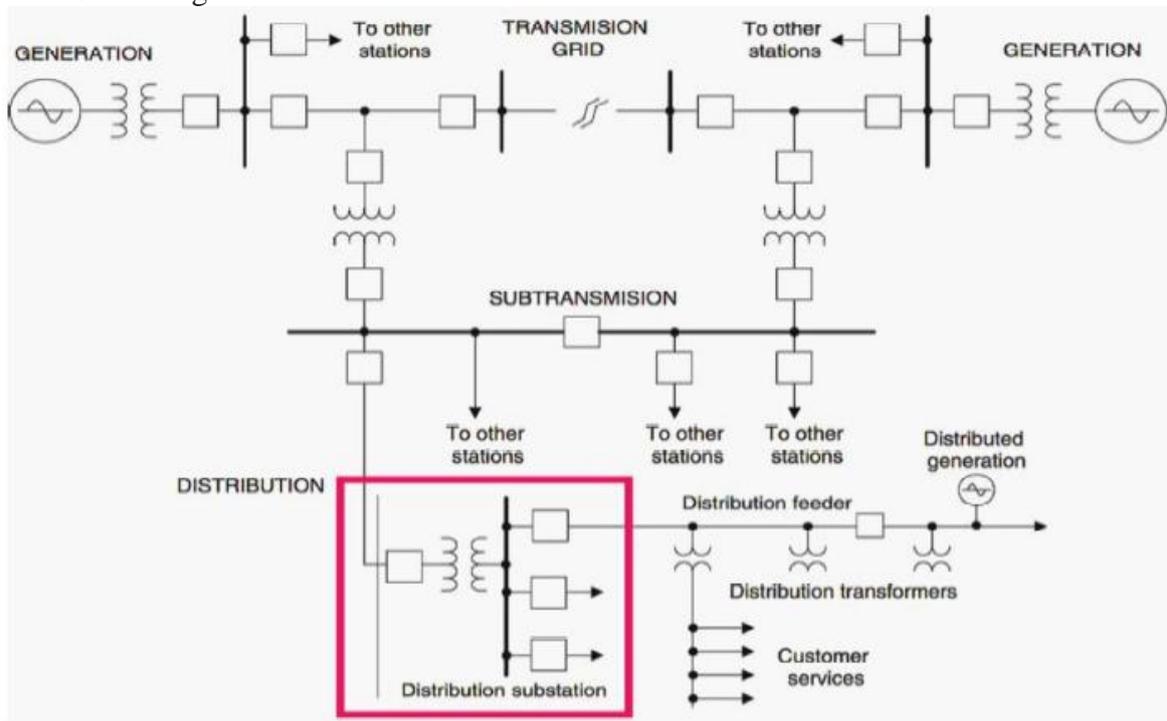
## Distribution substation

A distribution substation transfers power from the transmission system to the distribution system of an area. The input for a distribution substation is typically at least two transmission or sub transmission lines. Input voltage may be, for example, 115 kV, or whatever is common in the area. The output is a number of feeders. Distribution substation typically operates at

medium voltage levels, between 2.4 kV-33 kV. The feeders run along streets overhead (or underground, in some cases) and power the distribution transformers at or near the customer premises. In addition to transforming voltage, distribution substations also isolate faults in either the transmission or distribution systems. Distribution substations are typically the points of voltage regulation, although on long distribution circuits (of several miles/kilometres), voltage regulation equipment may also be installed along the line. The downtown areas of large cities feature complicated distribution substations, with high-voltage switching, and switching and backup systems on the low-voltage side. A distribution substation is a combination of switching, controlling, and voltage step-down equipment arranged to reduce sub-transmission voltage to primary distribution voltage for residential, farm, commercial, and industrial loads.

Distribution substation is generally comprised of the following major components:

- Supply Line
- Transformers
- Bus-bars
- Switchgear
- Out-coming feeders
- Switching apparatus
- Switches
- Fuses
- Circuit breakers
- Surge voltage protection
- Grounding



## Converter substations

Electrical machines or equipments operated on DC voltages from home to industrial applications. A converter station converts electricity between Alternating Current (AC) and Direct Current. for sending electricity. Converter substations may be associated with High Voltage DC (HVDC) converter plants, traction current, or interconnected non-synchronous

networks. These stations contain power electronic devices to change the frequency of current, or else convert from alternating to direct current or the reverse. Direct current or HVDC (high voltage direct current) links are used for exchanges between countries exclusively on a transmission network level. In DC power transmission lines, converter substations are used to convert a three-phase current to a direct current (rectification) at the sending end of the line and to achieve a reverse conversion (inversion) at the receiving end of the line. Converter stations are located at the terminals of a DC transmission line. Sometimes converter stations are located at a generation power plant or at transmission substations. Two unsynchronized AC transmission systems can be connected together with converter stations. Converter stations are also found in most substations for converting the emergency battery back-up system to AC power for use in an emergency.

## **Collector substation**

To build a wind farm, a solar farm or hydroelectric plants need a collector substation to tie all the generators and connect them to the power grid. It looks like a distribution substation although power flow is in the opposite direction, from many wind turbines or solar cells up into the transmission grid. Usually for economy of construction the collector system operates around 35 kV, and the collector substation steps up voltage to a transmission voltage for the grid. The collector substation can also provide power factor correction if it is needed, metering, and control of the wind farm. In some special cases a collector substation can also contain an HVDC converter station. Collector substations also exist where multiple thermal or hydroelectric power plants of comparable output power are in proximity. The collector system is comprised of many components. Transformer, high voltage conductors (underground or overhead), sensor (current, voltage, thermal and magnetic), Lightning protection, grounding system, circuit breakers and switches, monitoring system etc.

## **Switching station**

A switching station is a substation without transformers and operating only at a single voltage level. Switching stations are sometimes used as collector and distribution stations. Sometimes they are used for switching the current to back-up lines or for parallelizing circuits in case of failure. A switching station may also be known as a switchyard, and these are commonly located directly adjacent to or nearby a power station. In this case the generators from the power station supply their power into the yard onto the Generator Bus on one side of the yard, and the transmission lines take their power from a Feeder Bus on the other side of the yard.

An important function performed by a substation is switching, which is the connecting and disconnecting of transmission lines or other components to and from the system. Unplanned switching events are caused by a fault in a transmission line or any other component, for example:

- a line is hit by lightning and develops an arc,
- a tower is blown down by high wind.

The function of the switching station is to isolate the faulty portion of the system in the shortest possible time. De-energizing faulty equipment protects it from further damage, and isolating a fault helps keep the rest of the electrical grid operating with stability.

## **Classification of substation**

The substations can be classified in several ways including the following:

### **1. Classification based on voltage levels**

**A.C. Substation** : HV (between 33 KV and 66 kV),

EHV (132 kV and 400 kV),  
UHV (above 400 kV),  
MV/ distribution substation/public substation (2kV to 33kV),  
LV/private substation (220V and 440V),  
HVDC Substation.

## 2. Classification based on construction features

**Outdoor substation** -It is under open sky (rated voltage beyond 66kV).  
**Indoor substation**- This is inside a building (rated voltage beyond 11kV).  
**Mining Substation**- Needs special design consideration because of extra precaution for safety needed in the operation of electric supply.  
**Mobile Substation**- Temporary requirement.  
**Pole Substation**- This is an outdoor substation with equipment installed overhead on H- pole or 4-pole structure.

## 3. Classification based on configuration

**AIS** -Conventional Air insulated outdoor substation (up to 800 kV)  
**GIS** -SF6 Gas Insulated Substation (GIS)  
**Composite**- This types of substations having combination of the above two

## 4. Classification based on application

**Step Up Substation**- Associated with generating station as the generating voltage is low.  
**Primary Grid Substation**- Created at suitable load centre along primary transmission lines. (Step down 66kV from 220 kV)  
**Secondary Substation**- Along secondary transmission line (step down to 11 kV).  
**Distribution Substation**- Created where the transmission line voltage is step down to supply voltage. Bulk supply and industrial substation Similar to distribution sub-station but created separately for each consumer. 11kV delivered to distribution substation

## 5. Classification based on services

**Power-factor Substation**- They improve the power-factor of the system by using synchronous condensers.  
**Frequency Substation**- Those substations which change supply frequency  
**Industrial Substation**- Those substations which supply power to industries

## Selection of site:

Selection of site for construction of a Grid Substation is the first and important activity. This needs meticulous planning, fore-sight, skillful observation and handling so that the selected site is technically, environmentally, economically and socially optimal and is the best suited to the requirements.

The main points to be considered in the selection of site for construction of a Grid Substation are given below.

The site should be:

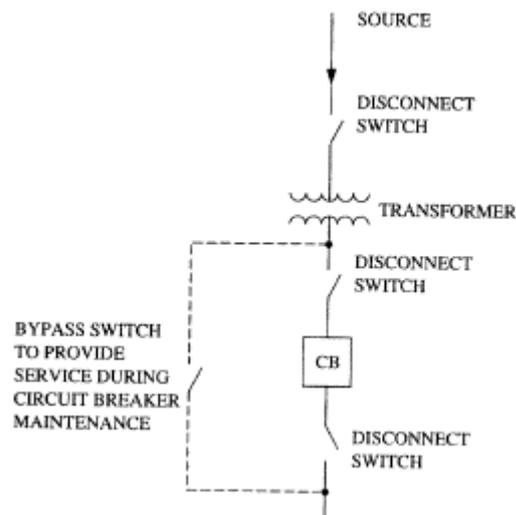
- a) As near the load centre as possible.
- b) Far away from obstructions, to permit easy and safe approach/termination of high voltage overhead transmission lines.
- c) Sufficient land area.

- d) Necessary clearances for electrical safety.
- e) Access to maintain large apparatus such as transformers.
- f) The site must have room for expansion due to load growth or planned transmission additions.
- g) Environmental effects ( drainage, noise and road traffic effects.
- h) Grounding must be taking into account to protect passers-by during a short circuit in the transmission system.
- i) The substation site must be reasonably central to the distribution area to be served.

## DISTRIBUTION SUBSTATION LAYOUT

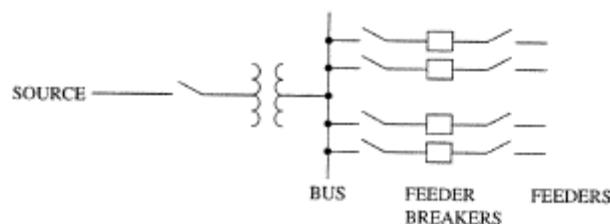
### 1. Single source, single feeder substation

The one-line diagram of a single-source, single-feeder substation with the minimum equipment used. A bypass switch is provided so service can continue during circuit breaker maintenance. The probability of a fault during circuit breaker maintenance is small, but still there as a result the transformer is protected by a primary fuse to back up the breaker, and provide some protection for internal transformer faults. The minimum relaying is over current on the secondary side of the transformer. The switches can be manually or motor operated.



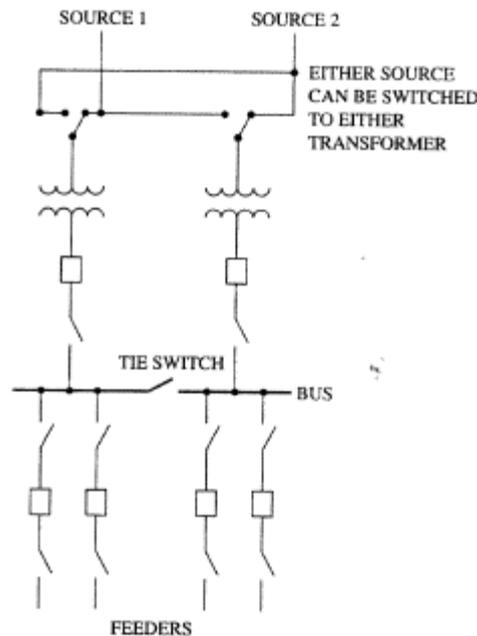
### 2. Single bus substation

This is the one line of a single bus substation fed by a single radial sub transmission line. Each feeder must have its own over current protection. The primary switch must be able to break the transformer excitation current. The transformer may have differential relaying that trips all of the feeder breakers in the event of a fault. Each distribution voltage the substation supplies must have its own bus. The possibility of a sub transmission circuit fault is much higher than a transformer fault. Two sources allow service to be restored more quickly upon a sub transmission circuit fault.



### 3. Two Transformer Distribution Substations

More critical loads implement a two transformer distribution substation allowing to significantly decreasing the out of service time. Normally the transformers are rated at 75% capacity when self cooled and equipped with automatic air cooling that is used when one transformer must handle the entire substation capacity. The tie switch between the two transformer connections to the bus which is in open state when both transformers are in use to prevent the transformer secondaries from operating in parallel. Momentary parallel operation during switching is often permissible but must be avoided for the extended operation time due to the high secondary currents. The primary side switching is arranged so that either or both transformers can be fed by either sub transmission line.



### Bus Arrangements

The ring bus requires only one circuit breaker per line so it is economical. Power can reach any feeder from two directions so no feeder need be disconnected when one breaker is down for service. Two breakers are operated when a feeder fault occurs, one on either side of the feeder. If a second breaker trips when one feeder is down the entire bus may be disconnected from a source. The ring bus is therefore seldom used if the feeders exceed the source lines by than a factor of two. The breaker and a half is a reasonably economical, versatile, Reliable and as a result is very popular. A bus or feeder fault can easily be isolated while the station remains in service. The breaker and a half is usually used in substations with more than four feeders.

