Mrs, Srabani Chakraborty



# UNIT - 8 : SUBSTATION

The present-day electrical power system is a.c. i.e. electric power is generated, transmitted and distributed in the form of alternating current. The electric power is produced at the power stations which are located at favourable places, generally quite away from the consumers. It is delivered to the consumers through a large network of transmission and distribution. At many places in the line of the power system, it may be desirable and necessary to change some characteristic (e.g. voltage, a.c. to d.c., frequency, p.f. etc.) of electric supply. This is accomplished by suitable apparatus called substation

The assembly of apparatus used to change some characteristic (e.g. voltage, a.c. to d.c., frequency, p.f. etc.) of electric supply is called a **substation.**

Substations are important part of power system. The continuity of supply depends to a considerable extent upon the successful operation of substations . It is, therefore, essential to exercise utmost care while designing and building a substation. The following are the important points which must be kept in view while laying out a substation :
(i) It should be located at a proper site. As far as possible, it should be located at the centre of gravity of load.
(ii) It should provide safe and reliable arrangement. For safety, consideration must be given to the maintenance of regulation clearances, facilities for carrying out repairs and maintenance, abnormal occurrences such as possibility of explosion or fire etc. For reliability, consideration must be given for good design and construction, the provision of suitable protective gear etc.
(iii) It should be easily operated and maintained.
(iv) It should involve minimum capital cost.

## Classification of Substations

There are several ways of classifying substations . However, the two most important ways of classifying them are according to (1) service requirement and (2) constructional features.

1. According to service requirement : A substation may be called upon to change voltage level or improve power factor or convert a.c. power into d.c. power etc. According to the service requirement, substations may be classified into :
**(i) Transformer substations** : Those substations which change the voltage level of electric supply are called transformer substations . These substations receive power at some voltage and deliver it at some other voltage. Obviously, transformer will be the main component in such substations. Most of the substations in the power system are of this type.

(ii) **Switching substations** : These substations do not change the voltage level i.e. incoming and outgoing lines have the same voltage. However, they simply perform the switching operations of
power lines.

(iii) **Power factor correction substations :** Those substations which improve the power factor of the system are called power factor correction substations . Such substations are generally located at the receiving end of transmission lines. These substations generally use synchronous condensers as the power factor improvement equipment.

(iv) **Frequency changer substations** : Those substations which change the supply frequency are known as frequency changer substations . Such a frequency change may be required for industrial utilisation.

(v) **Converting substations** : Those substations which change a.c. power into d.c. power are called converting substations . These substations receive a.c. power and convert it into d.c. power with suitable apparatus (e.g. ignitron) to supply for such purposes as traction, electroplating, electric welding etc.

(vi) **Industrial substations** : Those substations which supply power to individual industrial concerns are known as industrial substations .

2. According to constructional features : A substation has many components (e.g. circuit breakers, switches, fuses, instruments etc.) which must be housed properly to ensure continuous and reliable service. According to constructional features, the substations are classified as :
(i) Indoor substation (ii) Outdoor substation (iii) Underground substation (iv) Pole-mounted substation
(i) **Indoor substations** : For voltages upto 11 kV, the equipment of the substation is installed indoor because of economic considerations. However, when the atmosphere is contaminated with impurities, these substations can be erected for voltages upto 66 kV.

(ii) **Outdoor substations** : For voltages beyond 66 kV, equipment is invariably installed outdoor. It is because for such voltages, the clearances between conductors and the space required for switches, circuit breakers and other equipment becomes so great that it is not economical to install the equipment indoor.

(iii**) Underground substations** : In thickly populated areas, the space available for equipment and building is limited and the cost of land is high. Under such situations, the substation is created underground.

(iv) **Pole-mounted substations** : This is an outdoor substation with equipment installed overhead on H-pole or 4-pole structure. It is the cheapest form of substation for voltages not exceeding 11kV (or 33 kV in some cases). Electric power is almost distributed in localities through such substations.

## Advantages and Disadvantages of outdoor substation over indoor substation

Outdoor substation has following advantages over indoor substation.

**Advantages :**

i) **Easy operation** : Outdoor substation is easy to operate as compared to an indoor substation.

ii) **Low capital cost** : The capital cost of the outdoor substation is low.

iii**) Less requirement of building material** : The smaller amount of building materials (steel-concrete) is required.

iv) **Less time required for erection** : The time required in erection of such substations is lesser.

v) **Easy fault location** : All the equipment is within view and therefore fault location is easier.

vi) **Future expansion** : The expansion of the installation is easier, if required.

vii) **Less civil work** : The civil work required is comparatively smaller and cost of the switchgear installation is low.

viii) **Possibility of fault escalation** : There is practically no danger of a fault which appears at one point being carried over to another point in the installation because the apparatus of the adjoining connections can be spaced liberally, without any appreciable increase in costs.

ix) **Repairing work** : Repairing work is easy.

**Disadvantages :**

i) **Operation in open condition** : The various switching operations with the isolators, as well as supervision and maintenance of the apparatus are to be performed in the open air during all kinds of weather.

ii**) More space requirement** : Since the equipments are placed outdoor, more space is required for the substation.

iii) **Protection against lightning** : Devices are required to be installed for protection against lightning surges.

iv) **More control cable** : The length of control cables required is more.

v) **Higher maintenance** : The influence of rapid fluctuation in ambient temperature and dust and dirt deposits upon the outdoor substation equipment makes it necessary to install apparatus specially designed for outdoor service resulting in higher maintenance cost.



## Selection and Location of site

The site should be near the load centre keeping in view the future load growth. Some general factors to be considered are given below :

• Access road to the site for smooth movement of construction machines, equipments and transformers. Good Roadways to construction site and shorter distance to rail head are desired.
• The site should be chosen to avoid soil filling, earth removal etc. The requirement of soil filling and earth removal takes time and increases total cost of substation
• Historical data of worst flood is taken into account to avoid water logging of the substation in case of possibility of flood. Flood plains and wetlands are avoided.
• Adequate land required for the substation should be easily available and the cost of the land should not be high from economical point of view. Also sufficient land should be available for future extension.
• Atmospheric conditions like salt and suspended chemical contaminants influence selection of equipments and maintenance requirements.
• Interference with communication signals. The construction company have to take permission from the appropriate authority.
• Electric and magnetic field strength are of particular concern especially for Ultra High Voltage (UHV) systems at 765 kV,1200 kV or above. Research organisations has shown the impact of strong Electric/magnetic fields due to UHV substations and lines on human health. Such new concerns are also required to be addressed properly
• Forest land, sanctuaries and national parks are avoided. Almost all governments has laid stringent rules to comply for approval of forest land and wild life sanctuary. The usual process takes time to get approval from the concerned authorities. This process delays the construction activities.
• Approval is also required from aviation authority. Substation should be away from airport and defence establishments.
• Water supply and sewage system are the two most important facilities to be given due consideration.
• The substation should be located far from the crowded places. Efforts are always made to locate transmission substations outside the city areas.
• The locals should be made aware of the upcoming substation. To avoid public resentment it is better to involve the local people in the process. If required they should be educated and trained. Many times the local people also plays an important role to check vandalism and theft.
• Heritage sites and tourist spots are avoided.
• Electric substation is a source of noise. While charged transformers, reactors and EHV lines are sources of continuous hissing noise, operation of different equipment also emit sudden noise. The design should be adopted to tackle the issues by complying to the standards set by the appropriate authority for reduction of noise pollution and avoid public resentments.
• Landscaping should be done to keep the substation out of direct view of common people.

## Main connection Schemes

The main connection schemes of substation are as follows :

### Transformer Substations

The majority of the substations in the power system are concerned with the changing of voltage level of electric supply. These are known as transformer substations because transformer is the main component employed to change the voltage level. Depending upon the purpose served, transformer substations may be classified into :

(i) Step-up substation (ii) Primary grid substation (iii) Secondary substation (iv) Distribution substation

Fig.1 shows the block diagram of a typical electric supply system indicating the position of above types of substations . It may be noted that it is not necessary that all electric supply schemes include all the stages shown in the figure. For example, in a certain supply scheme there may not be secondary substations and in another case, the scheme may be so small that there are only distribution substations .

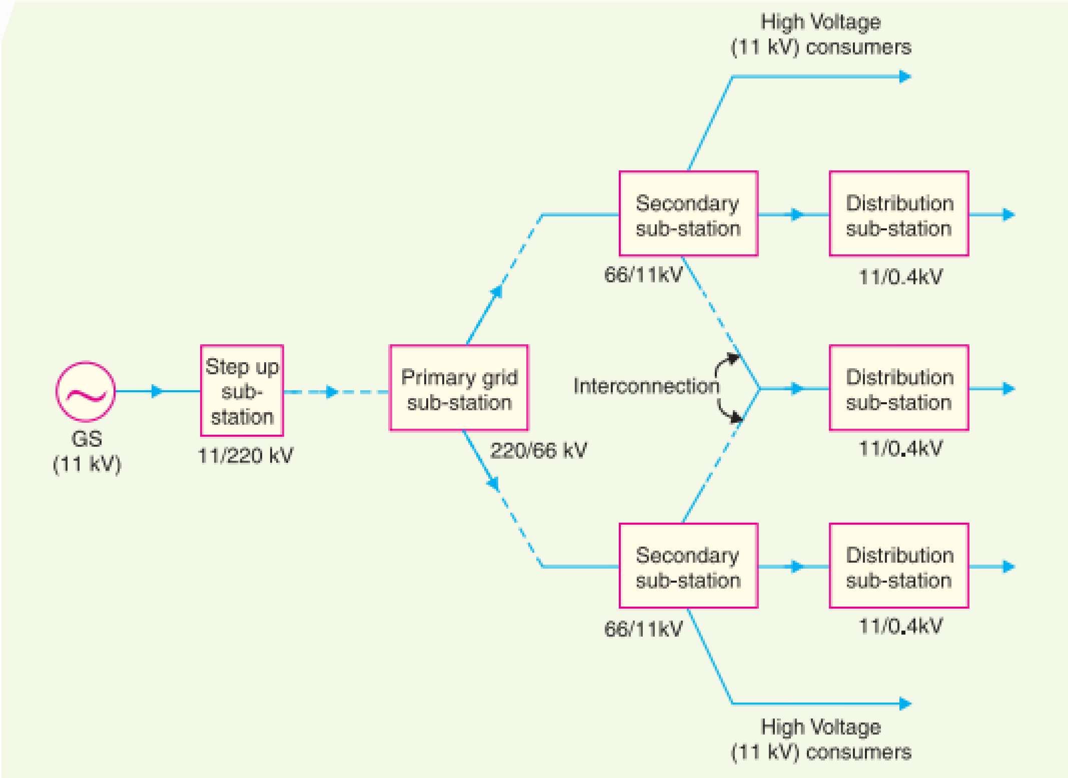



Fig. 1

(i) Step-up substation : The generation voltage (11 kV in this case) is stepped up to high voltage (220 kV) to affect economy in transmission of electric power. The substations which accomplish this job are called step-up substations. These are generally located in the power houses and are of outdoor type.

(ii) Primary grid substation : From the step-up substation, electric power at 220 kV is transmitted by 3-phase, 3-wire overhead system to the outskirts of the city. Here, electric power is received by the primary grid substation which reduces the voltage level to 66 kV for secondary transmission. The primary grid substation is generally of outdoor type.

(iii) Secondary substation : From the primary grid substation, electric power is transmitted at 66 kV by 3-phase, 3-wire system to various secondary substations located at the strategic points in the city. At a secondary substation, the voltage is further stepped down to 11 kV. The 11 kV lines run along the important road sides of the city. It may be noted that big consumers (having demand more than 50 kW) are generally supplied power at 11 kV for further handling with their own substations. The secondary substations are also generally of outdoor type.

(iv) Distribution substation. The electric power from 11 kV lines is delivered to distribution substations . These substations are located near the consumers localities and step down the voltage to 400 V, 3-phase, 4-wire for supplying to the consumers. The voltage between any two phases is 400V and between any phase and neutral it is 230 V. The single phase residential lighting load is connected between any one phase and neutral whereas 3-phase, 400V motor load is connected across 3-phase lines directly. It may be worthwhile to mention here that majority of the distribution substations are of pole-mounted type.

**Pole-Mounted Substation**
It is a distribution substation placed overhead on a pole. It is the cheapest form of substation as it does not involve any building work. Fig. 2 (i) shows the layout of pole-mounted substation whereas Fig. 2 (ii) shows the schematic connections. The transformer and other equipment are mounted on H-type pole (or 4-pole structure).

The 11 kV line is connected to the transformer (11kV / 400 V) through gang isolator and fuses. The lightning arresters are installed on the H.T. side to protect the substation from lightning strokes. The transformer steps down the voltage to 400V, 3-phase, 4-wire supply. The voltage between any two lines is 400V whereas the voltage between any line and neutral is 230 V. The oil circuit breaker (O.C.B.) installed on the L.T. side automatically isolates the transformer from the consumers in the event of any fault. The pole-mounted substations are generally used for transformer capacity upto 200 kVA. The following points may be noted about pole-mounted substations :
(i) There should be periodical check-up of the dielectric strength of oil in the transformer and O.C.B.
(ii) In case of repair of transformer or O.C.B., both gang isolator and O.C.B. should be shut off.

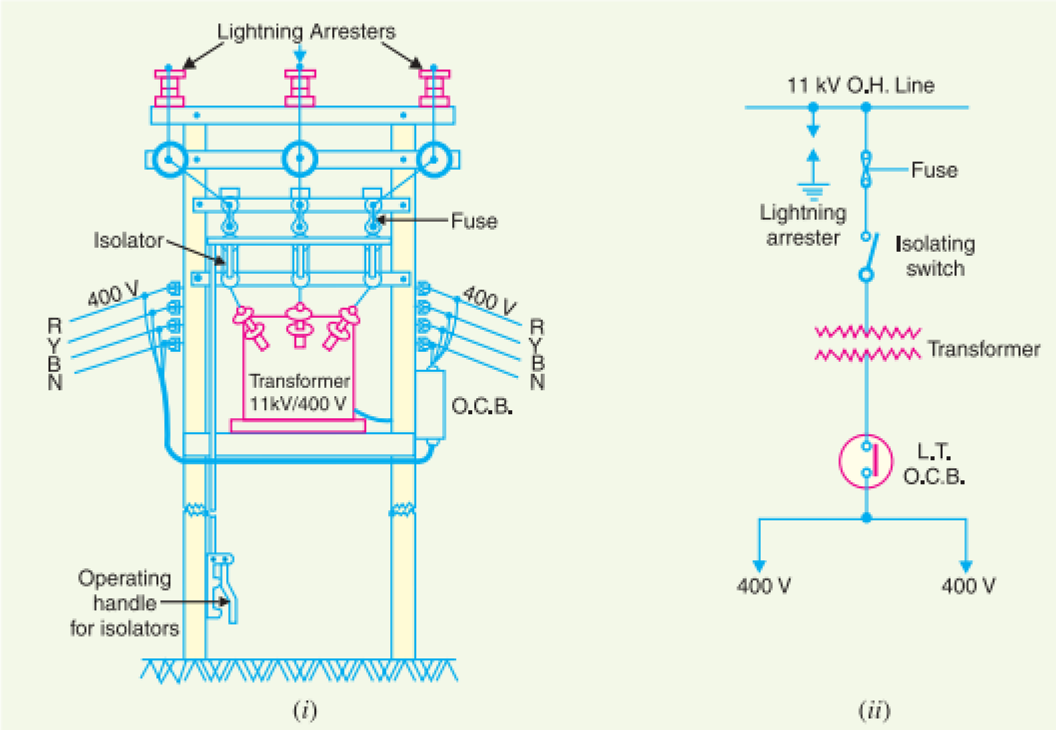



**Fig. 2**

**Underground Substation**

In thickly populated cities, there is scarcity of land as well as the prices of land are very high. This has led to the development of underground substation. In such substations , the equipment is placed underground. Fig.3 shows a typical underground substation.

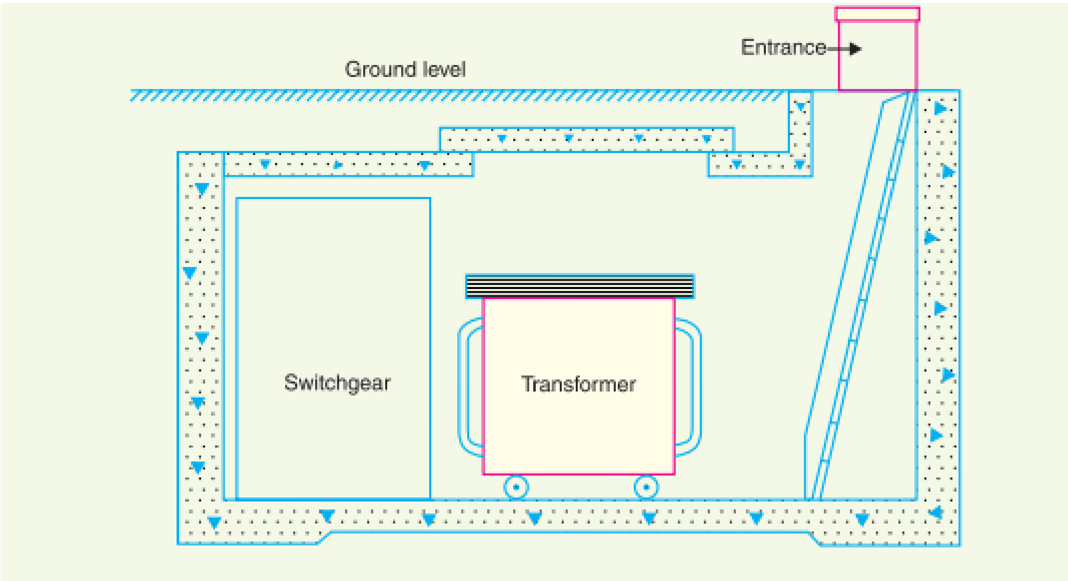



**Fig. 3**

The design of underground substation requires more careful consideration than other types of Substations . While laying out an underground substation, the following points must be kept in view:

(i) The size of the station should be as minimum as possible.

(ii) There should be reasonable access for both equipment and personnel.

(iii) There should be provision for emergency lighting and protection against fire.

(iv) There should be good ventilation.

(v) There should be provision for remote indication of excessive rise in temperature so that H.V. supply can be disconnected.

(vi) The transformers, switches and fuses should be air cooled to avoid bringing oil into the premises.

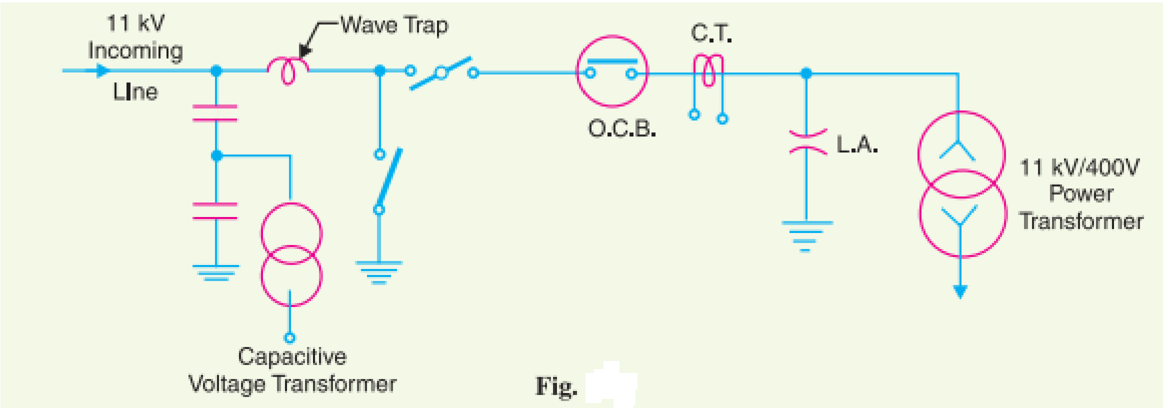
**Terminal and Through Substations**

All the transformer substations in the line of power system handle incoming and outgoing lines. Depending upon the manner of incoming lines, the substations are classified as :

(i) Terminal substation

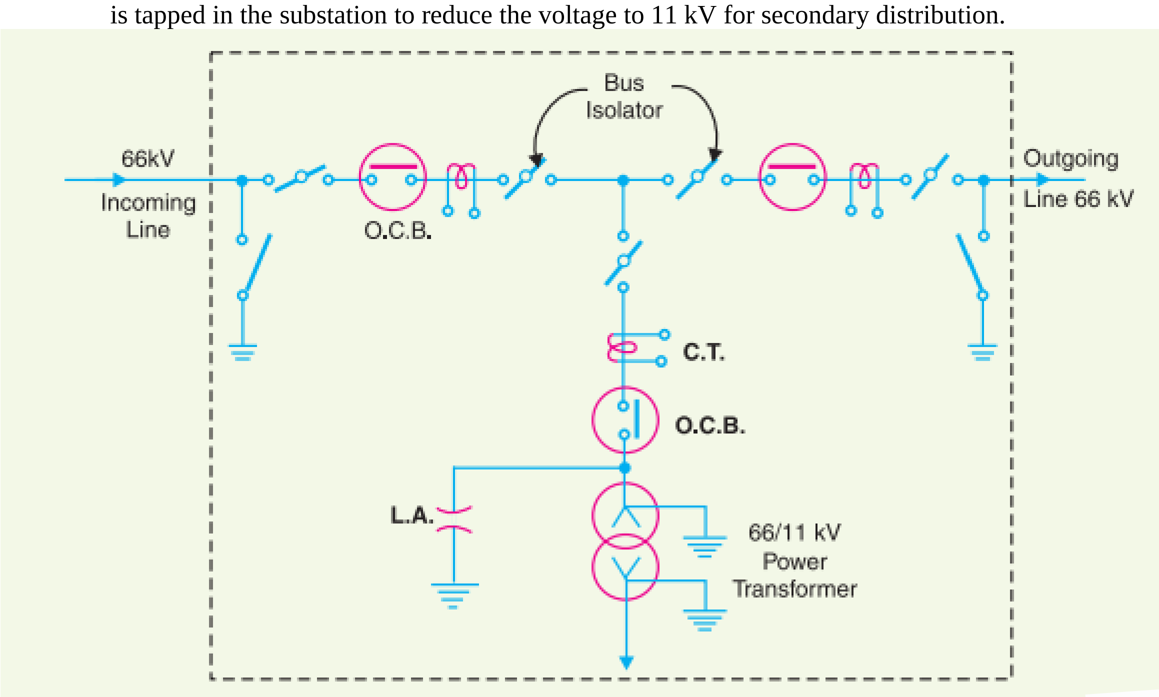
(ii) Through substation

(i) Terminal substation :. A terminal substation is one in which the line supplying to the substation terminates or ends. It may be located at the end of the main line or it may be situated at a point away from main line route. In the latter case, a tapping is taken from the main line to supply to the substation. Fig. below shows the schematic connections of a terminal substation. It is clear that incoming 11 kV main line terminates at the substation. Most of the distribution substations are of this type.




**Terminal substation**

(ii) Through substation : A through substation is one in which the incoming line passes 'through' at the same voltage. A tapping is generally taken from the line to feed to the transformer to reduce the voltage to the desired level. Fig. below shows the schematic connections of a through substation. The incoming 66 kV line passes through the substation as 66kV outgoing line. At the same time, the incoming line is tapped in the substation to reduce the voltage to 11 kV for secondary distribution.




**Through substation**



## <u>Equipments and circuit elements of substations</u>

**Isolators or Isolating switches:**

In substations, it is often desired to disconnect a part of the system for general maintenance and repairs. This is accomplished by an isolating switch or an isolator. An isolator is essentially a knife switch and is designed to open a circuit under no load. In other words, isolator switches are operated only when the lines in which they are connected carry no current. They also facilitate redistribution of loads.

**Bus-bars**

They are like electrical junction where electricity is collected from incoming transmission lines and then redistributed to the outgoing transmission line. All the important equipment in a substation are connected to the bus-bars, hence bus-bar protection is of outmost importance. If any fault occurs on the bus-bar then all other equipment in a substation connected to it might get affected and hence they must get tripped as soon as possible.

A substation can have more than one bus-bar housed in it. There are several bus-bar arrangements that can be used in a substation. The choice of a particular arrangement depends upon various factors such as system voltage, position of substation, degree of reliability, cost etc.

**Circuit breaker**

A circuit breaker is a protective device meant for breaking an electrical circuit during a fault condition. It is basically a type of automatic switch when the relay detects a fault condition it sets the circuit breaker into action and the circuit breaker has to break the circuit within minimum time, in order to quickly eliminate the source of fault. Once the fault is restored the circuit breaker can again make the circuit either manually or remotely.

A circuit breaker is used to open the circuit under normal condition as well. An isolator however cannot be used to open a circuit under normal conditions. It is because it has no provision to quench the arc that is produced during opening operation. Hence the use of circuit breaker is essential. The heaviest duty circuit breaker has to interrupt a short-circuit current of more than 100 kA.

**Power transformers**

During transmission and distribution of electricity one needs to increase or decrease its voltage to ensure proper transmission and distribution with minimum power loss. This work is achieved with the help of power transformers. A power transformer is used in a substation to step-up or step-down the voltage.

A step up transformer steps up the voltage or increases the voltage. It is also sometimes referred as transmission transformer. It is used to step-up generation voltage to a high value (say 132 kV or 220 kV or more) for transmission of electric power.

A step down transformer steps down the voltage or decreases the voltage. It is also sometimes referred as Distribution transformer. It is used to step-down the voltage from values like 132 kV or 220 kV to voltage levels like 11 kV, 22kV or 33 kV. Except at the generating station, all the subsequent substations use step-down transformers to gradually reduce the voltage of electric supply and finally deliver it at utilization voltage.

**Instrument transformers**

The lines in substations operate at high voltages and carry current of thousands of amperes. The measuring instruments and protective devices are designed for low voltages (generally 110 V) and currents (about 5 A). Therefore, they will not work satisfactorily if mounted directly on the power lines. This difficulty is overcome by installing instrument transformers on the power lines. The function of these instrument transformers is to transfer voltages or currents in the power lines to values which are convenient for the operation of measuring instruments and relays. There are two types of instrument transformers viz.

Current transformer (C.T.)

Potential transformer (P.T.)

(i) Current transformer (C.T.)

A **current transformer** is essentially a step-up transformer which steps down the current to a known ratio. The primary of this transformer consists of one or more turns of thick wire connected in series with the line. The secondary consists of a large number of turns of fine wire and provides current for the measuring instruments and relays a current which is a constant fraction of the current in the line. Suppose a current transformer rated at 100/5 A is connected in the line to measure current. If the current in the line is 100 A, then current in the secondary will be 5A.

A **voltage transformer** is essentially a step down transformer and steps down the voltage to a known ratio. The primary of this transformer consists of a large number of turns of fine wire connected across the line. The secondary winding consists of a few turns and it provides voltage for measuring instruments and relays a voltage which is a known fraction of the line voltage. Suppose a potential transformer rated at 66kV/110V is connected to a power line. If line voltage is 66kV, then voltage across the secondary will be 110 V.

**Insulators**

The overhead transmission lines and Bus-bars are supported on towers. Since the towers are at ground potential. The lined must be insulated with the tower structures. Overhead line insulators are used to electrically separate the line conductors from each other and from supporting structures. The most commonly used material for the manufacture of insulators is glass and porcelain. There are several types of insulators (e.g. pin type, suspension type, strain type, post insulator etc.) and their use in the substation will depend upon the service requirement

**Reactors**
In large capacity installations short circuit currents can attain such high values that unless certain means are used to limit them it becomes very difficult for the electrical equipment installed to withstand such high current levels. For this purpose auxiliary inductive devices called as reactors are introduced in each phase of the given installation.
Reactors are also used for power factor correction. If a transmission line has a load with poor power factor, reactors would be connected at the receiving end to correct the power factor.

**Lightning arrestor**
A lightning arrestor is another important protective device installed in the substation as well as on overhead transmission lines. As the name suggest it protects the electrical network from the damaging effects of lightning.
A lightening arrestor has two terminals high voltage terminal and one ground terminal. The high voltage terminal is typically connected to the overhead line or to the equipment to be protected. The ground terminal is connected through path of low resistance to ground. Between the high voltage and ground terminal there is either air or a material of high resistance. This material prevents the normal electrical power from being redirected to the ground. However when a lightning strikes it has very high current, and only this high current can cross the region of high resistance, thus diverting the strike away.

**Earth Switch**
It is a switch which connects a conductor to the earth so as to discharge the charges on the conductor to the earth. Earthing switches are generally installed on the frames of the isolators.

**Metering and Indicating Instruments**
There are several metering and indicating instruments (e.g. ammeters, voltmeters, energy meters etc.) installed in a substation to maintain watch over the circuit quantities. The instrument transformers are invariably used with them for satisfactory operation.

**Relay**
It is an automatic device, which closes its contacts when the actuating quantity/quantities reach a certain predetermined magnitude/phase.

**Reactors**
The main function of a reactor is to limit short circuit current or starting current.

**Neutral Grounding Resistor**
It is used to limit the earth fault current.

**Line trap**
It is used to prevent high frequency signals from entering other zones.

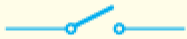
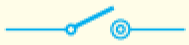
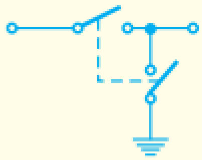
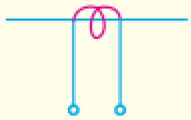
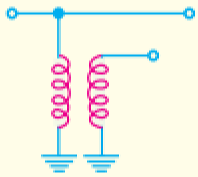
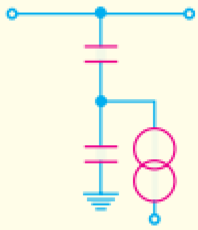
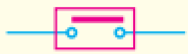
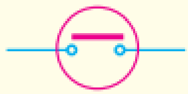
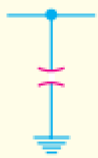
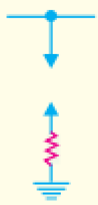
**Capacitor Bank**
It is used to improve the power factor of the system.

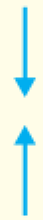
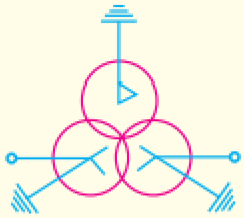
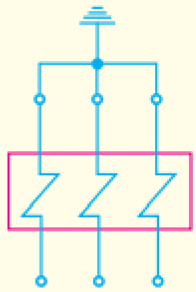
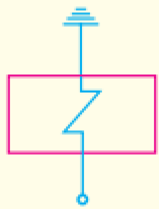
**Power Line Carrier Communication (PLCC)**
It is used for the communication purpose between various substations using power line.

**Structure**
Galvanized steel structures are made of bolted/welded structures of angles/channels/pipes. These are used for towers gantries equipment support structures. Galvanized structures provide rigid support to the various equipment and insulators. The design should be safe and economical. Compensating substations are installed at an interval of 300km along EHV – AC lines for feeding reactive power VAR to line.

## Symbols used for substation equipments

Symbols of important equipment in substation are given below :

| S.No. | Circuit element | Symbol |
|---|---|---|
| 1 | Bus-bar |  |
| 2 | Single-break isolating switch |  |
| 3 | Double-break isolating switch |  |
| 4 | On load isolating switch |  |
| 5 | Isolating switch with earth Blade |  |
| 6 | Current transformer |  |
| 7 | Potential transformer |  |
| 8 | Capacitive voltage transformer |  |
| 9 | Oil circuit breaker |  |
| 10 | Air circuit breaker with overcurrent tripping device |  |
| 11 | Air blast circuit breaker |  |
| 12 | Lightning arrester (active gap) |  |
| 13 | Lightning arrester (valve type) |  |

| S.No. | Circuit element | Symbol |
|---|---|---|
| 14 | Arcing horn |  |
| 15 | 3-ϕ Power transformer |  |
| 16 | Overcurrent relay |  |
| 17 | Earth fault relay |  |

## Bus-Bar Arrangements in Substations

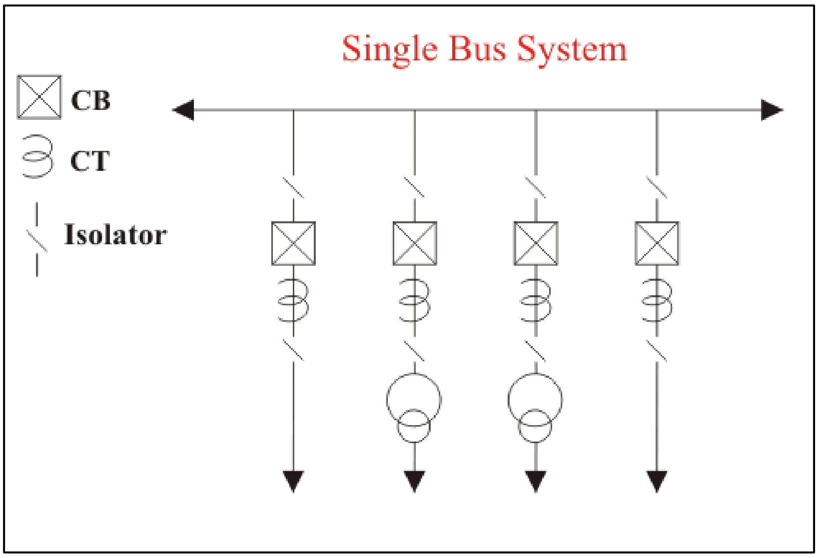
Bus-bars are the important components in a substation. There are several bus-bar arrangements that can be used in a substation. The choice of a particular arrangement depends upon various factors such as system voltage, position of substation, degree of reliability, cost etc. The following are the important bus-bar arrangements used in substations :
The main criterias to be considered during selection of one particular bus – bar arrangement scheme

1. Simplicity of system.
2. Easy maintenance of different equipments.
3. Minimizing the outage during maintenance.
4. Future provision of extension with growth of demand.
5. Optimizing the selection of bus bar arrangement scheme so that it gives maximum return from the system.

Some very commonly used bus bar arrangement are discussed below-

**1. Single Bus System**

Single Bus System is simplest and cheapest one. In this scheme all the feeders and transformer bay are connected to only one single bus as shown.




**Advantages of Single Bus System**

1. This is very simple in design.
2. This is very cost-effective scheme.
3. This is very convenient to operate.

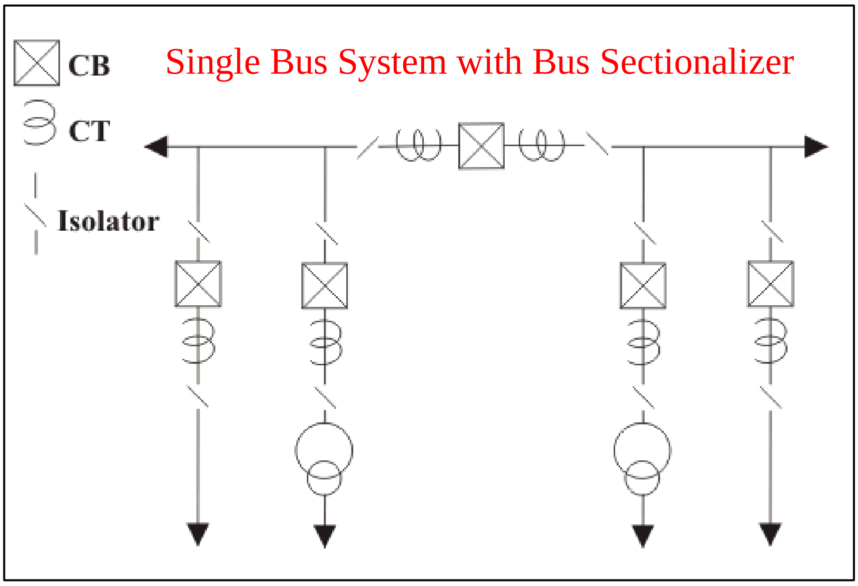
**Disadvantages of Single Bus System**

One but major difficulty of these type of arrangement is that, maintenance of equipment of any bay cannot be possible without interrupting the feeder or transformer connected to that bay.

The indoor 11 KV switch boards have quite often single bus bar arrangement.

2. **Single Bus System with Bus Sectionalizer**

Some advantages are realized if a single bus bar is sectionalized with circuit breaker. If there are more than one incoming and the incoming sources and outgoing feeders are evenly distributed on the sections as shown in the figure, interruption of a system can be reduced to a reasonable extent.




**Advantages of Single Bus System with Bus Sectionalizer**

If any of the sources is out of the system, still all loads can be fed by switching on the sectional circuit breaker or bus coupler breaker. If one section of the bus bar system is under maintenance, a part load of the substation can be fed by energizing the other section of the bus bar.

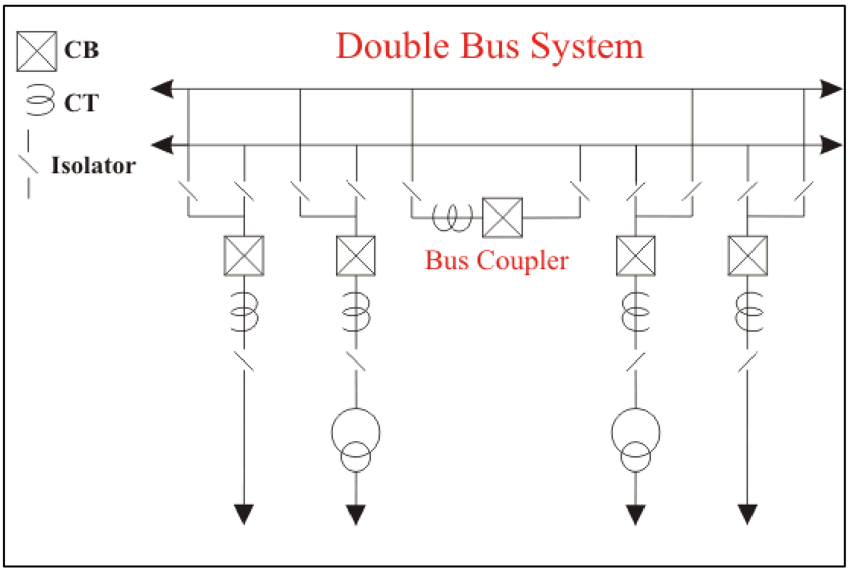
**Disadvantages of Single Bus System with Bus Sectionalizer**

1. As in the case of a single bus system, maintenance of equipment of any bay cannot be possible without interrupting the feeder or transformer connected to that bay.
2. The use of isolator for bus sectionalizing does not fulfill the purpose. The isolators have to be operated 'off circuit' and which is not possible without total interruption of bus-bar. So, investment for bus-coupler breaker is required.

3. **Double Bus System**

In double bus bar system two identical bus bars are used in such a way that any outgoing or incoming feeder can be taken from any of the bus.
Actually every feeder is connected to both of the buses in parallel through individual isolator as shown in the figure.

By closing any of the isolators, one can put the feeder to the associated bus. Both of the buses are energized, and total feeders are divided into two groups, one group is fed from one bus and other from other buses. But any feeder at any time can be transferred from one bus to other. There is one bus coupler breaker which should be kept close during bus transfer operation. For transfer operation, one should first close the bus coupler circuit breaker then close the isolator associated with the bus to where the feeder would be transferred and then open the isolator associated with the bus from where the feeder is transferred. Lastly, after this transfer operation, he or she should open the bus coupler breaker.



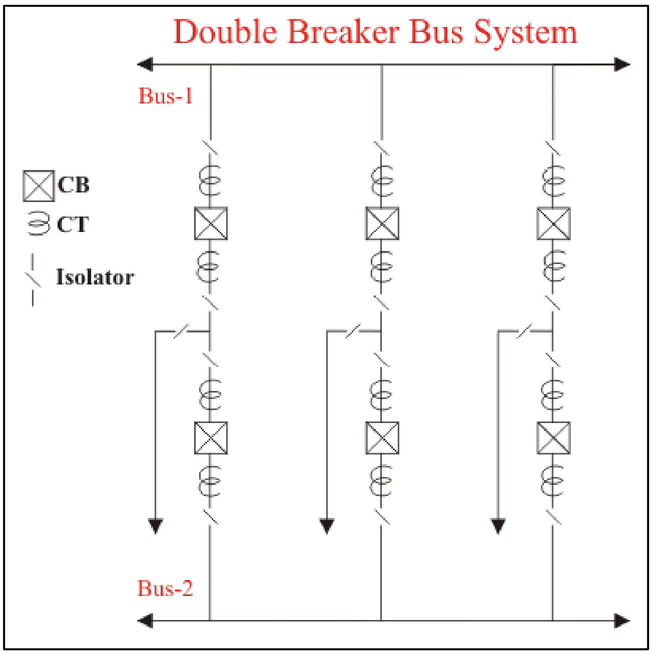

**Advantages of Double Bus System**

Double Bus Bar Arrangement increases the flexibility of system.

**Disadvantages of Double Bus System**

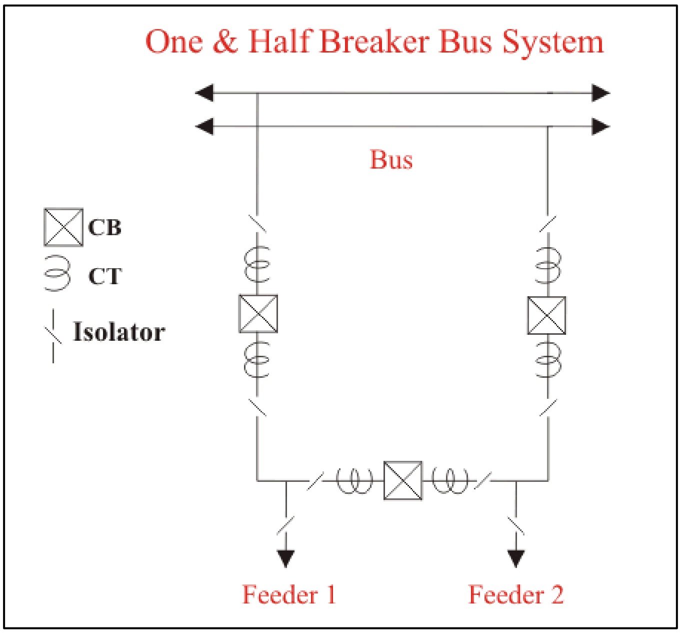
The arrangement does not permit breaker maintenance without interruption.

### 4. Double Breaker Bus System




In double breaker bus bar system two identical bus bars are used in such a way that any outgoing or incoming feeder can be taken from any of the bus similar to double bus bar system. The only difference is that here every feeder is connected to both of the buses in parallel through individual breaker instead only isolator as shown in the figure. By closing any of the breakers and its associated isolators one can put the feeder to respective bus. Both of the buses are energized, and total feeders are divided into two groups, one group is fed from one bus and other from other buses similar to the previous case. But any feeder at any time can be transferred from one bus to other. There is no need for bus coupler as because the operation is done by breakers instead of isolators. For transfer operation, one should first close the isolators and then the breaker associated with the bus to where the feeder would be transferred, and then he or she opens the breaker and then isolators associated with the bus from where the feeder is transferred.

5. **One and A Half Breaker Bus System**



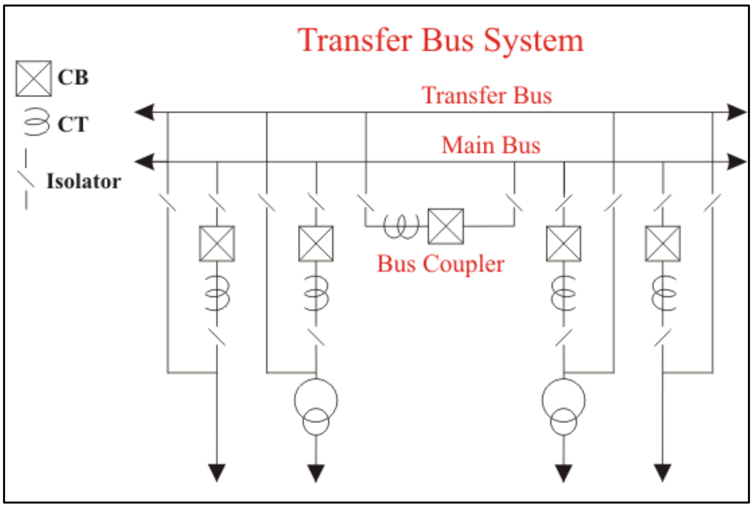

This is an improvement on the double breaker scheme to effect saving in the number of circuit breakers. For every two circuits, only one spare breaker is provided. The protection is however complicated since it must associate the central breaker with the feeder whose own breaker is taken out for maintenance. For the reasons given under double breaker scheme and because of the prohibitory costs of equipment, even this scheme is not much popular. As shown in the figure that it is a simple design, two feeders are fed from two different buses through their associated breakers, and these two feeders are coupled by a third breaker which is called tiebreaker. Normally all the three breakers are closed, and power is fed to both the circuits from two buses which are operated in parallel. The tiebreaker acts as a coupler for the two feeder circuits. During the failure of any feeder breaker, the power is fed through the breaker of the second feeder and tiebreaker, therefore each feeder breaker has to be rated to feed both the feeders, coupled by the tiebreaker.

**Advantages of One and A Half Breaker Bus System**
During any fault on any one of the buses, that faulty bus will be cleared instantly without interrupting any feeders in the system since all feeders will continue to feed from other healthy bus.

**Disadvantages of One and a Half Breaker Bus System**
This scheme is much expensive due to investment for third breaker.

6. **Main and Transfer Bus System**

This is an alternative of a double bus system. The main conception of Main and Transfer Bus System is, here every feeder line is directly connected through an isolator to a second bus called transfer bus. The said isolator in between transfer bus and feeder line is generally called bypass isolator. The main bus is as usual connected to each feeder through a bay consists of the circuit breaker and associated isolators at both sides of the breaker. There is one bus coupler bay which couples transfer bus and main bus through a circuit breaker and associated isolators at both sides of the breaker. If necessary, the transfer bus can be energized by main bus power by closing the transfer bus coupler isolators and then breaker. Then the power in transfer bus can directly be fed to the feeder line by closing the bypass isolator. If the main circuit breaker associated with the feeder is switched off or isolated from the system, the feeder can still be fed in this way by transferring it to transfer bus.

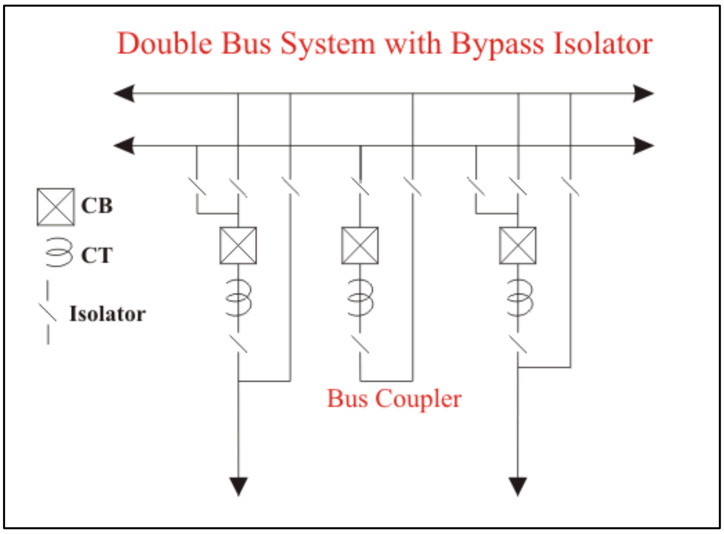



**Switching Operation for Transferring a Feeder to Transfer Bus from Main Bus without Interruption of Power**

1. First close the isolators at both side of the bus coupler breaker.
2. Then close the bypass isolator of the feeder which is to be transferred to transfer bus.
3. Now energized the transfer bus by closing the bus coupler circuit breaker from remote.
4. After bus coupler breaker is closed, now the power from the main bus flows to the feeder line through its main
5. breaker as well as bus coupler breaker via transfer bus.

6. Now if the main breaker of the feeder is switched off, total power flow will instantaneously shift to the bus coupler breaker, and hence this breaker will serve the purpose of protection for the feeder.
7. At last, the operating personnel open the isolators at both sides of the main circuit breaker to make it isolated from rest of the live system.

So, it can be concluded that in Main and Transfer Bus System the maintenance of circuit breaker is possible without any interruption of power. Because of this advantage, the scheme is very popular for 33 KV and 13 KV system.

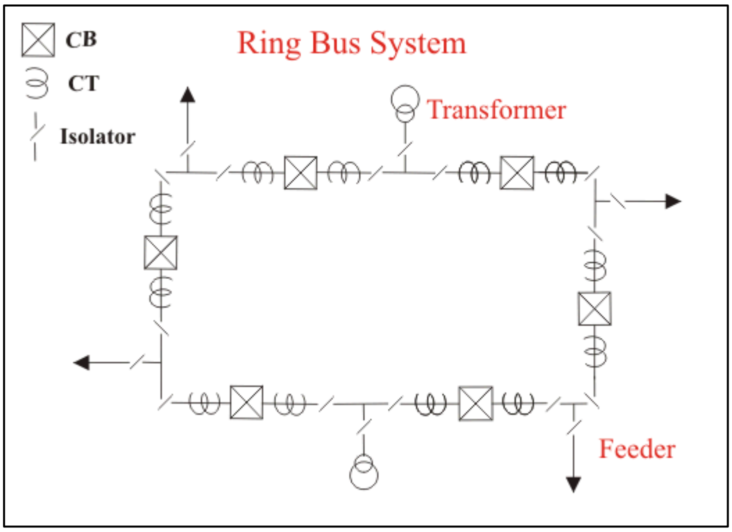



**8. Double Bus System with Bypass Isolators**

This is a combination of the double bus system and main bus and transfer bus system. In Double Bus System with Bypass Isolators either bus can act as main bus and second bus as transfer bus. It permits breaker maintenance without interruption of power which is not possible in a double bus system, but it provides all the advantages of the double bus system. It, however, requires one additional isolator (bypass isolator) for each feeder circuit and introduces slight complication in system layout. Still, this scheme is best for an optimum economy of the system, and it is the best excellent choice for 220 KV system.

**9. Ring Bus System**

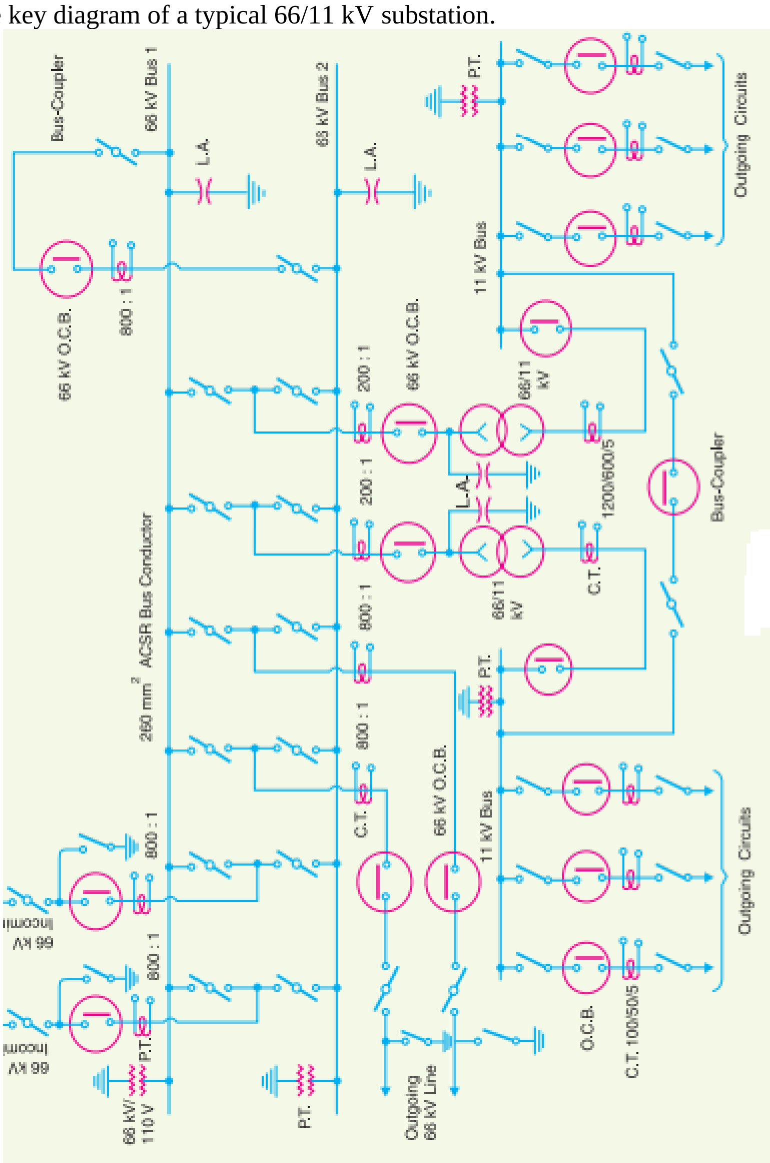
The schematic diagram of the system is given in the figure. It provides a double feed to each feeder circuit, opening one breaker under maintenance or otherwise does not affect supply to any feeder. But this system has two major disadvantages. One as it is a closed circuit system it is next to impossible to extend in future and hence it is unsuitable for developing systems. Secondly, during maintenance or any other reason, if any one of the circuit breaker in ring loop is switched off, the reliability of system becomes very poor as because closed loop becomes opened. Since at that moment for any tripping of any breaker in the open loop causes interruption in all the feeders between the tripped




# Key Diagram of 66/11 kV Substation

**Key Diagram of 66/11 kV Substation**

Fig. below shows the key diagram of a typical 66/11 kV substation.




The key diagram of this substation can be explained as under :

(i) There are two 66 kV incoming lines marked 'incoming 1' and 'incoming 2' connected to the bus-bars. Such an arrangement of two incoming lines is called a double circuit. Each incoming line is capable of supplying the rated substation load. Both these lines can be loaded simultaneously to share the substation load or any one line can be called upon to meet the entire load. The double circuit arrangement increases the reliability of the system. In case there is a breakdown of one incoming line, the continuity of supply can be maintained by the other line.

(ii) The substation has duplicate bus-bar system; one 'main bus-bar' and the other spare busbar. The incoming lines can be connected to either bus-bar with the help of a bus-coupler which consists of a circuit breaker and isolators. The advantage of double bus-bar system is that if repair is to be carried on one bus-bar, the supply need not be interrupted as the entire load can be transferred to the other bus.

(iii) There is an arrangement in the substation by which the same 66 kV double circuit supply is going out i.e. 66 kV double circuit supply is passing through the substation. The outgoing 66 kV double circuit line can be made to act as incoming line.

(iv) There is also an arrangement to step down the incoming 66 kV supply to 11 kV by two units of 3-phase transformers; each transformer supplying to a separate bus-bar. Generally, one transformer supplies the entire substation load while the other transformer acts as a standby unit. If need arises, both the transformers can be called upon to share the substation load. The 11 kV outgoing lines feed to the distribution substations located near consumers localities.

(v) Both incoming and outgoing lines are connected through circuit breakers having isolators on their either end. Whenever repair is to be carried over the line towers, the line is first switched off and then earthed.

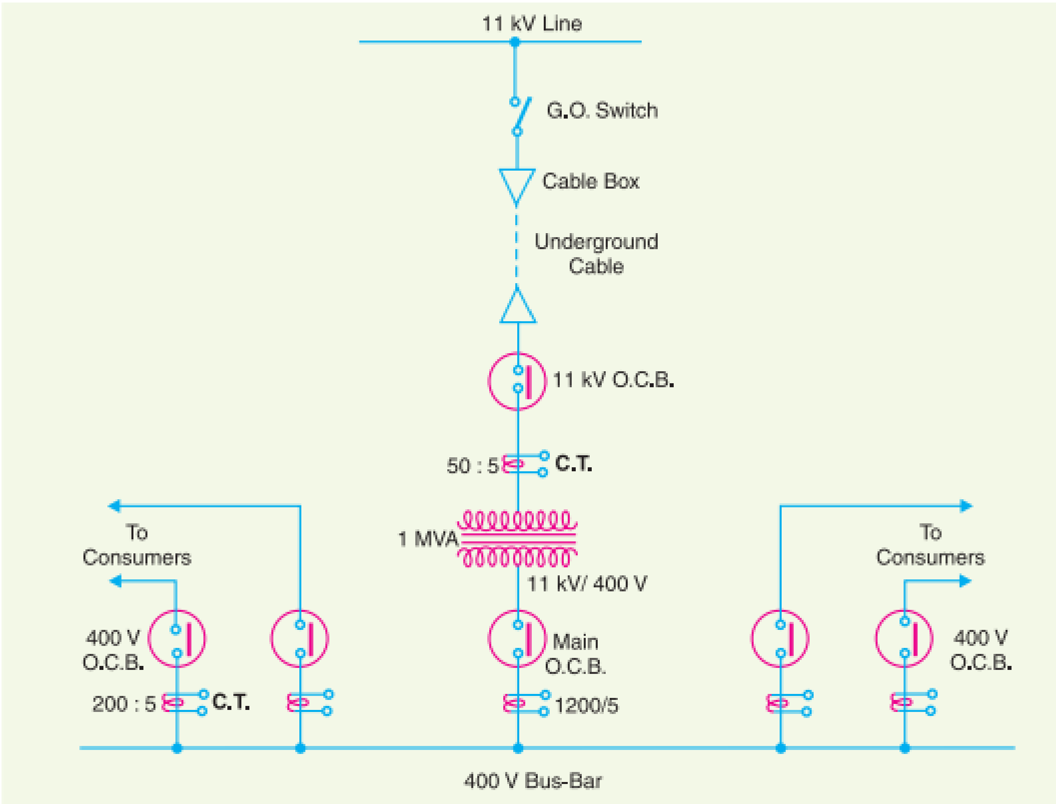
(vi) The potential transformers (P.T.) and current transformers (C.T.) and suitably located for supply to metering and indicating instruments and relay circuits (not shown in the figure). The P.T. is connected right on the point where the line is terminated. The CTs are connected at the terminals of each circuit breaker.

(vii) The lightning arresters are connected near the transformer terminals (on H.T. side) to protect them from lightning strokes.

(viii) There are other auxiliary components in the substation such as capacitor bank for power factor improvement, earth connections, local supply connections, d.c. supply connections etc. However, these have been omitted in the key diagram for the sake of simplicity.

**Key Diagram of 11 Key Diagram of 11 kV/400 V Indoor Substation**

Fig. below shows the key diagram of a typical 11 kV/400 V indoor substation.




The key diagram of this substation can be explained as under :

(i) The 3-phase, 3-wire 11 kV line is tapped and brought to the gang operating switch installed near the substation. The G.O. switch consists of isolators connected in each phase of the 3- phase line.

(ii) From the G.O. switch, the 11 kV line is brought to the indoor substation as underground cable. It is fed to the H.T. side of the transformer (11 kV/400 V) via the 11 kV O.C.B. The transformer steps down the voltage to 400 V, 3-phase, 4-wire.

(iii) The secondary of transformer supplies to the bus-bars via the main O.C.B. From the busbars, 400 V, 3-phase, 4-wire supply is given to the various consumers via 400 V O.C.B. The voltage between any two phases is 400 V and between any phase and neutral it is 230 V. The single phase residential load is connected between any one phase and neutral whereas 3- phase, 400 V motor load is connected across 3-phase lines directly.

(iv) The CTs are located at suitable places in the substation circuit and supply for the metering and indicating instruments and relay circuits.