UNIT - III
Air Insulated Substations (AIS)

SUBSTATION:

The assembly of apparatus used to change some characteristics (e.g. voltage, ac. to dc. frequency, p.f. etc.) of electric supply is called a Substation. Sub-stations are an important part of the power system. The continuity of supply depends to a considerable extent upon the successful operation of sub-stations. It is, therefore, essential to exercise utmost care while designing and building a sub-station. The following are the important points which must be kept in view while laying out a sub-station :

- It should be located at a proper site. As far as possible, it should be located at the centre of gravity of load. 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 It should be easily operated and maintained.
- It should involve minimum capital cost.

CLASSIFICATION OF SUBSTATION:

There are several ways of classifying sub-stations. However, the two most important ways of classifying them are according to

- **Service requirement and**
- **Constructional features.**

1. According to service requirement: A sub-station 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, sub-stations may be classified into:

(i) **Transformer sub-stations:** Those sub-stations which change the voltage level of electric supply are called transformer sub-stations. These sub-stations receive power at some voltage and deliver it at some other voltage. Obviously, transformer will be the main component in such sub Most of the sub-stations in the power system are of this type.

(ii) **Switching sub-stations:** These sub-stations 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 sub-stations: Those sub-stations which improve the power factor of the system are called power factor correction sub-stations. Such sub-stations are generally located at the receiving end of transmission lines. These sub-stations generally use synchronous condensers as the power factor improvement equipment.

(iv) Frequency changer sub-stations: Those sub-stations which change the supply frequency are known as frequency changer sub-stations. Such a frequency change may be required for industrial utilization.

(v) Converting sub-stations: Those sub-stations which change A.C. power into D.C. power are called converting sub-stations. These sub-stations receive ac. 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 sub-stations: Those sub-stations which supply power to individual industrial concerns are known as industrial sub-stations.

2. According to constructional features:
A sub-station 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 sub-stations are classified as :

- Indoor sub-station
- Outdoor sub-station
- Underground sub-station
- Pole-mounted sub-station

1. Indoor sub-stations:

For voltages upto 11 kV, the equipment of the sub-station is installed indoor because of economic considerations. However, when the atmosphere is contaminated with impurities, these sub-stations can be erected for voltages upto 66 kV.

2. Outdoor sub-stations:

For voltages beyond 66 kV, equipment is invariably installed out. 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.

3. Underground sub-stations:

In thickly populated areas, the space available for equipment and building is limited and the cost of land is high. Under such situations, the sub-station is created The reader may find further discussion on underground sub-stations.

4. **Pole-mounted sub-stations:**

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

Comparison between Outdoor and Indoor SubStation:

The comparison between outdoor and indoor sub-stations is given below in the tabular form:

S.No.	Particular	Outdoor Sub-station	Indoor Sub-station
1	Space required	More	Less
2	Time required for erection	Less	More
3	Future extension	Easy	Difficult
4	Fault location	Easier beacuse the equipment is in full view	Difficult because the equipment is enclosed
5	Capital cost	Low	High
6	Operation	Difficult	Easier
7	Possibility of fault escalation	Less because greater clearances can be provided	More

From the above comparison, it is clear that each type has its own advantages and disadvantages. However, comparative economics (i.e. annual cost of operation) is the most powerful factor influencing the choice between indoor and outdoor sub-stations. The greater cost of indoor sub-station prohibits its use. But sometimes non-economic factors (e.g. public safety) exert considerable influence in choosing indoor sub-station. In general, most of the sub-stations are of outdoor type and the indoor sub-stations are erected only where outdoor construction is impracticable or prohibited by the local laws.

Air Insulated Substation (AIS)

The AIS uses air as the primary dielectric from phase to phase, and phase to ground insulation. They have been in use for years before the introduction of GIS.

Actually, most substations across all regions are AIS. They are in extensive use in areas where space, weather conditions, seismic occurrences, and environmental concerns are not an issue such as rural areas, and favourable offsite terrain.
The indoor AIS version is only used in highly polluted areas, and saline conditions, as the air quality is compromised.

Advantages

1. The primary choice for areas with extensive space
2. With quality design, the system is viable due to the low construction costs and cost of switchgear
3. Less construction time, thereby more suited for expedited installations
4. Easy maintenance as all the equipment is within view. It is easy to notice and attend to faults.

Disadvantages

1. More space is required compared to GIS
2. Vulnerable to faults since the equipment are exposed to the external elements such as human intrusion, pollution, deposition of saline particles, lightning strikes and extreme weather conditions
3. More maintenance requirements, thus leading to high costs
4. The poor dielectric properties of air, as well as secondary factors such as humidity, pollutants, moisture means that more space is required for efficiency.

SUBSTATION LAYOUT

- **Description**

An Air Insulated Switchgear substation (AIS substation) uses atmospheric air as the phase to ground insulation for the switchgear of an electrical substation. The main advantage of the AIS substation is the scope of the substation for future offloading, for this reason AIS substations tend to be the most popular 400kV substation type. The equipment of an AIS substation is easily sourced and has a short lead-time; this means that the required future offloading does not need to be built immediately, unlike GIS where it must be considered. The main disadvantage to the AIS substation is its overall size. At 400kV level these substations can have a significant footprint and require sensitive locating in any rural environment. AIS are usually installed outdoor.

AIS Substation Size

Based on the single line diagrams given in Appendix B the minimum size of an AIS substation for this project would be as follows:

1. Overall substation Compound Size 46,864.5m2(235.5m x 199m or approximately 11.6 acres)
2. Height of highest element of substation ~ 28m (lightning protection structures situated in the substation compound)

Note: The switchgear in an AIS substation is outdoors therefore no building sizes are considered.

AIS Maintenance Requirements

1. Ongoing maintenance requirements, all equipment exposed to weather conditions
2. Disconnect contacts must be cleaned regularly, operating mechanisms must be checked and maintained

INDOOR AND OUTDOOR SUBSTATIONS

INDOOR SUBSTATIONS:

In these substations, the apparatus is installed within the substation building. Such substations are usually for a voltage up to 11,000 V but can be erected for 33,000 V and 66,000 volts when the surrounding atmosphere is contaminated with impurities such as metal corroding gases and fumes, conductive dust etc. The switchgear on supply or primary side will consist of oil circuit breakers only.

The high voltage supply is given to the primary of the transformer through circuit breaker. From the bus-bar various feeders emerge out. The panel for each feeder consists of an isolator switch and circuit breaker. In addition to isolator and circuit breaker, the panel is provided with the measuring instruments. As regards protection of feeders usually reverse power relay is employed. For the protection of oil filled transformers with conservator tanks Buchholz's relay is most common.

The auxiliaries of the indoor type of substations are:

(i) Storage batteries,

(ii) Fire-fighting equipment such as water buckets, fire extinguishers, etc.

The batteries are used for the:

(i) Operation of the protective gear and switch operating solenoids, and

(ii) Emergency lighting in substations in case of failure of supply.

The several compartments in which the indoor substation is divided are control compartment, indicating and metering instruments and protective device compartment, circuit breaker and operating mechanism compartment, main bus-bar compartment and current transformer and cable sealing box compartment.

Indoor distribution and transformer substations as well as high voltage switchboards consist of a series of open and enclosed chambers or compartments. The main equipment of the given installation is arranged in these compartments. The chamber space, within which the equipment of any one main bus-bar connection is mounted, as a whole, is called as a cell, cubicle or compartment.

According to construction indoor distribution transformer substations and high voltage switchboards are further subdivided into the following categories:

1. Substations of the Integrally Built Type:

It is that in which the apparatus is installed on site. In such substations the cell structures are constructed of concrete or bricks.

2. Substations of the Composite Built-Up Type:

It is that type in which the assemblies and parts are factory or workshop prefabricated, but is assembled on site within a substation switchgear room. The compartments of such substations take form of metal cabinets or enclosures, each of which contains the equipment of one main connection cell. Within such cabinets or enclosures an oil minimum circuit breaker, a load-interrupter switch and one or more voltage transformers may be mounted.

3. Unit Type Factory Fabricated Substations and Metal Clad Switchboards:

These are built in electrical workshops and are shipped to the site of installations fully pre-assembled. After installations of substations and switchboards only connection to the incoming and outgoing power circuits are required to be made. Cubicles for unit type switchboards or substations take the form of fully enclosed metal clad cabinets.

Metal clad cubicles designed with withdrawable trucks and divided into several compartments are usually employed. The several compartments in which the cubicle is divided are control compartment, indicating and metering instrument and protective device compartment, circuit breaker and operating mechanism compartment, main bus-bar compartment and current transformers and cable sealing box compartment.

By partitioning of the cubicle space into compartments safe access to the apparatus is provided. The circuit breaker and its operating mechanism are mounted on the truck, which can be withdrawn from the cubicle. In withdrawable-truck unit-type cubicles the isolating device is of the plug-in-type.

When the truck is rolled out from the cubicle the holes in which the isolating devices enter for making contacts are automatically closed by metal shutters serving to isolate the live parts from possible casual contact. When the truck is rolled back into the cubicle, the shutters open automatically.

To prevent any possible opening or closing of the disconnecting devices when the circuit breaker is closed, these cubicles are designed with interlocks which prevent the truck from being rolled in or withdrawn when the circuit breaker is closed.

OUTDOOR SUBSTATIONS:

Outdoor substations are of two types namely:

1. Pole-mounted substations, and

2. Foundation-mounted substations.

1. Pole-Mounted Substations:

Such substations are erected for mounting distribution transformers of capacity up to 250 kVA. Such substations are the cheapest, simple and smallest of substations. All the equipment is of outdoor type and mounted on the supporting structure of HT distribution line. Triple Pole Mechanically Operated (TPMO) switch is used for switching "on" and "off" of HT transmission lines. HT fuse unit is installed for protection of HTt side.

To control HT side iron clad low tension switch of suitable capacity with fuses is installed. Lightning arresters are installed over the ht line to protect the transformer from the surges. Substation is earthed at two or more places.

Generally a transformer of capacity up to 125 kVA are mounted on a double pole structure and for transformers of capacity above 125 kVA but not exceeding 250 kVA 4-pole structures with suitable platform is used. This type of pole-mounted substation is erected in a very thickly populated location.

The maintenance cost of such substations is low and by using a large number of such substations in a town it is possible to lay the distributors, at a lower cost. But owing to increase in number of transformers, total kVA is increased, no load losses increase and the cost per kVA is thus more. Economy is the main consideration when a choice is made for such substations.

2. Foundation Mounted Substations:

These substations are built entirely in the open and in such substations all the equipment is assembled into one unit usually enclosed by a fence from the point of view of safety. Substations for primary and secondary transmission and for secondary distribution, (above 250 kVA) are foundation mounted outdoor type. Since equipment required for such substations is heavy, therefore, site selected for these substations must have a good access for heavy transport.

Again, owing to exposed bus-bars and other associated equipment the clearances and spacings are not only to be governed by the operating voltage but also from the considerations of the encroachment from outside. Low level types of substations are designed except when the space available is limited as these provide facility of easy inspection, cleaning and maintenance.

The switchgear consists of circuit breakers of suitable type on both the sides but with the increased reliability of the modern transformers, the practice is to dispense with the circuit breaker on the incoming side form the economic consideration. The isolating switches thus serve the purpose.

Advantages and Disadvantages of Outdoor Substations over Indoor Substations:

The outdoor substations have the following main advantages over indoor substations:

(i) All the equipment is within view and therefore fault location is easier.

(ii) The extension of the installation is easier, if required.

(iii) The time required in erection of such substations is lesser.

(iv) The smaller amount of building materials (steel-concrete) is required.

(v) The construction work required is comparatively smaller and cost of the switchgear installation is low.

(vi) 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.

(vii) Repairing work is easy.

The disadvantages of outdoor installations in comparison of indoor installations are:

(i) 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 is required for the substation.

(iii) Protection devices are required to be installed for protection against lightning surges.

(iv) The length of control cables required is more.

(v) 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 and, therefore, more costly.

Notwithstanding the disadvantages, outdoor substations are very widely used in power systems.

COMPONENTS OF SUB-STATIONS:

Besides the transformers, the several other equipment include

- Bus bars
- Circuit Breakers
- Isolators

- Surge Arresters
- Substation Earthing system
- Current Transformers
- Voltage Transformers
- Shunt Reactors
- Shunt Capacitors etc.

Each equipment has certain functional requirement.

BUSBARS

Bus bars are conducting bars to which number of circuit connections is connected. Bus-bars are copper or aluminum bars (generally of rectangular *x*-section) and operate at constant voltage. The incoming and outgoing lines in a sub-station are connected to the bus-bars. The most commonly used bus-bar arrangements in sub-stations are :

(i) Single bus-bar arrangement

(ii) Single bus-bar system with sectionalisation

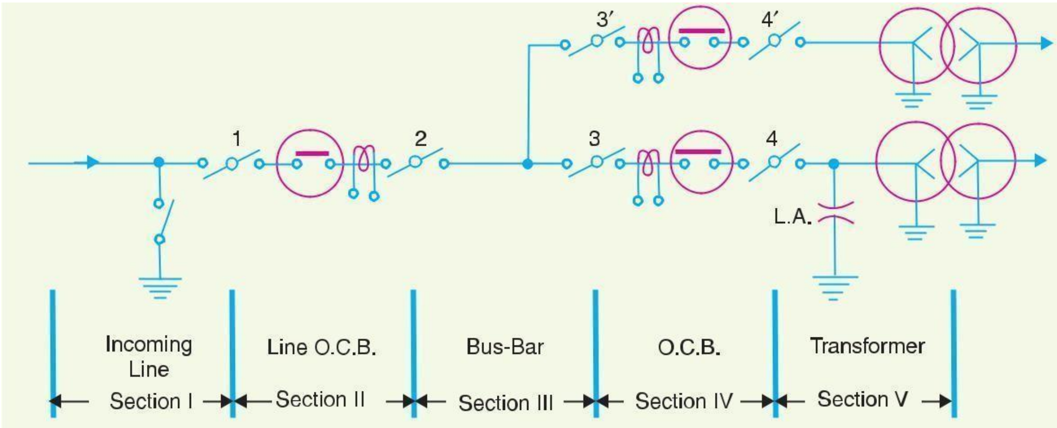
(iii) Double bus-bar arrangement

INSULATORS:

The insulators serve two purposes. They support the conductors (or bus-bars) and confine the current to the conductors. The most commonly used material for the manufacture of insulators is porcelain. There are several types of insulators (*e.g.* pin type, suspension type, post insulator etc.) and their use in the sub-station will depend upon the service requirement. For example, post insulator is used for bus-bars. A post insulator consists of a porcelain body, cast iron cap and flanged cast iron base. The hole in the cap is threaded so that bus-bars can be directly bolted to the cap.

ISOLATING SWITCHES:

In sub-stations, it is often desired to disconnect a part of the system for general maintenance and repairs. This is accomplished by an isolating switch or 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.



The entire sub-station has been divided into V sections. Each section can be disconnected with the help of isolators for repair and maintenance. For instance, if it is desired to repair section No. II, the procedure of disconnecting this section will be as follows. First of all, open the circuit breaker in this section and then open the isolators 1 and 2. This procedure will disconnect section II for repairs. After the repair has been done, close the isolators 1 and 2 first and then the circuit breaker.

CIRCUIT BREAKER:

A circuit breaker is equipment which can open or close a circuit under normal as well as fault conditions. It is so designed that it can be operated manually (or by remote control) under normal conditions and automatically under fault conditions. For the latter operation, a relay circuit is used with a circuit breaker. Generally, bulk oil circuit breakers are used for voltages upto 66kV while for high (>66 kV) voltages, low oil circuit breakers are used. For still higher

POWER TRANSFORMERS:

A power transformer is used in sub-station to step-up or step-down the voltage. Except at the power station, all the subsequent sub-stations use step-down transformers to gradually reduce the voltage of electric supply and finally deliver it at utilisation voltage. The modern practice is to use 3-phase transformers in sub-stations ; although 3 single phase bank of transformers can also be used. The use of 3-phase transformer (instead of 3 single phase bank of transformers) permits two advantages. Firstly, only one 3-phase load-tap changing mechanismcan be used. Secondly, its installation is much simpler than the three single phase transformers. The power transformer is generally installed upon lengths of rails fixed on concrete slabs having foundations 1 to 1·5 m deep. For ratings upto 10 MVA, naturally cooled, oil immersed transformers are used. For higher ratings, the transformers are generally air blast cooled.

INSTRUMENT TRANSFORMERS:

The lines in sub-stations 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 trans-formers* 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.*

(i) Current transformer (C.T.)

(ii) 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 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 con-nected in the line to measure current. If the current in the line is 100 A, then current in the secondary will be 5A. Similarly, if current in the line is 50A, then secondary of C.T. will have a current of 2·5 A. Thus the C.T. under consideration will step down the line current by a factor of 20.

(ii) Voltage transformer:

It 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 provides 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.

Metering and Indicating Instruments:

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

Miscellaneous equipment.

In addition to above, there may be following equipment in a substation:

- Fuses
- carrier-current equipment
- sub-station auxiliary supplies

BUSBAR ARRANGEMENTS IN SUBSTATIONS:

Busbar are the important components in a sub-station. There are several Busbar Arrangements in Substations that can be used in a sub-station. The choice of a particular arrangement depends upon various factors such as system voltage, position of sub-station, degree of reliability, cost etc.

The following are the important bus-bar arrangements used in sub-stations:

(i) Single bus-bar system:

As the name suggests, it consists of a single bus-bar and all the incoming and outgoing lines are connected to it. The chief advantages of this type of arrangement are low initial cost, less maintenance and simple operation. However, the principal disadvantage of single bus-bar system is that if repair is to be done on the bus-bar or a fault occurs on the bus, there is a complete interruption of the supply. This arrangement is not used for voltages exceeding 33kV. The indoor 11kV sub-stations often use single Busbar Arrangements in Substations.

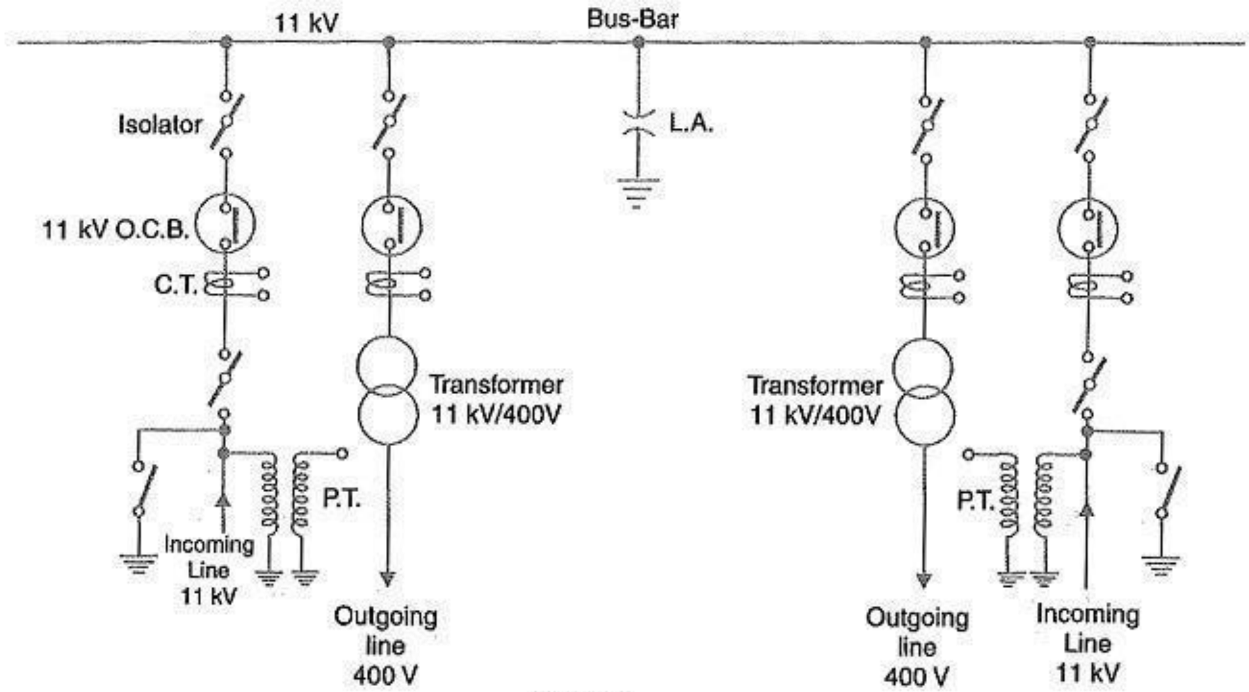


Fig. 25.5

Fig. 25.5 shows single Busbar Arrangements in Substations. There are two 11 kV incoming lines connected to the bus-bar through circuit breakers and isolators. The two 400V outgoing lines are connected to the bus bars through transformers (11kV/400 V) and circuit breakers.

(ii) Single bus-bar system with sectionalisation:

In this arrangement, the single bus-bar is divided into sections and load is equally distributed on all the sections. Any two sections of the bus-bar are connected by a circuit breaker and isolators. Two principal advantages are claimed for this arrangement. Firstly, if a fault occurs on any section of the bus, that section can be isolated without affecting the supply from other sections. Secondly, repairs and maintenance of any section of the bus-bar can be carried out by de-energising that section only, eliminating the possibility of complete shut down. This arrangement is used for voltages upto 33 kV.

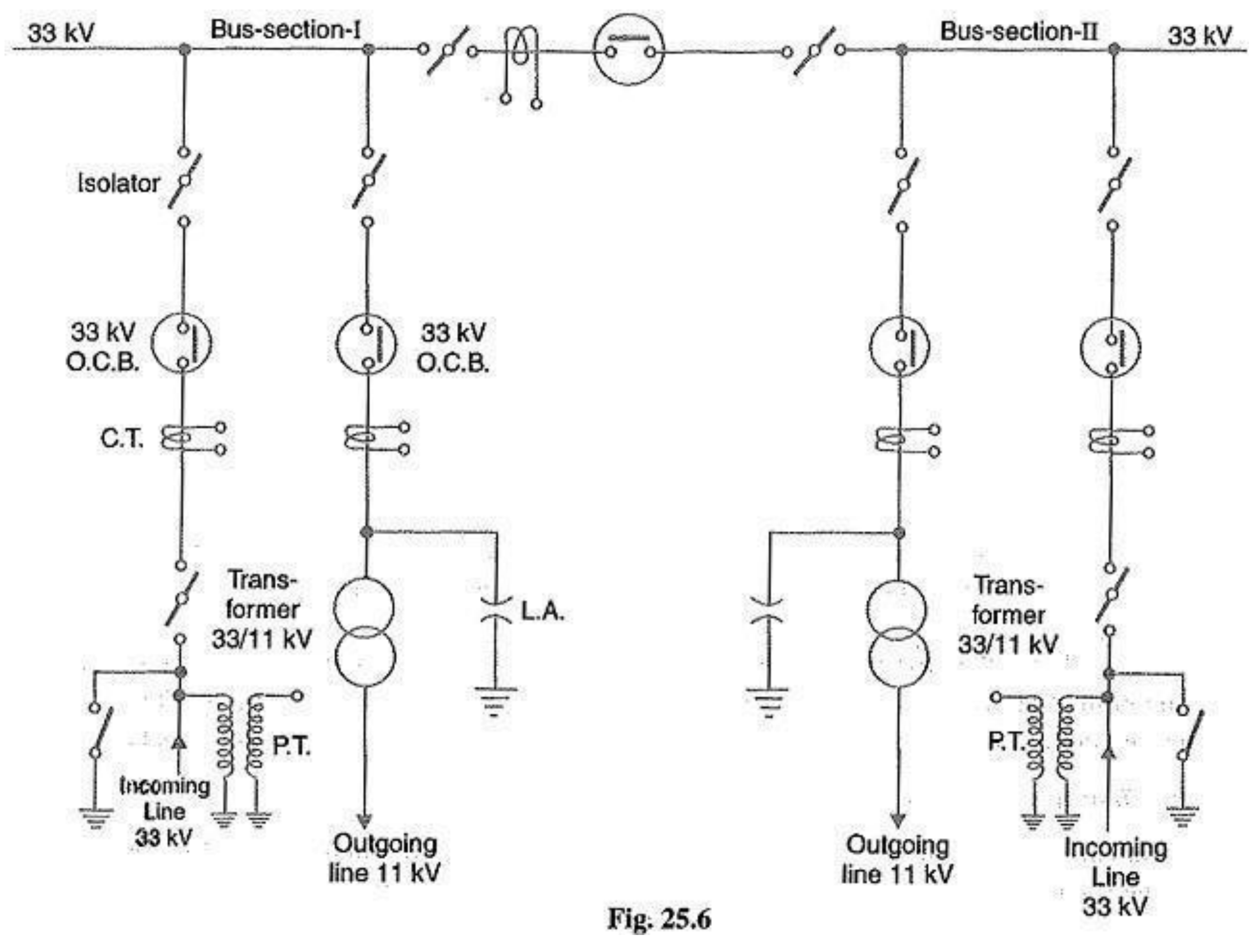


Fig. 25.6

Fig. 25.6 shows bus-bar with sectionalisation where the bus has been divided into two sections. There are two 33 kV incoming lines connected to sections I and II as shown through circuit breaker and isolators. Each 11 kV outgoing line is connected to one section through transformer (33/11 kV) and circuit breaker. It is easy to see that each bus-section behaves as a separate bus-bar.

(iii)Duplicate bus-bar system:

This system consists of two bus-bars, a "main" bus-bar and a "spare" bus-bar. Each bus-bar has the capacity to take up the entire sub-station load. The incoming and outgoing lines can be connected to either bus-bar with the help of a bus-bar coupler which consists of a circuit breaker and isolators. Ordinarily, the incoming and outgoing lines remain connected to the main bus-bar. However, in case of repair of main bus-bar or fault occurring on it, the continuity of supply to the circuit can be maintained by transferring it to the spare bus-bar. For voltages exceeding 33kV, duplicate bus-bar system is frequently used.

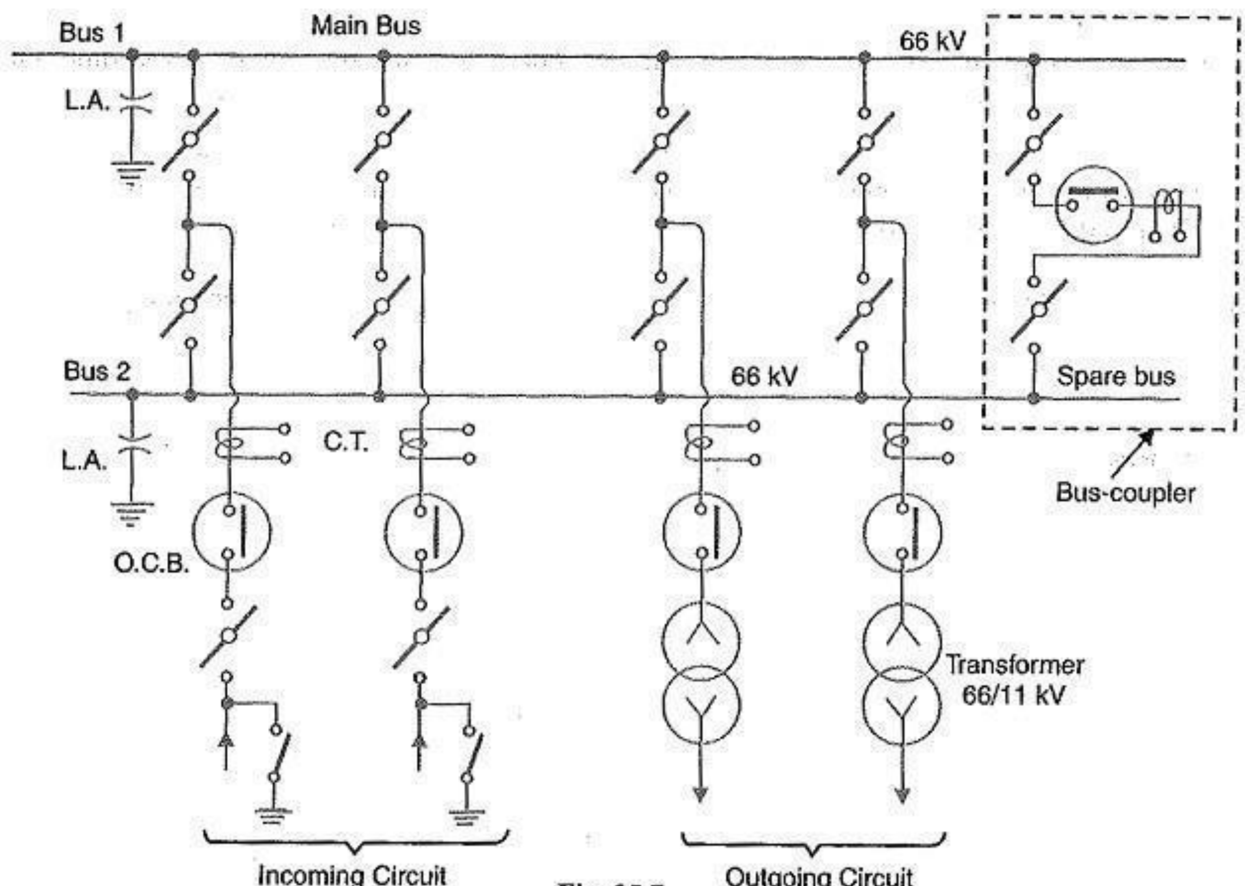


Fig. 25.7

Fig. 25.7 shows the arrangement of duplicate bus-bar system in a typical sub-station. The two 66kV incoming lines can be connected to either bus-bar by a bus-bar coupler. The two 11 kV outgoing lines are connected to the bus-bars through transformers (66/11 kV) and circuit breakers.

TERMINAL AND THROUGH SUBSTATIONS:

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

- **Terminal sub-station**
- **Through sub-station**

TERMINAL SUB-STATION:

A terminal sub-station 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 sub-station. Fig. 25.8 shows the schematic connections of a terminal sub-station. It is clear that incoming 11 kV main line terminates at the sub-station. Most of the distribution sub-stations are of this type.

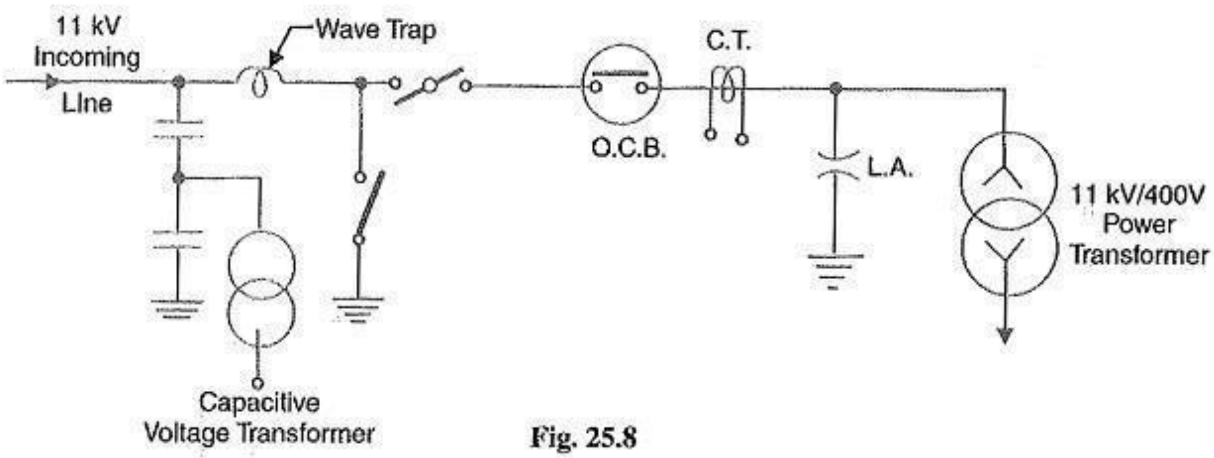


Fig. 25.8

THROUGH SUB-STATION:

A through sub-station 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. 25.9 shows the schematic connections of a through substation. The incoming 66 kV line passes through the sub-station as 66kV outgoing line. At the same time, the incoming line is tapped in the sub-station to reduce the voltage to 11 kV for secondary distribution.

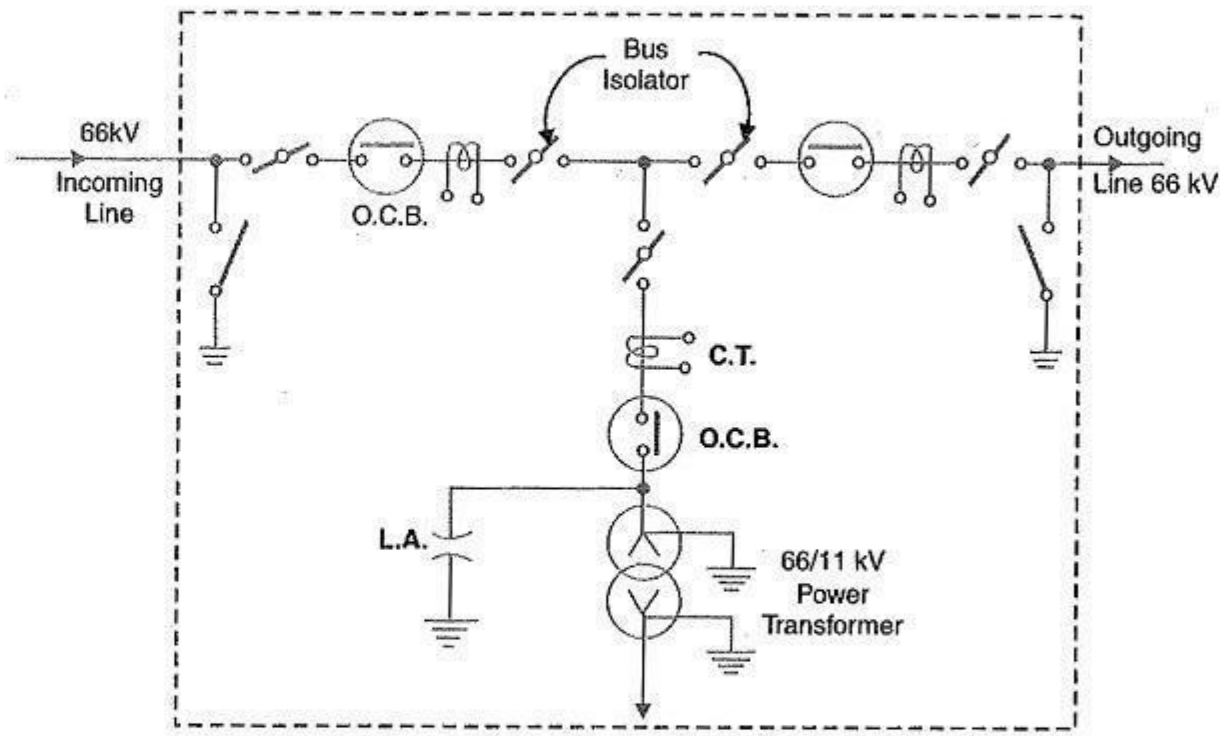


Fig. 25.9

BUS-BAR ARRANGEMENT: (VERSION 2.0)

Different bus-bar arrangements in an electric circuit will be discussed here. All the diagrams refer to 3-phase arrangement but are shown in single phase for simplicity.

Type # 1. Single Bus-Bar Arrangement:

This is the simplest arrangement consisting of a single set of bus-bars for the full length of the switchboard and to this set of bus-bars are connected all the generators, transformers and feeders, as illustrated by single line diagram in Fig. 1.10. Each generator and feeder is controlled by a circuit breaker. The isolators permit isolation of generators, feeders and circuit breakers from the bus-bars for maintenance. The chief advantages of such a bus-bar arrangement are low initial cost, less maintenance and simple operation.

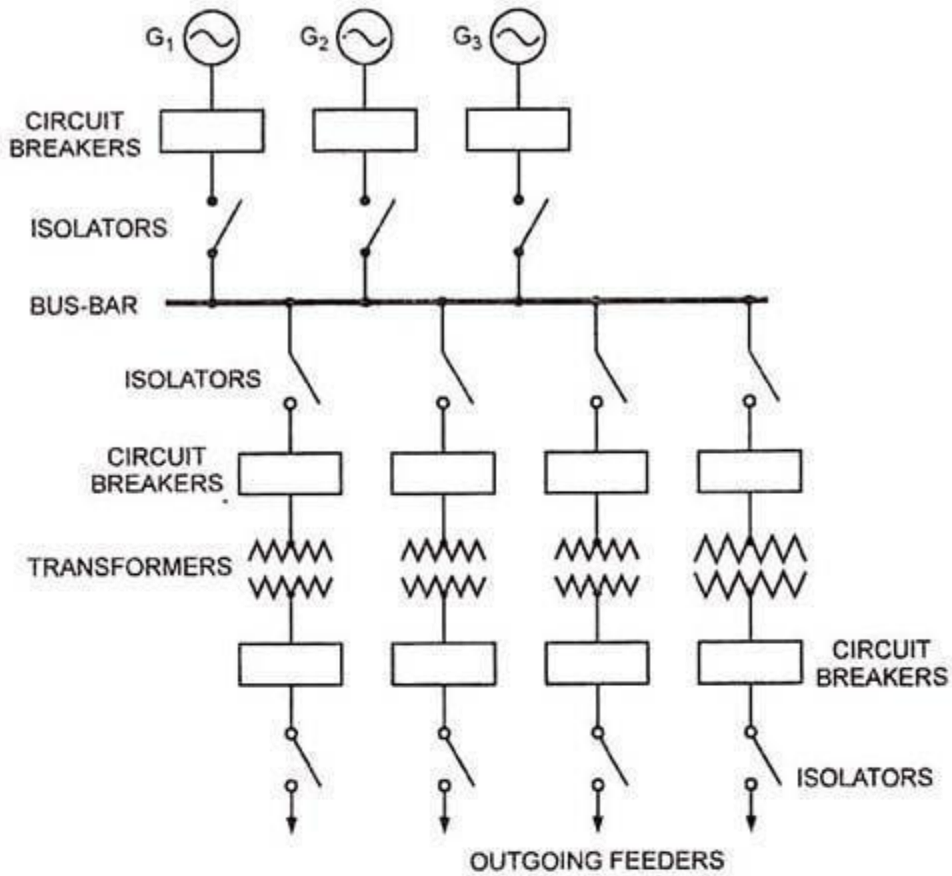


Fig. 1.10. *Single Bus-Bar Arrangement*

The glaring drawback of this system is that in case of fault on the bus-bars, whole of the supply is affected and all the healthy feeders are disconnected. Moreover, when maintenance is to be carried out on any of the feeder sections or on a part of bus-bar the whole supply is to be disrupted. Thus such an arrangement provides least flexibility and immunity from total shutdown.

Such bus-bar arrangement is employed for switchboards, small and medium sized substations, small power stations and dc stations.

Type # 2. Single Bus-Bar Arrangement with Bus Sectionalization:

The bus-bar may be sectionalized by a circuit breaker and isolating switches so that a fault on one part does not cause a complete shutdown. In large generating stations, where several units are installed, it is a common practice to sectionalize the bus as illustrated in Fig. 1.11.

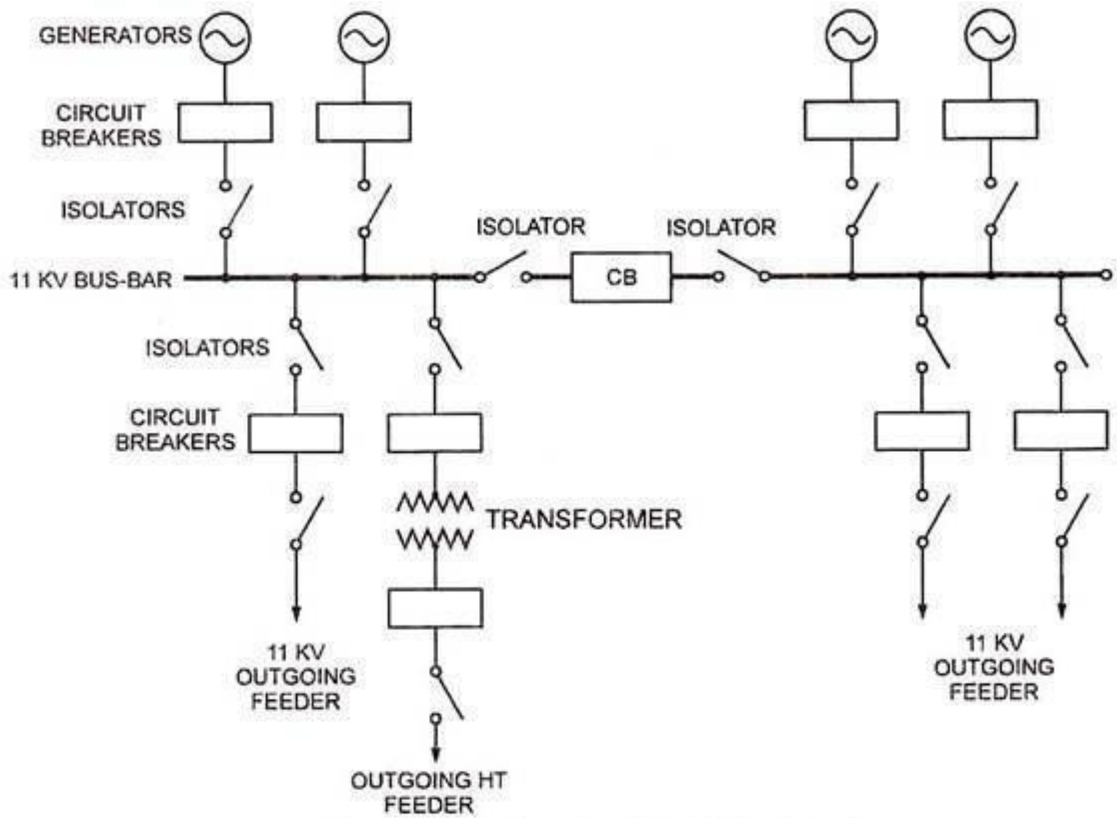


Fig. 1.11. ***Sectionalized Single Bus-Bar System***

Normally the number of sections of a bus-bar are 2 to 3 in a substation, but actually it is limited by the short-circuit current to be handled. In a sectionalized bus-bar arrangement only one additional circuit breaker is required which does not cost much in comparison to the total cost of the bus-bar system.

Such an arrangement provides three main advantages over simple single bus-bar arrangement. Firstly, in the event of occurrence of fault on any section of the bus-bar, the faulty section can be isolated without affecting the supply of other section or sections.

Secondly, one section can be completely shut-down for maintenance and repairs without affecting the supply of the other section (s). Thirdly, by adding a current limiting reactor between the sections the fault level (MVA) can be reduced thereby circuit breakers of lower capacity can be used.

At times air-break isolators were used in place of circuit breakers as bus-sectionalizer due to economy, but it must be remembered that any isolation affected by them must be affected under off-load conditions otherwise it may cause spark. It will be preferable to provide circuit breaker as a sectionalizing switch so that uncoupling of bus-bar may be carried out safely during load transfer. A double isolation is however necessary when the circuit breaker is employed as sectionalizing switch so that the maintenance work can be carried out on circuit breaker while the bus-bars are alive.

Type # 3. Main and Transfer Bus Arrangement:

This arrangement has been quite frequently adopted whore the loads and continuity of supply justify additional costs. This arrangement provides additional flexibility, continuity of supply and allows periodic maintenance without total shutdown. Such an arrangement is suitable for highly interconnected power network in which flexibility is very important.

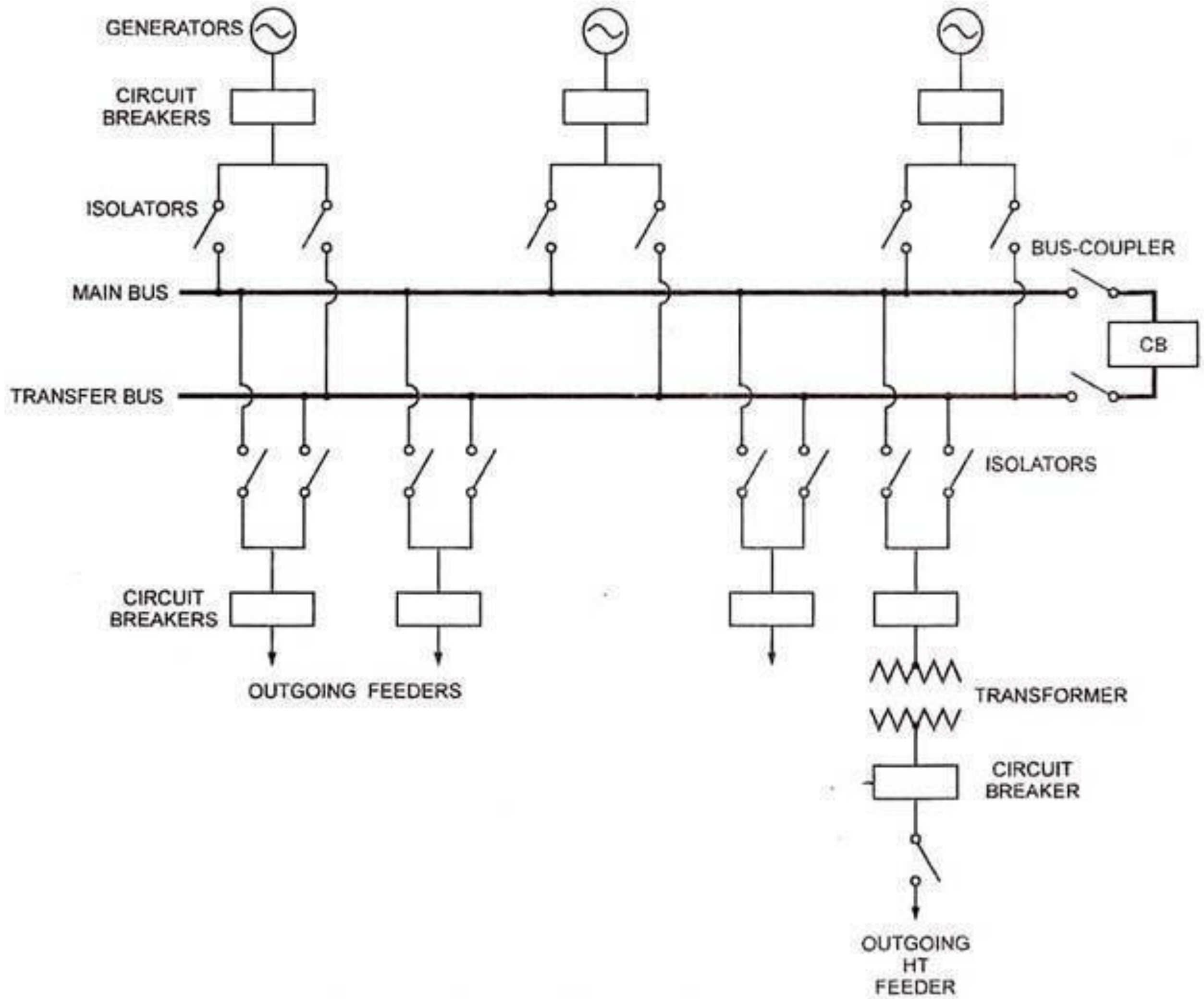


Fig. 1.12. *Main and Transfer Bus Arrangement*

Figure 1.12 illustrates the main and transfer bus arrangement in a generating station. Such an arrangement consists of two bus-bars, known as main bus-bar and transfer bus-bar used as an auxiliary bus-bar. Each generator and feeder may be connected to either bus-bar with the help of bus coupler which consists of a circuit breaker and isolating switches. In this arrangement a bus coupler is usually used so that change-over from one bus-bar to the other can be carried out under load conditions.

While transferring the load to the reserve bus, the following steps may be taken:

1. Close the bus-coupler (circuit breaker) so as to make the two buses at the same potential.
2. Close isolators on the reserve bus.
3. Open isolators on the main bus.

The load is now transferred to the reserve or auxiliary bus and main bus is disconnected.

The advantages and disadvantages of the arrangement are gives below:

Advantages:

1. It ensures continuity of supply in case of bus fault. In the event of occurrence of fault on one of the bus, the entire load can be transferred to the other bus.
2. Repair and maintenance can be carried out on the main bus without interrupting the supply as the entire load can be transferred to the auxiliary bus.
3. Each load can be supplied from either bus.
4. The infeed and load circuit may be divided into two separate groups if required from operational considerations.
5. The testing and maintenance of feeder circuit breakers can be done by putting them on spare bus, thus keeping the main bus undisturbed.
6. The maintenance cost of substation is lowered.
7. The bus potential can be used for relays.

Disadvantages:

1. Additional costs.
2. The bus is maintained or expanded by transferring all of the circuits to the auxiliary bus depending upon the remote backup relays and breakers for removing faults of the circuits. During this condition a line fault on any of the circuits of the bus would shut-down the entire station.

Type # 4. Double Bus Double Breaker Arrangement:

In very important power stations two circuit breakers are employed for each circuit, as illustrated in Fig. 1.13. Such a bus-bar arrangement does not require any bus-coupler and permits switchover from one bus to the other whenever desired, without interruption. This bus arrangement is very costly and its maintenance cost is also high.

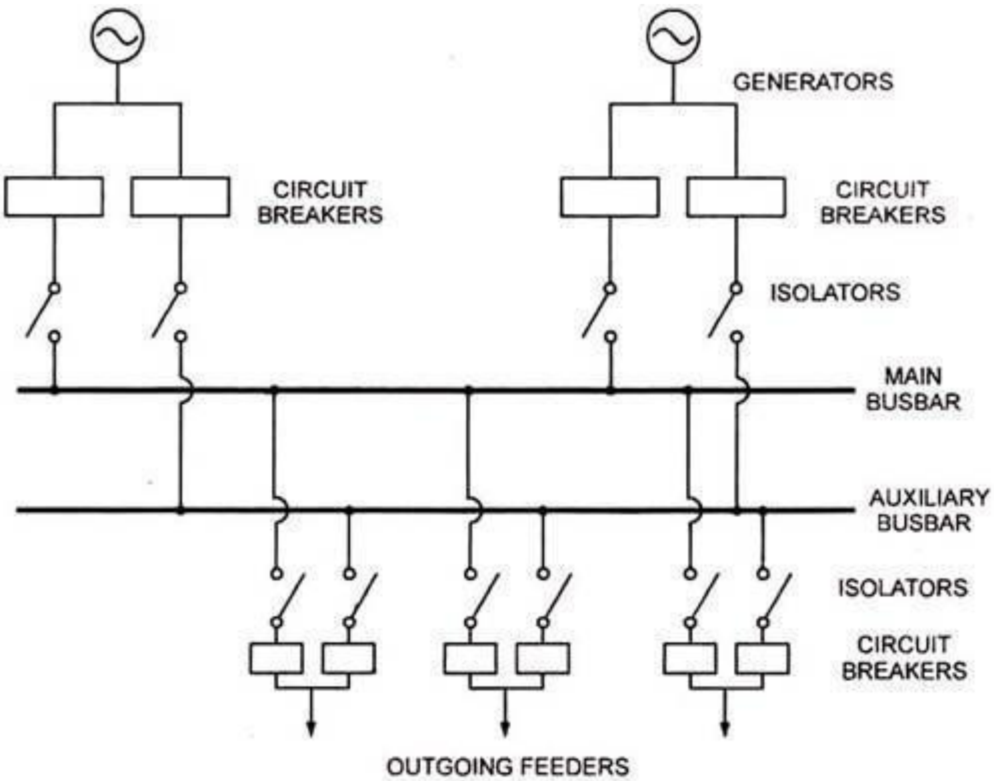


Fig. 1.13. ***Double Bus Double Breaker Arrangement***

This arrangement provides maximum flexibility and reliability as the faults and maintenance interrupt the supply to the minimum. A circuit breaker can be opened for repairs and usual checks and the load can be shifted on the other circuit breaker easily. But because of its higher cost, this arrangement is- seldom used at the substations.

For 400 kV switchyards two main buses plus one transfer bus scheme is preferred. The transfer bus is used for transferring power from main bus 1 to main bus 2 and vice-versa.

Type # 5. Sectionalized Double Bus Arrangement:

In this arrangement duplicate bus-bars are used with the main bus-bar in sections connected through a bus-coupler, as illustrated in Fig. 1.14. In this arrangement, any section of bus-bar can be isolated for maintenance, while any section may be synchronised with any other through the auxiliary bus-bar. Sectionalization of auxiliary bus-bar is not required and would increase the cost if done.

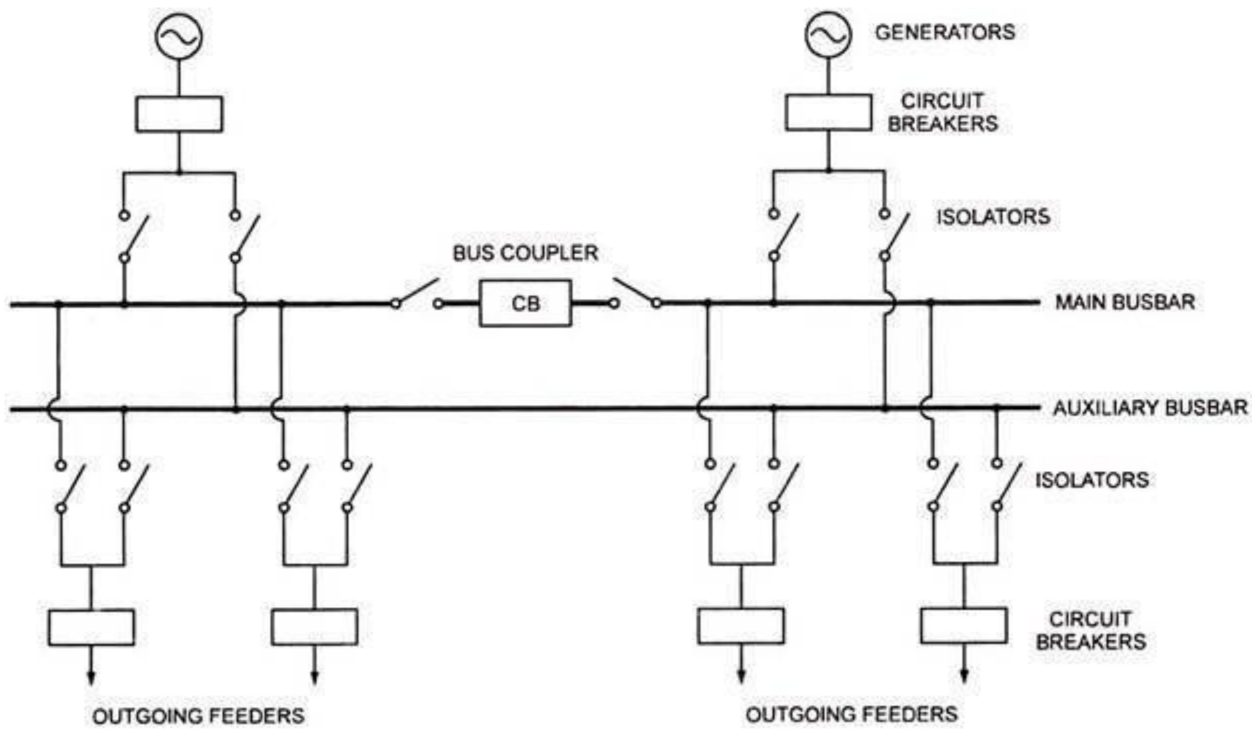


Fig. 1.14. ***Sectionalized Double Bus Arrangement***

Type # 6. One-and a Half Breaker Arrangement:

This is an improvement over double bus double breaker arrangement and it affects saving in the number of circuit breakers. This arrangement needs three circuit breakers for two circuits. The number of circuit breakers per circuit comes out to be 1½ hence the name. This arrangement is preferred in important large stations where power handled per circuit is large.

This arrangement is shown in Fig. 1.15. This arrangement provides high security against loss of supply as a fault in a bus or in a breaker will not interrupt the supply. Possibility of addition of circuits to the system is another advantage. The bus potential can be used as supply to relays, however, at the time of bus fault such potential to the relay should be thrown off.

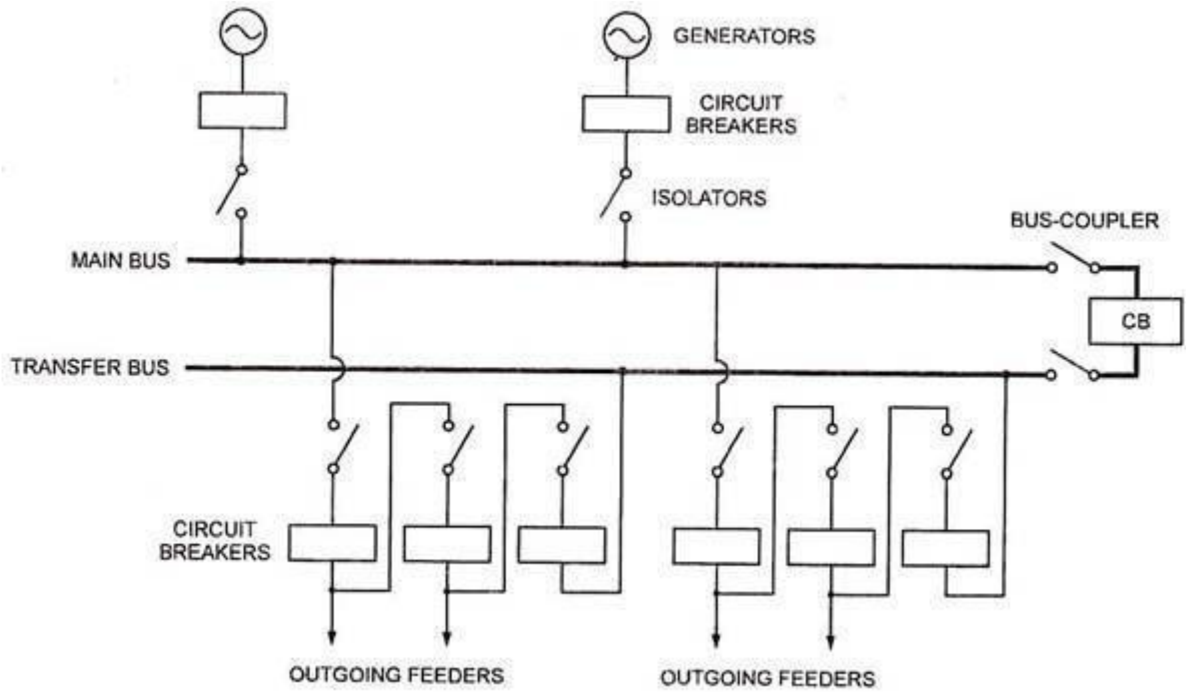


Fig. 1.15. *One-and-a-Half Circuit Breaker Arrangement*

The main drawback of this arrangement is complications in relaying system because at the time of fault two breakers are to be opened. The other drawback is that for maintenance of circuit breakers if the load shedding is not used, two breakers are to be opened in which case the other circuit in the line-up will be operating with one breaker from one bus only. At the time of fault in that bus supply to the other circuit is also interrupted. The maintenance cost is higher.
The above arrangement has been used in important 400 kV and 750 kV substations.

Type # 7. Ring Main Arrangement:

This is an extension of the sectionalized bus-bar arrangement where the ends of the bus-bars are returned upon themselves to form a ring, as illustrated in Fig. 1.16. This arrangement provides greater flexibility as each feeder is supplied by two paths, so that the failure of a section does not cause any interruption of the supply.

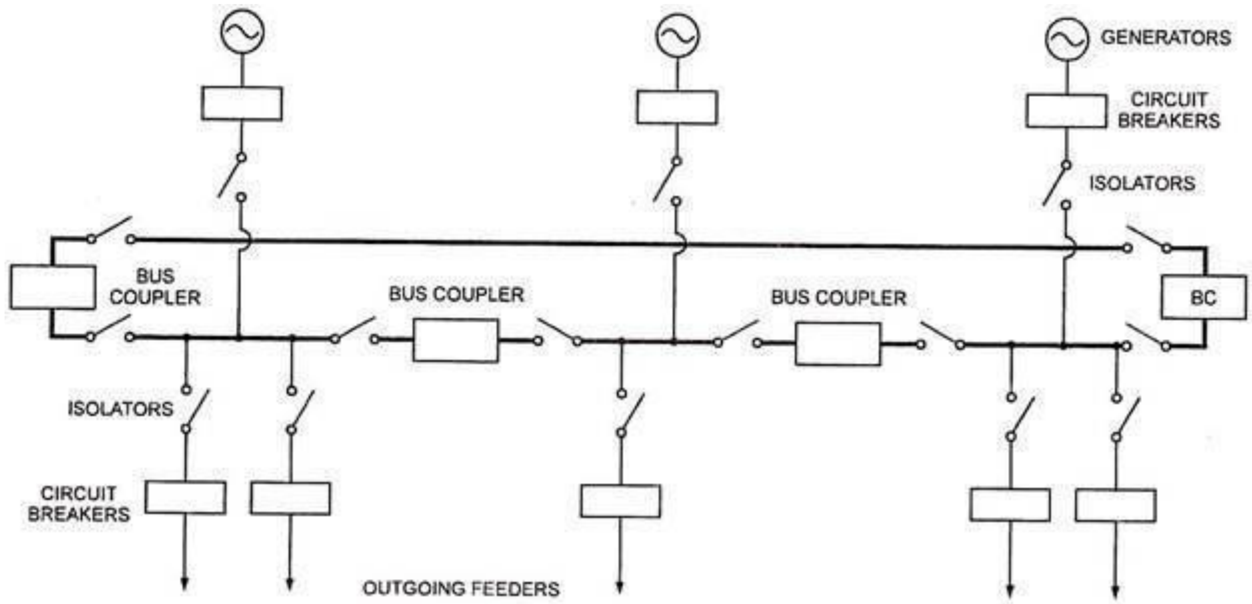


Fig. 1.16. ***Ring Main Arrangement***

The effect of fault in one section is localised to that section alone. The rest of the sections continue to operate. Circuit breakers can be maintained without interrupting the supply. The cost is also not much as the numbers of breakers used are nearly the same as that of a single bus-bar system.

The drawbacks of the system are:

(i) Difficulties in addition of any new circuit in the ring,

(ii) Possibility of overloading of the circuits on opening of any section of the breaker and

(iii) Necessity of supplying potential to relays separately to each of the circuit.

Type # 8. Mesh Arrangement:

This is another arrangement making economical use of circuit breakers in a substation. In this bus-bar arrangement, the circuit breakers are installed in the mesh formed by the buses, as illustrated in Fig. 1.17. The circuits are tapped from the node points of the mesh. In Fig. 1.17 eight circuits are controlled by four circuit breakers.

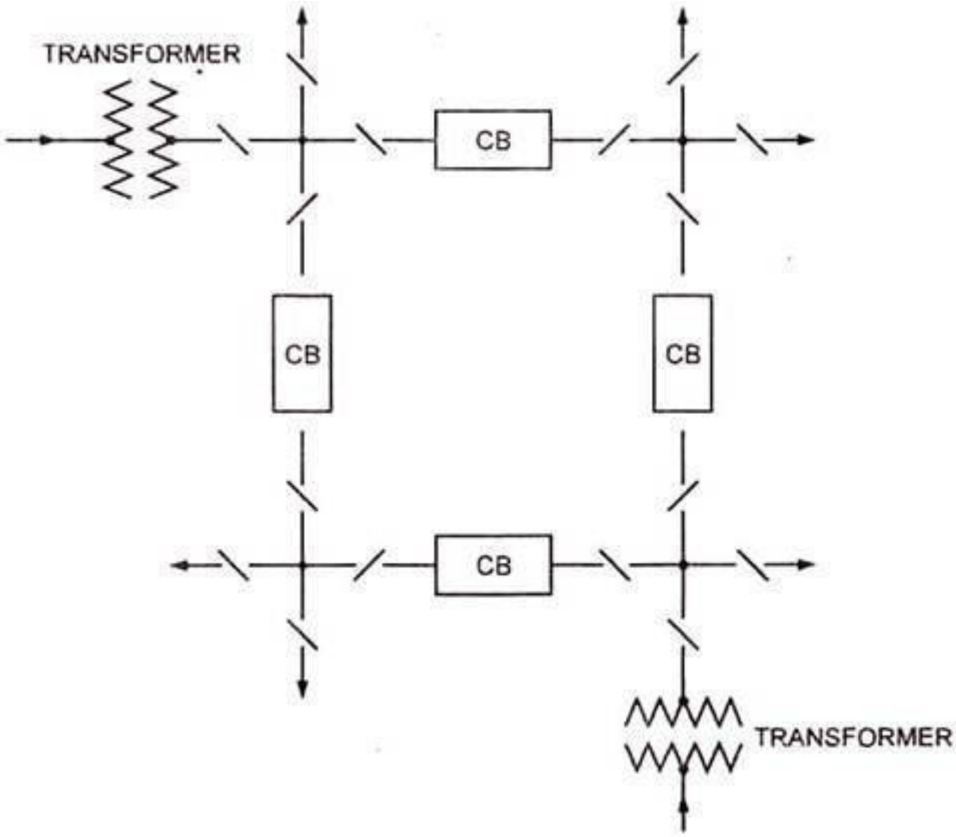


Fig. 1.17. *Mesh Arrangement*

When fault occurs on any section, two circuit breakers have to open, resulting in opening of the mesh. This arrangement provides security against bus-bar faults but lacks switching facility. It needs fewer circuit breakers than that required by one-and a half breaker arrangement. It is preferred for substations having a large number of circuits.