PUSHPALATHA B

LECTURER

BAPUJI POLYTECHNIC, SHABNUR.

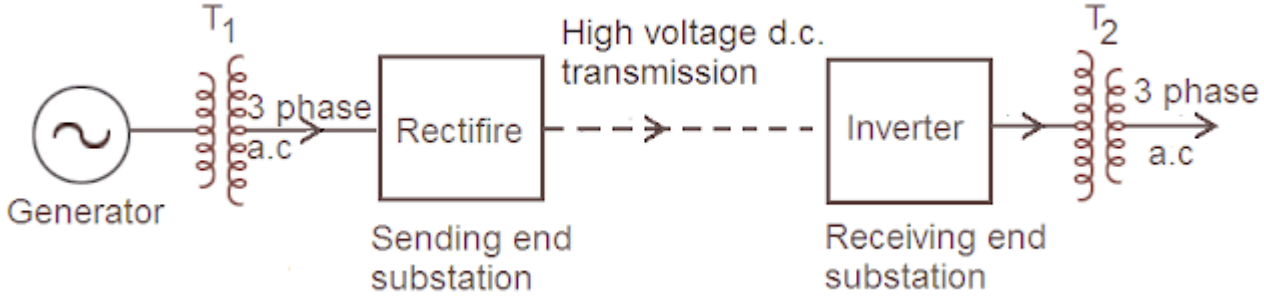
DEPARTMENT OF ELECTRICAL AND ELECTRONICS

TRANSMISSION DISTRIBUTION AND UTALISATION (15EE52T)

UNIT-2

HVDC Transmission and FACTS & Distribution

Single line diagram of HVDC transmission



A typical HVDC transmission system is shown in Figure. In this system, the AC produced by generating stations is stepped up and converted to DC with the help of a rectifier unit. Then this DC is transmitted by the HVDC transmission line. At the receiving end, an inverter unit converts the received DC back to AC. Now, this DC is stepped down and distributed.

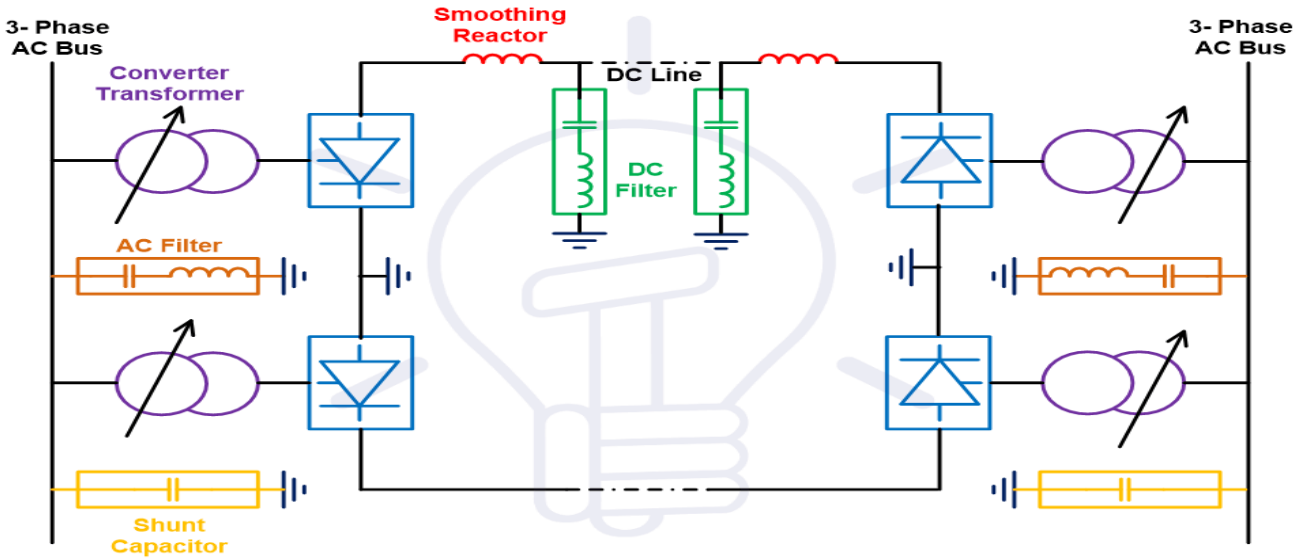
The converter at sending end converts AC power into DC power while the converter at the receiving end converts DC power back to AC power. Thus, the first converter acts as a rectifier unit, whereas the other one acts as an inverter unit.

Components of HVDC TM

Following are the main components used in HVDC TM

- convertors,
- harmonic filters,

- converter transformers,
- a reactive power source,
- ground electrodes,
- communication link



convertor: **convertors are the main components of HVDC TM system each TM should have atleast 2 convertors one at sending end which converts power from AC toDC that means works as rectifier convertor placed at receiving end which converts power from DC in to AC that means works as invertor**

Harmonic Filters

On the DC and AC side of the HVDC transmission system, harmonics are produced. It may produce undesirable noise in the neighboring communication system. Thus to remove these harmonic currents, harmonic filters are used. This filter bypasses the harmonic currents to the ground by providing a low impedance path. The filters for each phase are connected in star, and the neutral point is grounded.

Converter Transformer

It is used to provide the AC voltage required by the converter. A delta type three-phase transformer may be used for this purpose. A third winding known as tertiary winding may be added sometimes for a direct connection to the source of the reactive power.

The converter transformer on the rectifier side is provided with tappings to maintain the input AC voltage nearly constant. A motorized tap changer automatically switches the taps. The taps are also provided on the converter transformer on the inverter side.

Reactive Power Source

The variable static capacitors or synchronous capacitors are used for absorbing the reactive power of the converters. The requirement of the reactive power increases with the firing angle of the rectifier and extinction angle of the inverter. This power requirement is about 50 % to 60 % of real power transfer. As the transmitted active power varies, the reactive power must also be varied

Ground Electrode

The DC currents in the ground have a corrosive effect on cables, metallic structures, and cables, and it causes interference in the converter transformer. The actual ground electrode is placed far from the converter station to avoid these problems. At the grounding site, special methods are adopted to minimize electrode resistance.

Communication Link

A communication link is necessary between the converters at both ends of the line for controlling purposes. A high-speed communication link between the two converters continuously transmits the controlling information.

Advantages of HVDC Transmission System

1) The HVDC system needs only one or two conductors. Therefore, the cost of the conductor reduces considerably. Hence it is very economical for bulk transmission of power over long distances. The cost of towers and insulators is also reduced.

2.) Due to corona loss considerations, when the AC system voltage exceeds 200 kV, 'bundle conductors' are required. With HVDC transmission, this limit is 400 kV.

2) The radio interference is less, and corona loss is low with the HVDC system.

3) The transmission losses are less with the DC system.

4) In the HVDC system rectifier unit can be converted into inverter unit very easily and vice versa. Thus in this system, **power flow can be reversed very easily**.

5) The charging current considerations at 400 kV for AC cables limit the 'critical length' to 40 km. HVDC cables do not need such charging current, and there is no such limit for DC cables. Cables in the DC system do not suffer from the high dielectric loss. The skin effect is also low in the DC system.

6) DC power can be transmitted between two systems operating at different frequencies. This is not possible with AC transmission.

7) Greater power transmission per conductor is possible with the HVDC system.

8) There are no serious problems in voltage regulation, as there is no reactance drop in this system.
AC cables require shunt inductors for compensation. DC can be compensated by capacitors, which are cheaper and with little-associated losses. Further, these capacitors can be used as 'harmonic filter' also.

9) In the development stage, a DC system can be worked with a single conductor and earth as the return. It is also an advantage under emergency conditions.

10) During fault with the HVDC system, the **grid control of the converter reduces the fault current significantly**.

disadvantages of HVDC Transmission

1. **This system is uneconomical if the length of the transmission line is less than 500 km** as converters, inverters, and filters are required additionally in this system.

2. **DC circuit breaking is difficult and expensive**

3. Filtration is very necessary for this system due to the excessive generation of harmonics.

4. The overload capacity of this system is low.

5. As HVDC does not transmit reactive power, it has to supply locally, if required.

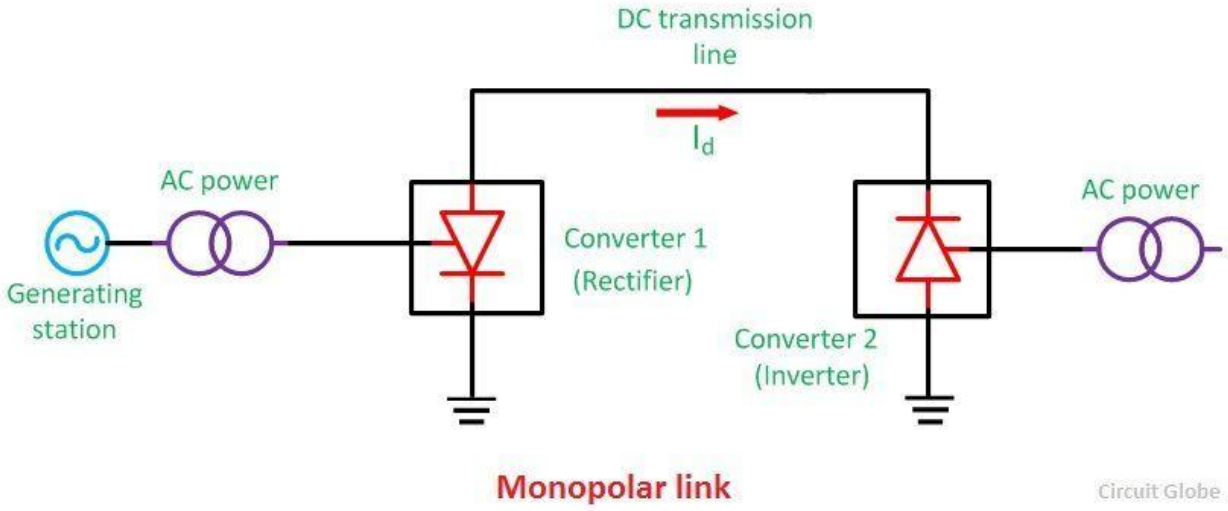
6. The maintenance of insulators in this system is more.

7. There are additional losses in valves and converter transformers. These losses are continuous. Hence, a **very efficient cooling system has to be provided**.
8. Tapping is not possible that means it is not possible to tap power in serval points in hvdc .

Types of HVDC links

Hvdc links are broadly classified in to 3 types
1) Monopolar
2) Bipolar
3) Homopolar

1) MONOPLOAR

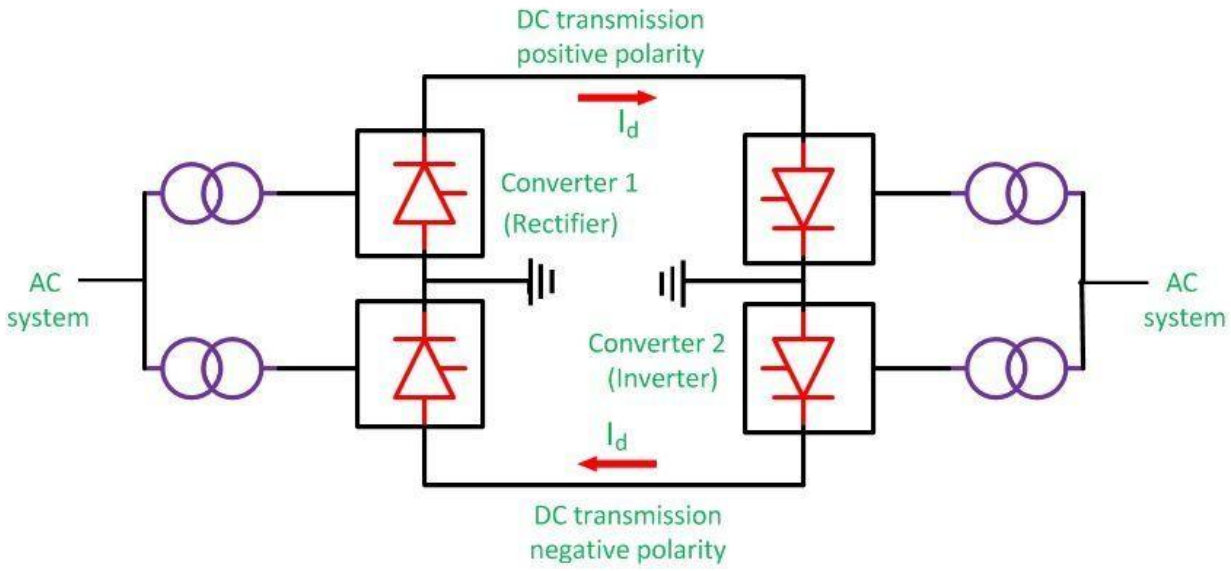


Monopolar link – It has a single conductor of negative polarity and uses earth or sea for the return path of current. Sometimes the metallic return is also used. In the Monopolar link, two converters are

placed at the end of each pole. Earthing of poles is done by earth electrodes placed about 15 to 55 km away from the respective terminal stations. But this link has several disadvantages because it uses earth as a return path. The monopolar link is not much in use nowadays.

2 BIPOLAR

Bipolar link – The Bipolar link has two conductors one is positive, and the other one is negative to the earth. The link has converter station at each end. The midpoints of the converter stations are earthed through electrodes. The voltage of the earthed electrodes is just half the voltage of the conductor used for transmission the HVDC.

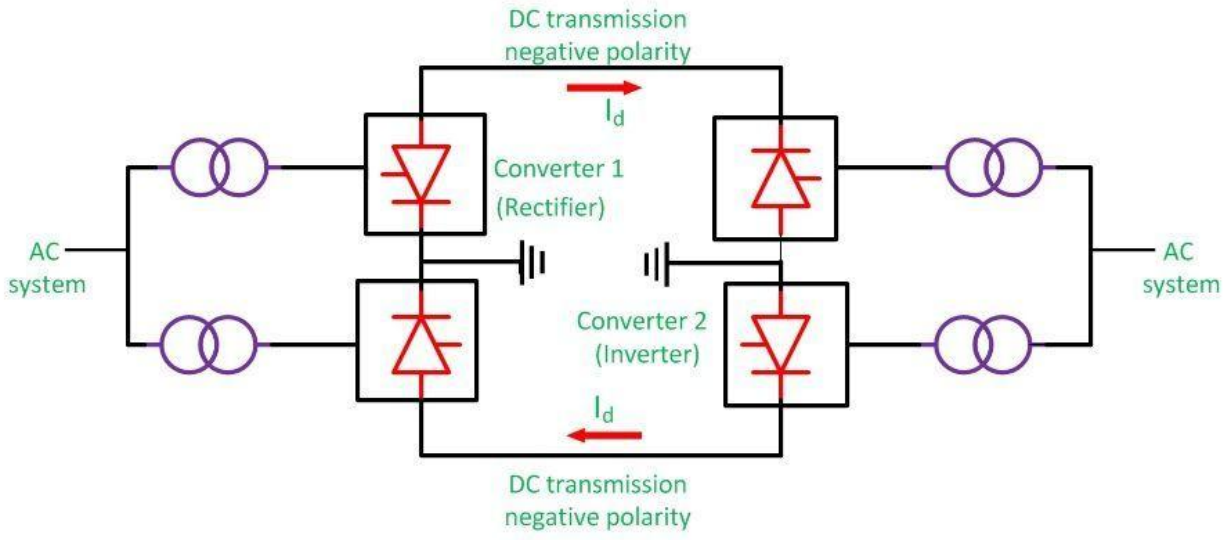


Bipolar link

The most significant advantage of the bipolar link is that if any of their links stop operating, the link is converted into Monopolar mode because of the ground return system. The half of the system continues supplies the power. Such types of links are commonly used in the HVDC systems.

3 HOMOPLOAR

Homopolar link– It has two conductors of the same polarity usually negative polarity, and always operates with earth or metallic return. In the homopolar link, poles are operated in parallel, which reduces the insulation cost.



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Substation

It can be defined as an assembly of apparatus installed to change certain characteristics of supply system.

The substations are important part of power system network .the

Safety and reliability of electrical supply depends upon successful operation of substation.

Functions of substation

1 To switch on and off the power lines

2 To change voltage level of system.

3 To convert AC to DC and DC to AC.

4 To improve the power factor.

5 To change magnitude of frequency.

Classification of substation

Sub stations are classified in different ways

1 on the basis of nature of duties

- **Step up primary substation**
- **Primary grid substation**
- **Step down substation**

2 on the basis of service rendered

- **Transformation substation**
- **Switching substation**
- **Converting substation**

3 **on the basis of operating voltage**

- **High vg substation (HV)→ (11KV or 66KV)**
- **Extra high vg substation (EHV) → (130KV)**
- **Ultra extra high vg SS (UEHV) → (400KV)**

4 **On the basis of importance**

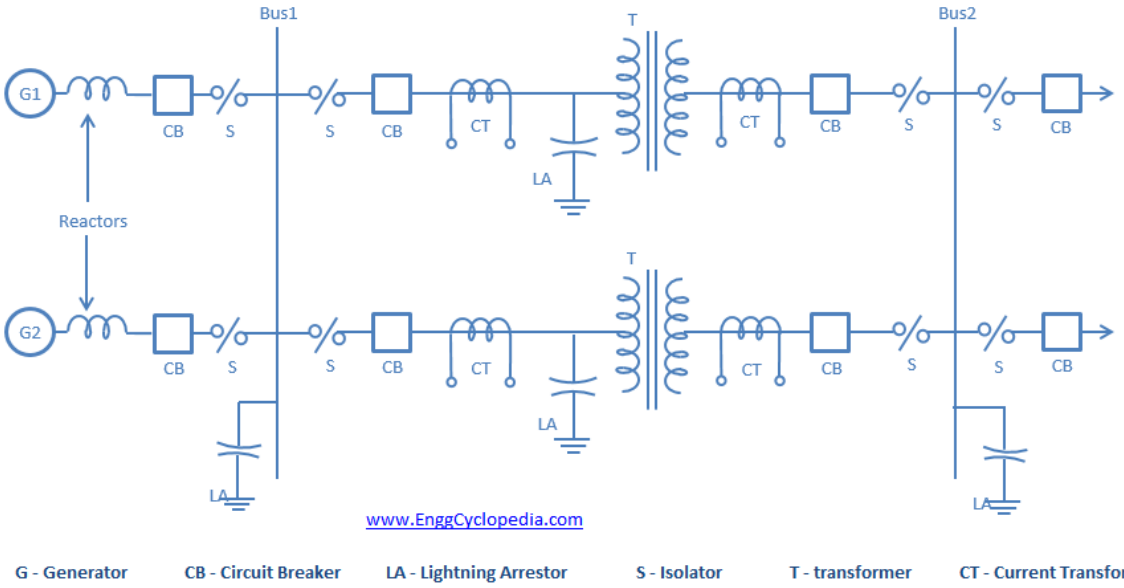
- **Grid substation**
- **Town substation**

5 **on the basis of design**

- **Indoor substation**
- **outdoor substation**

MAIN COMPONENETS OF SUBSTATION

- **Busbar**
- **Isolators**
- **Current transformers**
- **Potential transformer**
- **Circuit breaker**
- **Earth switch**
- **Capacitor bank**
- **Lighting arrestors**
- **Indicating & metering instruments**



Bus bar:

The bus bar is among the most important elements of the substation and is a conductor which carries current to a point having numerous connections with it. The bus bar is a kind of electrical junction which has outgoing and incoming current paths. The bus bar is made up of copper clad steel tube or alluminiumtube supported on insulator

Isolator: The isolators in substations are mechanical switches which are used for isolation of circuits when there is an interruption of current. These are also known with the name of disconnected switches
It gives physical separation between live part dead part these are triple pole switch with manual or motor mechanism.

Current transformer:

- A current transformer is a device for the transformation of current from a higher value to a lower value. It is used in parallel with AC instruments, meters or control apparatus so that the meter or instrument coil cannot conveniently be made of sufficient current carrying capacity.

potential transformer:

The potential transformers are similar in characteristics as current transformers but are utilized for converting high voltages to lower voltages for protection of relay system and for lower rating metering of voltage measurements.

Circuit breaker :

The circuit breakers are such type of switches utilized for closing or opening circuits at the time when a fault occurs within the system. The circuit breaker has 2 mobile contacts which are in OFF condition in normal situations. At the time when any fault occurs in the system, a relay is sending the tripped command to the circuit breaker which moves the contacts apart, hence avoiding any damage to the circuitry.

Capacitor Banks:

The capacitor bank is defined as a set of numerous identical capacitors which are connected either in parallel or series inside an enclosure and are utilized for the correction of power factor as well as protection of circuitry of the substation. These are acting like the source of reactive power and are thus reducing phase difference amid current and voltage. These are increasing the capacity of ripple current of supply and avoid unwanted selves in the substation system. The use of capacitor banks is an economical technique for power factor maintenance and for correction of problems related to power lag.

Metering and Indication Instruments:

There are numerous instruments for metering and indication in each substation such as watt-meters, voltmeters, ammeters, power factor meters, kWh meters, volt-ampere meters, and KVARH meters etc. These instruments are installed at different places within substation for controlling and maintaining values of current and voltages. For instance, **33/11KV substation equipment** will comprise digital multi-meters for various readings of currents and voltages.

Earth switch:

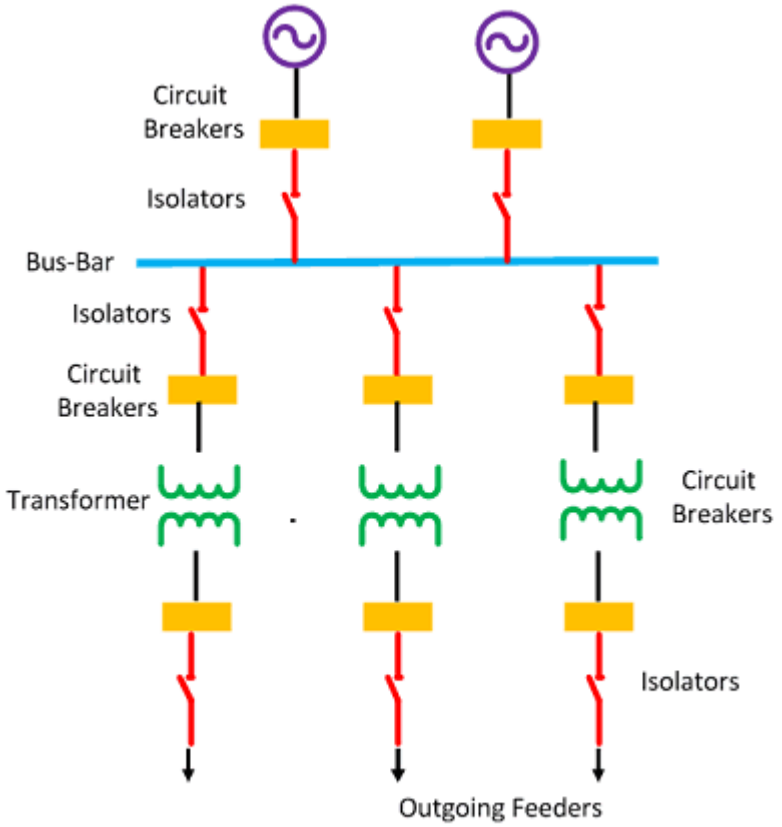
At incoming & outgoing side of line earth switch is provided which is normally open .by using this switch current is discharged to the earth .

Definition: An electrical bus bar is defined as a conductor or a group of conductor used for collecting electric power from the incoming feeders and distributes them to the outgoing feeders. In other words, it is a type of electrical junction in which all the incoming and outgoing electrical current meets. Thus, the electrical bus bar collects the electric power at one location.

Single Bus-Bar Arrangement

The arrangement of such type of system is very simple and easy. The system has only one bus bar along with the switch. All the substation equipment like the transformer, generator, the feeder is connected to this bus bar only. The advantages of single bus bar arrangements are

- It has low initial cost.
- It requires less maintenance
- It is simple in operation



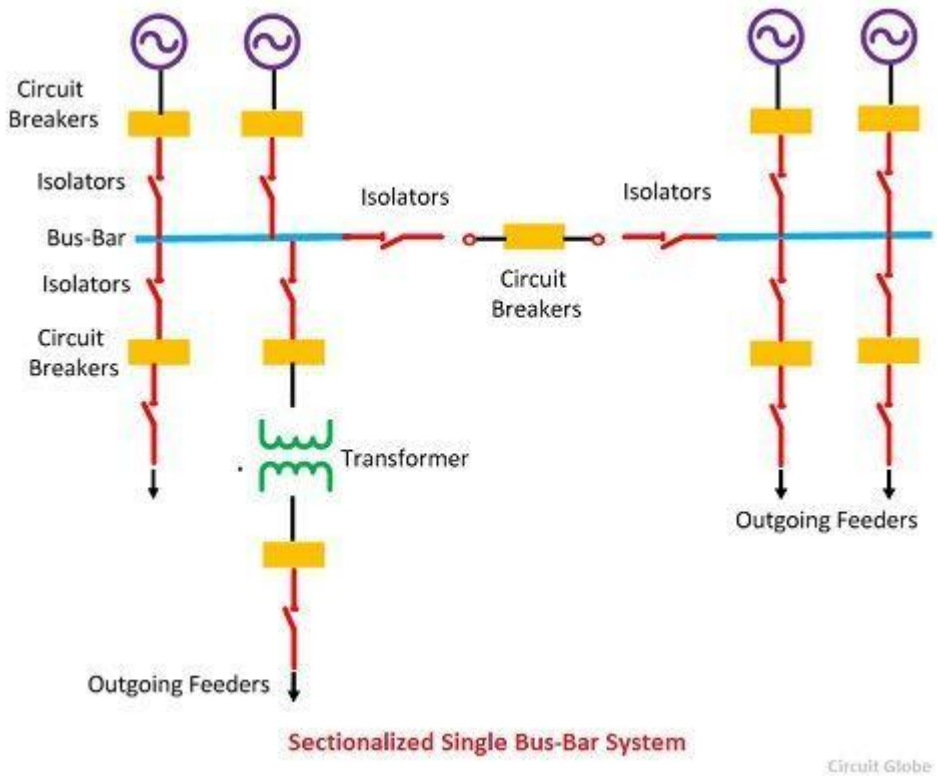
Single Bus-Bar Arrangement

Drawbacks of Single Bus-Bars Arrangement

- The only disadvantage of such type of arrangement is that the complete supply is disturbed on the occurrence of the fault.
- The arrangement provides the less flexibility and hence used in the small substation where continuity of supply is not essential.

Single Bus-Bar Arrangement With Bus Sectionalized

In this type of busbar arrangement, the circuit breaker and isolating switches are used. The isolator disconnects the faulty section of the busbar, hence protects the system from complete shutdown. This type of arrangement uses one addition circuit breaker which does not much increase the cost of the system



he following are the advantages of sectionalized bus bar.

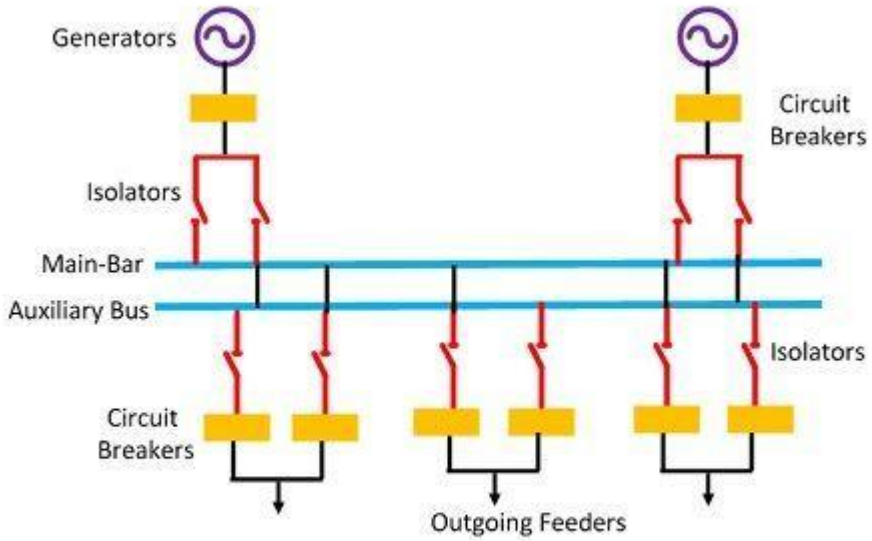
- The faulty section is removed without affecting the continuity of the supply.
- The maintenance of the individual section can be done without disturbing the system supply.
- The system has a current limiting reactor which decreases the occurrence of the fault.

Disadvantages of Single Bus-Bar Arrangement with Sectionalization

- The system uses the additional circuit breaker and isolator which increases the cost of the system.

Double Bus Double Breaker Arrangement

This type of arrangement requires two bus bar and two circuit breakers. It does not require any additional equipment like bus coupler and switch.



Double Bus Double Breaker Arrangement

Advantages of Double Bus Double Breaker

- This type of arrangement provides the maximum reliability and flexibility in the supply. Because the fault and maintenance would not disturb their continuity.
- The continuity of the supply remains same because the load is transferrable from one bus to another on the occurrence of the fault.

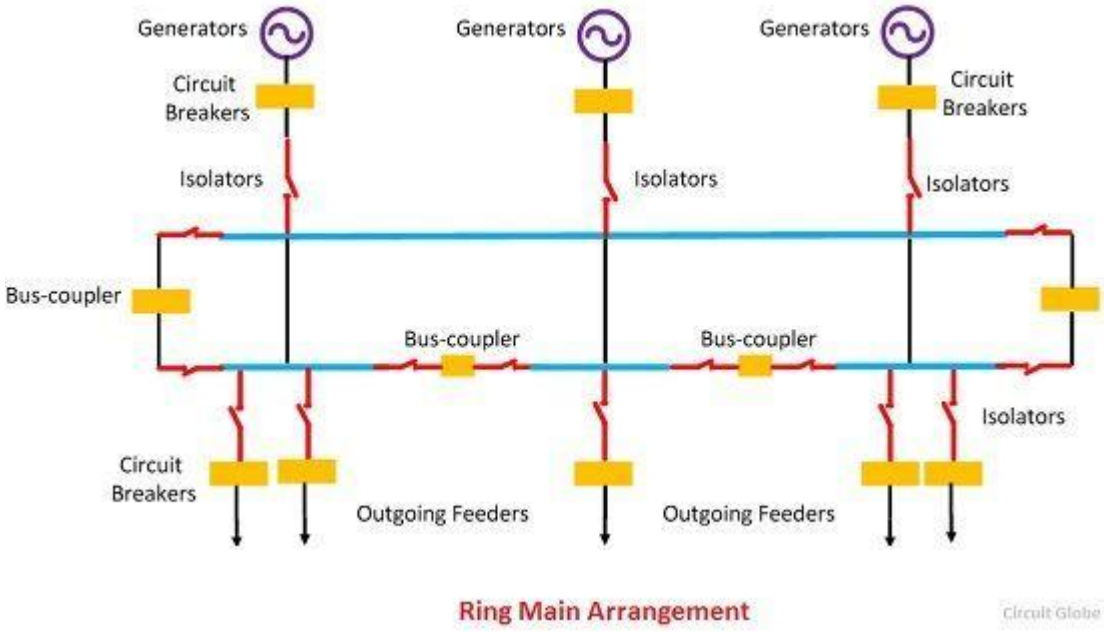
Disadvantages of double bus Double breaker

- In such type of arrangement two buses and two circuit breakers are used which increases the cost of the system.
- Their maintenance cost is very high.

Because of its higher cost, such type of bus-bars is seldom used in substations.

Ring Main Arrangement

In such type of arrangement, the end of the bus bar is connected back to the starting point of the bus to form a ring.



Advantages of Ring Main Arrangement

- Such type of arrangement will provide two paths for the supply. Thus the fault will not affect their working.
- The fault is localized for the particular section. Hence the complete circuit is not affected by the fault.
- In this arrangement, a circuit breaker can be maintained without interrupting the supply.

Disadvantages of Ring Main Arrangement

- Difficulties occur in the addition of the new circuit.
- Overloading occurs on the system if any of the circuit breakers is opened

.Flexible AC transmission system (FACTS)

FACTS devices are static power-electronic devices installed in AC transmission networks to increase power transfer capability, stability, and controllability of the networks through series and/or shunt compensation [19]. T

Flexible AC transmission system devices are a family of power electronic-based devices growingly used in the power system transmission grid. These devices can offer different functionalities such as increased power transfer capacity and improved grid stability and provided fast reactive power/voltage support

Features of Flexible AC Transmission Systems (FACTS)

- Fast voltage regulation,
- Increased power transfer over long AC lines,
- Damping of active power oscillations, and
- Load flow control in meshed systems,

FACTS controllers are generally divided into four categories:

i. Series Controllers

ii. Shunt Controllers

iii. Combined Series-Series Controllers

iv. Combined Series-Shunt Controllers

Types of FACTS Controller:

a) Series Controller:

Series controller could be a variable impedance, such as impedance, such on capacitor, reactor etc.

All series controllers inject a voltage in series with the line. As long on the voltage is in phase quadrature with the line current, series controlled only supplies reactive power. Any other phase relationship will involve real power as well.

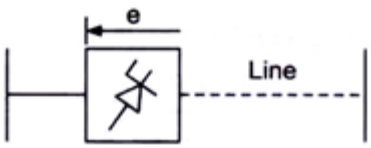


Fig. 5.14 Sereis controller

b) Shunt Controllers:

Shunt controllers, may be variable impedance, variable sources or a combination of these. Shunt controller inject current into the system at the point of connection.

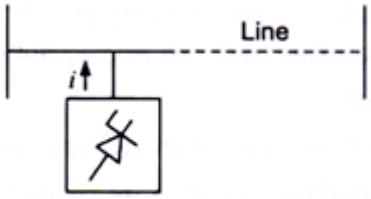


Fig. 5.15 Shunt controller

(c) Combined Series-Series Controllers:

If could be a combination of separate series controllers, which are controlled in a coordinated manner, in a multi-line transmission system.

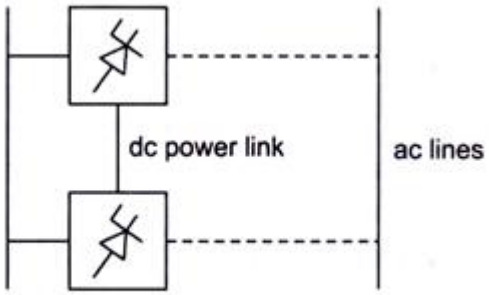


Fig. 5.16 Combined series-series controller

d) Combined Series-Shunt Controllers:

This could be a combination of separate shunt and series controller, which are controlled in a coordinated manner or a unified power flow controller (UPFC) with series and shunt elements.

UPFC can provide effective current/power control along with voltage control.

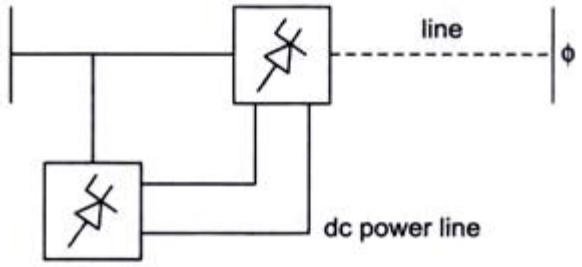
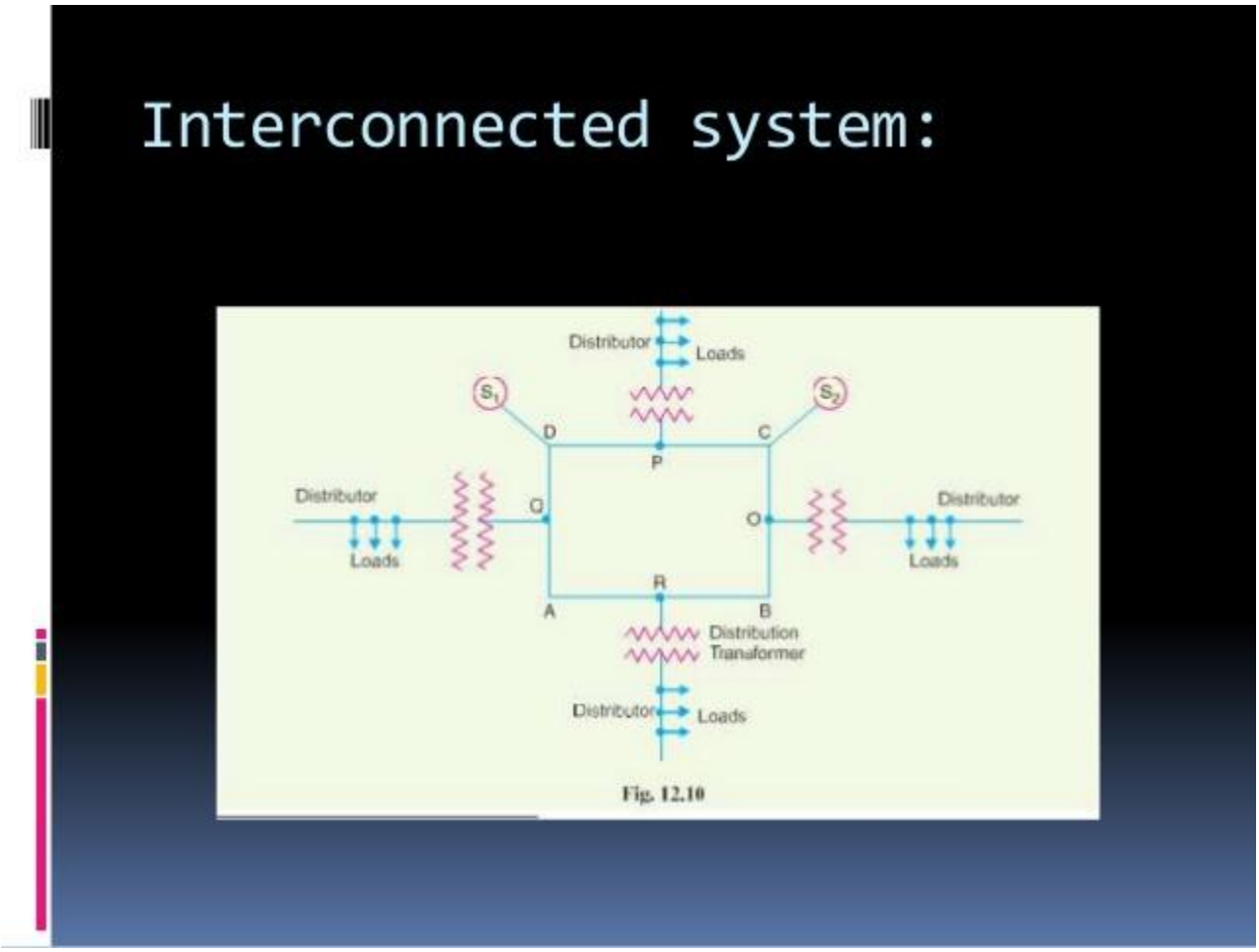


Fig. 5.17 Combined series-shunt controllers

Advantages

1. FACTS increase the reliability of AC grids.
2. They reduce power delivery costs.
3. They supply inductive or reactive power to the grid and improve transmission quality and efficiency of power transmission.
4. There is fast voltage regulation.
5. Increased power transfer over long AC lines.

Importance of interconected system



The connection of several generating stations in a network of particular transmission voltage level is commonly known as **electrical grid system**. By interconnecting different power generating stations we can solve various difficulties arise in power system. The structure, or "network topology" of a grid can vary depending on the the load and generation characteristics, constraints of budget and the requirements for system reliability. The physical layout is often forced by the geology and land availablility.

Although, forming a grid by interconnecting different generating stations located at different places is significantly expensive since the protections and operations of the entire system become more complicated. But untill modern power system demands the interconnected grid between the power stations because of its tremendous benefits against the power stations which are running individually. There are some advantages of interconnected grid system listed below one by