5.3 AC DISTRIBUTION

Now-a-days electrical energy is generated, transmitted and distributed in the form of alternating cur-rent. One important reason for the widespread use of alternating current in preference to direct current is the fact that alternating voltage can be conveniently changed in magnitude by means of a transformer. Transformer has made it possible to transmit a.c. power at high voltage and utilise it at a safe potential. High transmission and distribution voltages have greatly reduced the current in the conductors and the resulting line losses.

There is no definite line between transmission and distribution according to voltage or bulk capacity. However, in general, the a.c. distribution system is the electrical system between the step- down substation fed by the transmission system and the consumers' meters. The a.c. distribution system is classified into

i. Primary distribution system and
ii. Secondary distribution system.

i) Primary distribution system.

It is that part of a.c. distribution system which operates at voltages somewhat higher than general utilization and handles large blocks of electrical energy than the average low-voltage consumer uses. The voltage used for primary distribution depends upon the amount of power to be conveyed and the distance of the substation required to be fed. The most commonly used primary distribution voltages are 11 kV, 6·6 kV and 3·3 kV. Due to economic considerations, primary distribution is carried out by 3- phase, 3-wire system Fig.5.3.1 shows a typical primary distribution system Electric power from the generating station is transmitted at high voltage to the substation located in or near the city.

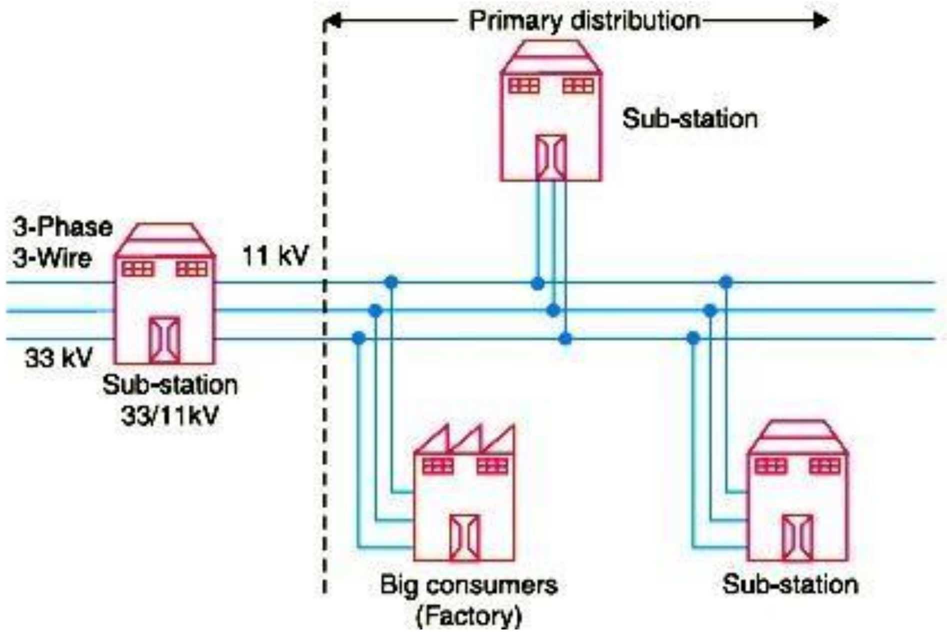


Figure 5.3.1 Primary AC Distribution System

[Source: "Principles of Power System" by V.K.Mehta Page: 302]

ii) Secondary distribution system

It is that part of a.c. distribution system.Thesecondarydistributionemploys400/230V,3-phase,4wire system. Fig.5.3.2 shows a typical secondary distribution system. The primary distribution circuit delivers power to various substations, called distribution sub-stations.

The substations are situated near the consumers' localities and contain step-down transformers. At each distribution substation, the voltage is stepped down to 400Vandpowerisdeliveredby 3-phase,4- wire a.c .system. The voltage between any two phases is 400V and between any phase and neutralize 230V. The single phase domestic loads are connected between any one phase and the neutral,whereas3- phase400Vmotor loadsareconnectedacross3- phase lines directly.

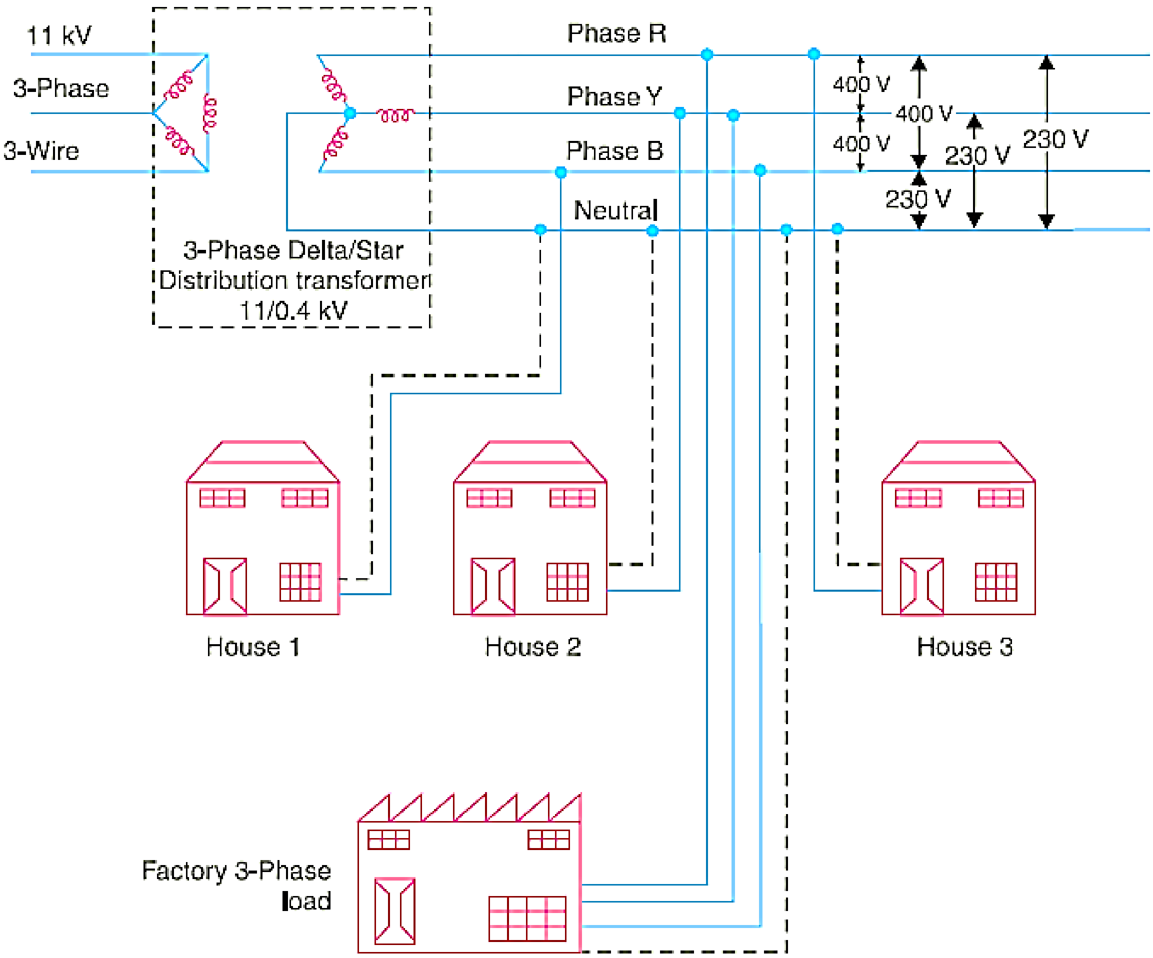


Figure 5.3.2 Secondary AC Distribution System

[Source: "Principles of Power System" by V.K.Mehta Page: 303]

5.4 D.C. DISTRIBUTION

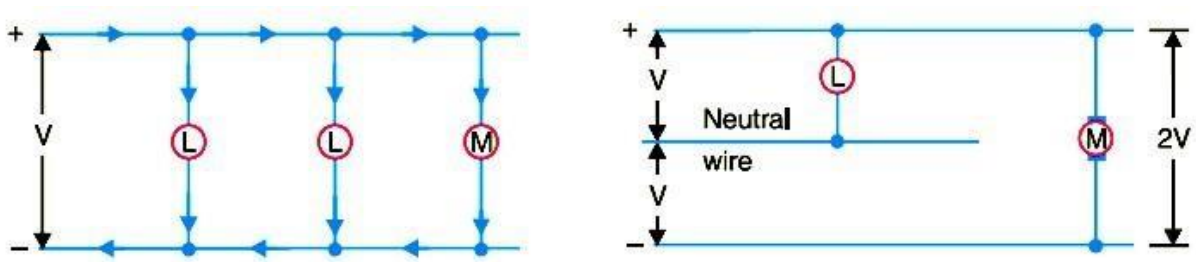
It is a common knowledge that electric power is almost exclusively generated, transmitted and distributed as a.c. However, for certain applications, d.c. supply is absolutely necessary. For instance, d.c. supply is required for the operation of variable speed machinery (d.c. motors), for electro-chemical work and for congested areas where storage battery reserves are necessary. For this purpose, a.c. power is converted into d.c. power at the substation by using converting machinery e.g., mercury arc rectifiers, rotary converters and motor-generator sets. The d.c. supply from the substation may be obtained in the form of

(i) 2-wire

(ii) 3-wire for distribution.

(i) 2-wire d.c. system.

As the name implies, this system of distribution consists of two wires. One is the outgoing or positive wire and the other is the return or negative wire. The loads such as lamps, motors etc. are connected in parallel between the two wires as shown in Fig. 12.4. This system is never used for transmission purposes due to low efficiency but may be employed for distribution of d.c. power.



(i) 2-wire d.c. system **(ii) 3-wire d.c. system**

Figure 5.4.1 DC Distribution System

[Source: "Principles of Power System" by V.K.Mehta Page: 303]

(ii) 3-wire d.c. system.

It consists of two outers and a middle or neutral wire which is earthed at the substation. The voltage between the outers is twice the voltage between either outer and neutral wire as shown in Fig. 12.5. The principal advantage of this system is that it makes available two voltages at the consumer terminals viz., V between any outer and the neutral and 2V between the outers. Loads requiring high voltage (e.g., motors) are connected across the outers, whereas lamps and heating circuits requiring less voltage are connected between either outer and the neutral. The methods of obtaining 3-wire system are discussed in the following article.

5.4.1 Overhead Versus Underground System

The distribution system can be overhead or underground. Overhead lines are generally mounted on wooden, concrete or steel poles which are arranged to carry distribution transformers in addition to the conductors. The underground system uses conduits, cables and manholes under the surface of streets and sidewalks. The choice between overhead and underground system depends upon a num-ber of widely differing factors. Therefore, it is desirable to make a comparison between the two.

(i) Public safety.

The underground system is more safe than overhead system because all distribution wiring is placed underground and there are little chances of any hazard.

(ii) Initial cost.

The underground system is more expensive due to the high cost of trenching, conduits, cables, manholes and other special equipment. The initial cost of an underground system may be five to ten times than that of an overhead system.

(iii) Flexibility.

The overhead system is much more flexible than the underground system. In the latter case, manholes, duct lines etc., are permanently placed once installed and the load expansion can only be met by laying new lines. However, on an overhead system, poles, wires, transformers etc., can be easily shifted to meet the changes in load conditions.

(iv) Faults.

The chances of faults in underground system are very rare as the cables are laid underground and are generally provided with better insulation.

(v) Appearance.

The general appearance of an underground system is better as all the distribution lines are invisible. This factor is exerting considerable public pressure on electric supply companies to switch over to underground system.

(vi) Fault location and repairs.

In general, there are little chances of faults in an underground system. However, if a fault does occur, it is difficult to locate and repair on this system. On an overhead system, the conductors are visible and easily accessible so that fault locations and repairs can be easily made.

(vii) Current carrying capacity and voltage drop.

An overhead distribution conductor has a considerably higher current carrying capacity than an underground cable conductor of the same material and cross-section. On the other hand, underground cable conductor has much lower inductive reactance than that of an overhead conductor because of closer spacing of conductors.

(viii) Useful life.

The useful life of underground system is much longer than that of an overhead system. An overhead system may have a useful life of 25 years, whereas an underground system may have a useful life of more than 50 years.

(ix) Maintenance cost.

The maintenance cost of underground system is very low as compared with that of overhead system because of less chances of faults and service interruptions from wind, ice, lightning as well as from traffic hazards.

(x) Interference with communication circuits.

An overhead system causes electromagnetic interference with the telephone lines. The power line currents are superimposed on speech currents, resulting in the potential of the communication channel being raised to an undesirable level. However, there is no such interference with the underground system.

It is clear from the above comparison that each system has its own advantages and disadvan tages. However, comparative economics (i.e., annual cost of operation) is the most powerful factor influencing the choice between underground and overhead system. The greater capital cost of underground system prohibits its use for distribution. But sometimes non- economic factors (e.g., general appearance, public safety etc.) exert considerable influence on choosing underground system. In general, overhead system is adopted for distribution and the use of underground system is made only where overhead construction is impracticable or prohibited by local laws.

5.1 DISTRIBUTION S Y S T E M S – GENERAL ASPECTS

The electrical energy produced at the generating station is conveyed to the consumers through a network of transmission and distribution systems. It is often difficult to draw a line between the transmission and distribution systems of a large power system. It is impossible to distinguish the two merely by their voltage because what was considered as a high voltage a few years ago is now considered as a low voltage. In general, distribution system is that part of power system which distributes power to the consumers for utilization.

The transmission and distribution systems are similar to man's circulatory system. The trans- mission system may be compared with arteries in the human body and distribution system with capillaries. They serve the same purpose of the ultimate consumer in the city with the life- giving blood of civilization–electricity. In this chapter, we shall confine our attention to the general introduction to distribution.

5.1.1 Distribution System

That part of power system which distributes electric power for local use is known as distribution system. In general, the distribution system is the electrical system between the substation fed by the Transmission system and the consumer's meters. It generally consists of feeders, distributors, and service mains. Fig. 12.1 shows the single line diagram of a typical low tension distribution system.

i) Feeders

A feeder is a conductor which connects the sub-station (or localized generating station) to the area where power is to be distributed. Generally, no tappings are taken from the feeder so that current in it remains the same throughout. The main consideration in the design of a feeder is the current carrying capacity.

(ii) Distributor

A distributor is a conductor from which tappings are taken for supply to the consumers. In Fig. AB, BC, CD and DA are the distributors. The current through a distributor is not constant because tappings are taken at various places along its length. While designing a distributor, voltage drop along its length is the main consideration since the statutory limit of voltage variations is ± 6% of rated value at the consumers' terminals.

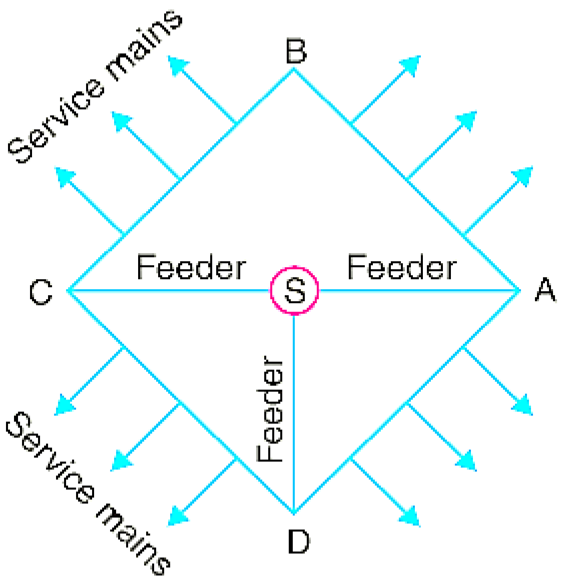


Figure 5.1 Distribution System

[Source: "Principles of Power System" by V.K.Mehta Page: 301]

(iii) Service mains

A service mains is generally a small cable which connects the distributor to the consumers' terminals

5.5 EHVAC and HVDC TRANSMISSION SYSTEM

EHVAC

The first 735 kV system was commissioned in Canada in 1965. Since then, voltage levels up to 765 kV have been introduced in Russia with neighboring countries, U.S.A, South Africa, Brazil, Venezuela and South Korea. The general trend of 800 kV investments is indicated in the diagram, which shows the total capacity of power transformers and generator step-up transformers for 800 kV delivered by ABB. Since the 90's, the investments in 800 kV systems have been much lower compared to the 70's and 80's. However, plans are under way for future introduction of 800 kV in India and China. The planned introductions of voltages in the UHV range, i.e. 1000 kV and above, have been cancelled or postponed in several countries. e.g. Russia, Italy and U.S.A. Future 1000 kV lines are only considered in Japan.

HVDC

The first HVDC system for ± 500 kV and above was the Cabora Bassa project, commissioned in 1979. The Brasilian Itaipu project is the only HVDC system operating at ±600 kV so far. The major HVDC investments at these voltage levels were made in the late 80's and early 90's. However, an increasing interest in high-capacity HVDC links have been noted in recent years, as seen from the diagram, which shows all HVDC projects for ±500 kV and above. The need for higher voltage levels can be anticipated for HVDC projects in the near future, especially when the transmission line is more than 1000 km long. From a technical point of view, there are no special obstacles against higher DC voltages. Present solutions are extendable to e.g. ±800 kV when the need arises. The need for higher voltage levels can be anticipated for HVDC projects in the near future, especially when the transmission line is more than 1000 km long. From a technical point of view, there are no special obstacles against higher DC voltages. Present solutions are extendable to e.g. ±800 kV when the need arises.

Design aspects for AC DC transmission lines

The general design criteria for AC and DC transmission lines can be divided into electrical and mechanical aspects, both having considerable effects on the investment and operation costs. The power transmission capacity determines the voltage level and the number of parallel circuits, which has a great influence on the investment costs. Other aspects are emergency loading capability and reactive power compensation of AC lines. The power losses affects mainly the operating costs and should therefore be optimized with regard to investment cost of the line conductors at the given voltage level. The insulation performance is determined by the overvoltage levels, the air clearances, the environmental conditions and the selection of insulators. The requirements on the insulation performance affect mainly the investment costs for the towers. The corona performance influences heavily on the design of the conductor bundles and, subsequently, on the mechanical forces on the towers from wind and ice loading of the conductors. Any constraints on the electromagnetic fields at the ground level will, however, primarily influence the costs for the right-of-way. The mechanical loading, and hence the investment cost of towers, insulators and conductors, depends mainly on the design of the conductor bundles and the climatic conditions.

5.5.1 MERITS & DEMERITS OF HVDC

Merits of HVDC

- Undersea cables, where high capacitance causes additional AC losses. (e.g., 250 km
  Baltic Cable between Sweden and Germany)
- Endpoint-to-endpoint long-haul bulk power transmission without intermediate.
- Increasing the capacity of an existing power grid in situations where additional wires are difficult or expensive to install.
- Power transmission and stabilization between unsynchronized AC distribution systems.

- Connecting a remote generating plant to the distribution grid, for example Nelson River Bipoler.
- Stabilizing a predominantly AC power-grid, without increasing prospective short circuit current.
- Reducing line cost. HVDC needs fewer conductors as there is no need to support multiple phases. Also, thinner conductors can be used since HVDC does not suffer from the skin effect.
- Facilitate power transmission between different countries that use AC at differing voltages and/or frequencies.
- Synchronize AC produced by renewable energy sources.

Demerits

- Circuit breaking Is difficult in D.C circuits, therefore the coast of dc circuit is high.
- D.C system does not have step up or step down transformers to change the voltage level.
- The coast of converter station is very high. Both ac and dc harmonics are generated. System control stability is quite difficult.

5.5.2 ECONOMICAL COMPARISION EHVAC and HVDC

The trend of power electronic components, for use in the main circuit of an HVDC transmission, being developed means that the relative cost of HVDC transmissions is reduced as the components become cheaper as a result of continuing innovative technological developments. Thus a large converter station with a cost of 50 USD/kW is today cheaper in current dollars compared with the situation 20 years ago. The dc line is less costly compared with an 800 kV ac line. On the other hand, the converter station cost offsets the gain in reduced cost of the transmission line. Thus a short line is cheaper with ac transmission, while a longer line is cheaper with dc.

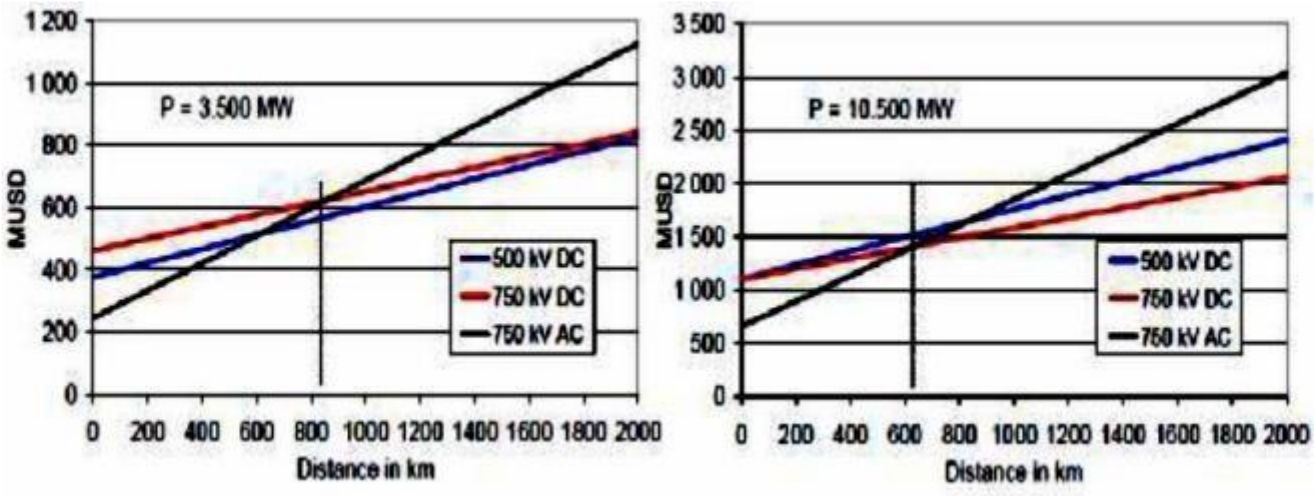


Figure 1.1 Economical Comparision EHVAC And HVDC

[Source: https://www.brainkart.com/article/EHVAC-and-HVDC-Transmission-System_12351/]

In a general comparison of HVDC vs. EHVAC power transmission, the design of the transmission lines and the related investment costs are of great importance. The aim of this paper has been to focus on the differences in the design of line insulation and conductor configuration, and its influence on the mechanical loads. For the line insulation, air clearance requirements are more critical with EHVAC due to the nonlinear behavior of the switching overvoltage withstand. The corona effects are more pronounced at AC voltage, therefore, larger conductor bundles are needed at higher system voltages. The altitude effects are more important to HVDC lines, since the lightning overvoltage withstand is the most sensitive insulation parameter with regard to air density. The mechanical load on the tower is considerably lower with HVDC due to less number of sub conductors required to fulfill the corona noise limits. The high transmission capacity of the HVDC lines, combined with lower requirements on conductor bundles and air clearances at the higher voltage levels, makes the HVDC lines very cost efficient compared to EHVAC lines. The cost advantage is even more pronounced at the highest voltage levels.

5.8 FACTS

- A Flexible Alternating Current Transmission System (FACTS) is a system composed of static equipment used for the AC transmission of electrical energy and it is meant to enhance controllability and increase power transfer capability of the network and it is generally a power electronics-based system.
- A FACT is defined by the IEEE as "a power electronics based system other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability".

Description

The main objective of FACTS devices is to replace the existing slow acting mechanical controls required to react to the changing system conditions by rather fast acting electronic controls. The mechanical controls require power system operators and designers to provide generous margins to assure a stable and reliable operation of the system. As a result the existing systems cannot be made use of to their full capacity. However, with the use of fast acting controls, the power system margins could be reduced and power system capability could be more fully utilised while maintaining the present levels of quality and reliability.

The concept of FACTS is explaining as follows:

We know that, the power transfer between two systems interconnected through a tie line is given as

$$p = \frac{V_1 V_2}{X} \sin \delta$$

It can be seen that the power flow can be controlled by three parameters, the voltages at the two systems, the reactance of the tie-line and the difference in the voltage angles at the two ends. The FACTS devices can be used to control one or more of these parameters. The various devices used are (*i*) Static var compensators (SVC) (*ii*) Controlled series compensation (*iii*) Static condensers (STATCOM) (*iv*) Advanced controlled series compensation (*v*) Thyristor controlled phase shifting transformer.

5.8.1 Stati Compensators (STATCOM)

Figure.5.8.1 shows a basic circuit of a STATCOM which is GTO (gate turn-off) based compensation system. These devices are known as STATCOM or static synchronous condensers as these exhibit characteristics similar to conventional synchronous condensers without the moving parts.

The basic elements of a Voltage Source Inverter (VSI) based STATCOM are an inverter, a d.c. capacitor and a transformer to match the line voltage as shown in Fig.5.8.1. Voltage source inverter inverts a d.c. voltage (PWM inverter) with a balanced set of three quasi-square voltage waveforms by connecting the d.c. source sequentially to three output terminals. The three phase a.c. generated by inverter is synchronised to the a.c. line through a small tie reactance, which is the leakage reactance of a transformer.

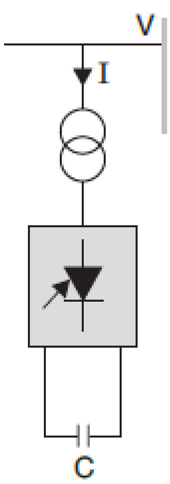


Figure 5.8.1 Statcom

[Source: "Electrical Power Systems" by C.L.Wadhwa Page: 714]

When the inverter fundamental output voltage is higher than the system line voltage, the STATCOM works as a capacitor and reactive vars are generated. However when the inverter voltage is lower than the system line voltage, the STATCOM acts as an inductor thereby absorbing the reactive Vars from the system. To control the reactive current, thus the magnitude of d.c. voltage is raised or lower by adjusting the phase angle of the inverter output voltage. The capacitor here does not play an active role in the var generation. It is only required to maintain a smooth d.c. voltage while carrying the ripple current drawn by the inverter.

5.8.2 Thyristor Controlled Series Compensator

Just as static var compensator can be improved to STATCOM device using GTO converter, a controlled series compensator (CSC) can be improved to an ATCSC using a voltage-driven GTO converter is series with the line as shown in Fig.5.8.2.

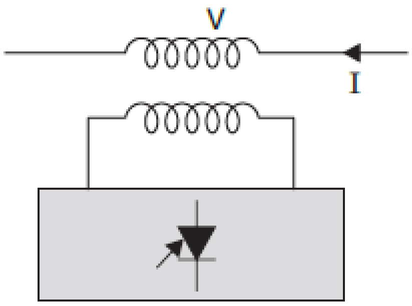


Figure 5.8.2 Thyristor Controlled Series Compensator

[Source: "Electrical Power Systems" by C.L.Wadhwa Page: 715]

Here the line current *I* is made perpenditure to the injected voltage *V* with the help of an ATCSC coordinator which forms a part of the whole control scheme.

5.8.3 Thyristor controlled phase shifting transformer

Thyristor controlled phase shifting transformer or phase angle regulator consists of a shunt transformer and a boosting transformer inserted in the line as shown in Fig.5.8.3.

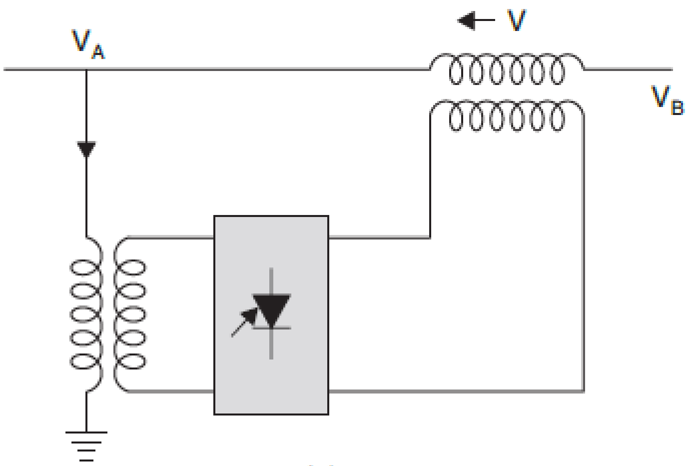


Figure 5.8.2 Thyristor controlled phase shifting transformer

[Source: "Electrical Power Systems" by C.L.Wadhwa Page: 715]

The voltage *V* is perpendicular to the terminal voltage *VA* as shown in phasor diagram. Its' magnitude can be controlled by the thyristor converter. The reactive power required to induce voltage *V* is transmitted via the shunt transformer and the thyristor converter to the boosting transformer.

5.2 KELVIN'S LAW

Kelvin's Law states that the most economical area of conductor is that for which the variable part of annual charge is equal to the cost of energy losses per year.

5.2.1 Graphical illustration of Kelvin's law.

Kelvin's law can also be illustrated graphically by plotting annual cost against X-sectional area '*a*'of the conductor as shown in Fig. 7.28.

In the diagram, the straight line

(1) shows the relation between the annual charge (*i.e.*, $P1 + P2a$) and the area of X-section *a* of the conductor.

Similarly, the rectangular hyperbola

(2) gives the relation between annual cost of energy wasted and X-sectional area *a*. By adding the ordinates of curves (1) and (2), the curve (3) is obtained.

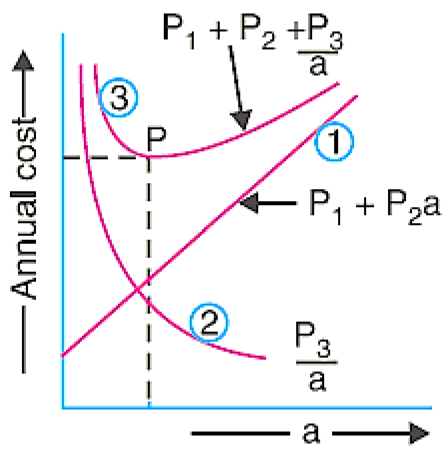


Figure 5.2.1 Graphical Representation of Kelvin's Law

[Source: "Principles of Power System" by V.K.Mehta Page: 128]

This latter curve shows the relation between total annual cost ($P1 + P2a + P3\_a$) of transmission line and area of X-section *a*. The lowest point on the curve (*i.e.*, point *P*) represents the most economical area of X-section.

Limitations of Kelvin's law.

(*i*) It is not easy to estimate the energy loss in the line without actual load curves, which are not available at the time of estimation.

(*ii*) The assumption that annual cost on account of interest and depreciation on the capital outlay is in the form $P1 + P2a$ is strictly speaking not true. For instance, in cables neither the cost of cable dielectric and sheath nor the cost of laying vary in this manner.

(iii) This law does not take into account several physical factors like safe current density, mechanical strength, corona loss etc.

(iv) The conductor size determined by this law may not always be practicable one because it may be too small for the safe carrying of necessary current.

(v) Interest and depreciation on the capital outlay cannot be determined accurately.

5.6 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 sub-station. Sub-stations are important part of 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 :

(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.

5.6.1 Classification of Sub-Stations

There are several ways of classifying sub-stations. 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 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 :

(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 utilisation.

(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 a.c. power and convert it into d.c power with suitable apparatus 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 :

(i) Indoor sub-station

(ii Outdoor sub-station

(iii) Underground sub-station

(iv) Pole-mounted sub-station

(i) Indoor sub-stations
(ii) Switching 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.

(ii) Outdoor sub-stations

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

(iv) Pole-mounted sub-stations

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

5.6.2 Transformer Sub-Stations

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

(*i*) Step-up sub-station **(*ii*)** Primary grid sub-station

(*iii*) Secondary sub-station **(*iv*)** Distribution sub-station

)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-stations. Most of the sub-stations in the power system are of this type.

(ii) Switching sub-stations .

Fig. 5.6.1 shows the block diagram of a typical electric supply system indicating the position of above types of sub-stations. 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 sub-stations and in another case, the scheme may be so small that there are only distribution sub-stations.

(i) Step-up sub-station.

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 sub-stations which accomplish this job are called step-up sub-stations. These are generally located in the power houses and are of outdoor type.

(ii) Primary grid sub-station.

From the step-up sub-station, 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 sub-station which reduces the voltage level to 66 kV for secondary transmission. The primary grid sub-station is generally of outdoor type.

(iii) Secondary sub-station.

From the primary grid sub-station, electric power is transmitted at 66 kV by 3-phase, 3-wire system to various secondary sub-stations located at the strategic points in the city. At a secondary sub-station, 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 sub station stations. The secondary sub-stations are also generally of outdoor type.

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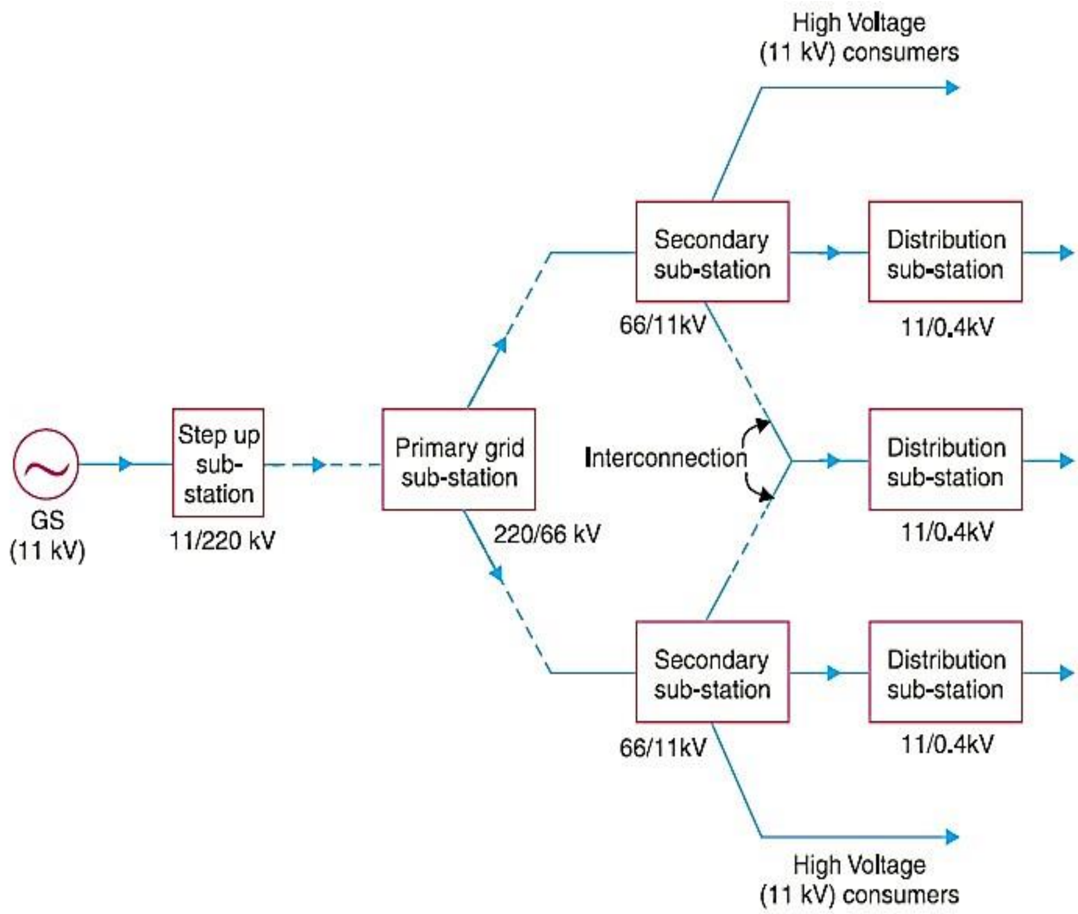

Figure 5.6.1 Transformer Sub-Stations

[Source: "Principles of Power System" by V.K.Mehta Page: 572]

(iv) Distribution sub-station.

The electric power from 11 kV lines is delivered to distribution sub-stations. These sub-stations 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.

5.6.3 Pole-Mounted Sub-Station

It is a distribution sub-station placed overhead on a pole. It is the cheapest form of sub-station as it does not involve any building work. Fig 5.6.2 (*i*) shows the layout of pole-mounted sub-station whereas Fig.5.6.2 (*ii*) shows the schematic connections.

(ii) Switching sub-stations

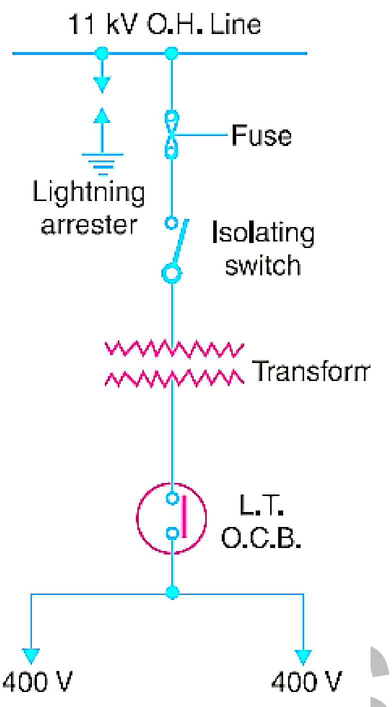

Figure 5.6.2 Pole-Mounted Sub-Station

[Source: "Principles of Power System" by V.K.Mehta Page: 573]

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 sub-station 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 sub-stations are generally used for transformer capacity upto 200 kVA. The following points may be noted about pole-mounted sub-stations :

(*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.

5.6.4 Underground Sub-Station

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 sub-station. In such sub-stations, the equipment is placed underground. Fig. 5.6.3 shows a typical underground sub-station. The design of underground sub-station requires more careful consideration than other types of sub-stations. While laying out an underground sub-station, 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.

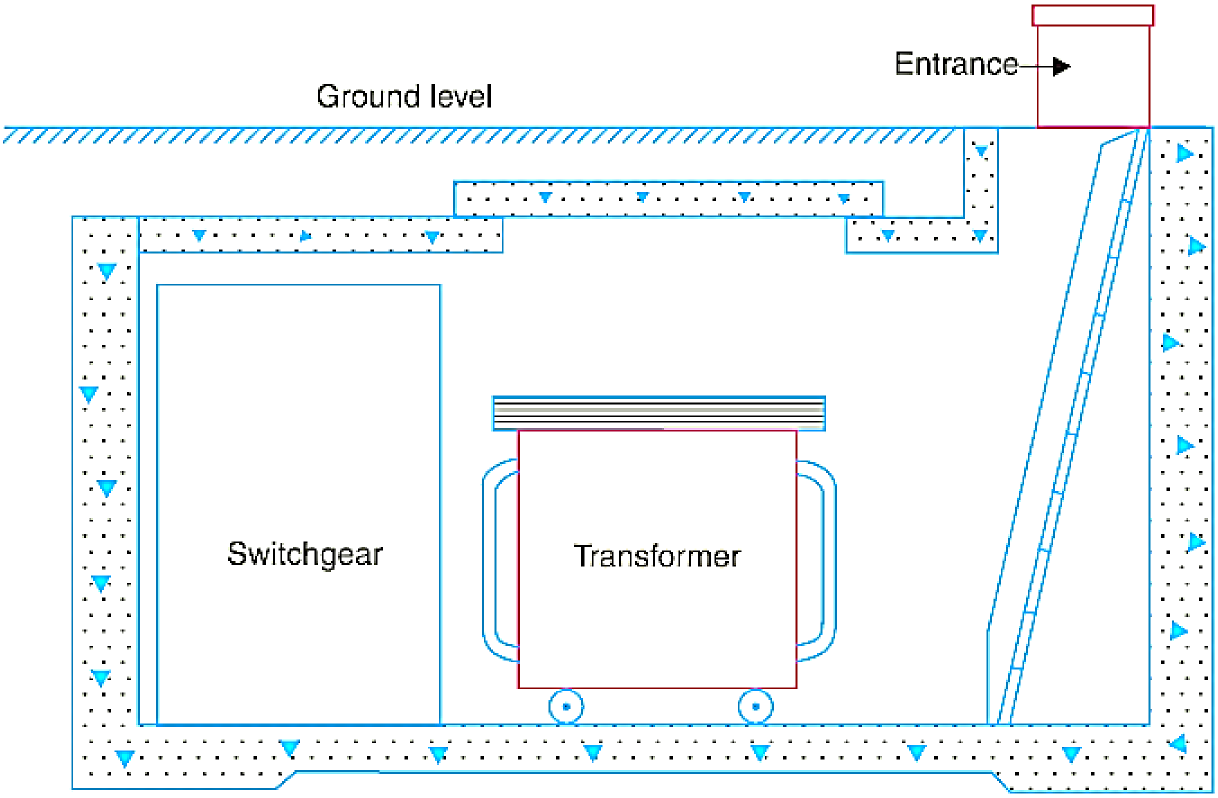

Figure 5.6.3 Underground Sub-Station

[Source: "Principles of Power System" by V.K.Mehta Page: 574]

(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.

5.6.5 Substation Layout

1.Substation Layout AIS

- AIS Substation 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

2.Substation Layout GIS

A gas insulated substation (GIS) is a high voltage substation in which the major structures are contained in a sealed environment with sulfur hexafluoride gas as the insulating medium. GIS technology originated in Japan, where there was a substantial need to develop technology to make substations as compact as possible. The clearance required for phase to phase and phase to ground for all equipment is much lower than that required in an air insulated substation; the total space required for a GIS is 10% of that needed for a conventional substation

Gas insulated substations offer other advantages in addition to the reduced space requirements. Because the substation is enclosed in a building, a GIS is less sensitive to pollution, as well as salt, sand or large amounts of snow. Although the initial cost of building a GIS is higher than building an air insulated substation, the operation and maintenance costs of a GIS are less.

The primary applications for gas insulated substations include:

High voltage installations

The higher the voltage, the more favorable gas insulated technology becomes. The footprint of 765kV conventional substation is enormous, and GIS technology allows a significant size reduction.

Urban Installations

GIS technology can be used for installations in areas where the cost of real estate or aesthetic appeal is a significant consideration.

Indoor Installations

Building an air insulated substation indoors is usually impractical, but a GIS can easily go inside buildings.

Environmentally Sensitive Installations

GIS technology is popular in desert and arctic areas because it can be enclosed in a building with environmental control. Gas insulated substations also contain the electrical components within a Faraday cage and are therefore totally shielded from lightning.