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Research Paper

Transmission System: A Comparative Analysis of HVAC and HVDC

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ABSTRACT

The generation of the electrical energy was started with the Direct current (DC) power in late 18th centaury. So the first transmission system was DC transmission system. The DC transmission system was inefficient because of the power losses in the transmission line, and the line losses were less in Alternating current (AC) transmission system. It was also possible to transmit the AC power at the high voltage to minimize the line losses. In the last four decades Power Electronics went through various inventions, these made easy the transmission of DC power at higher voltage with the minimum losses.

Because of the economical and technical benefits, now a day the HVDC transmission systems are being used to transmit the power over long distances and it is an alternative of HVAC transmission system also. We neither ignore the HVAC system completely nor the HVDC system. Both the HVAC and HVDC transmission systems have their own advantages and disadvantages this paper has been designed to differentiate both of these systems and the feasibility of these systems.

Key Terms: - HVDC, HVAC

1. Introduction: -

The generation of the electrical energy was started with the (Direct Current) DC power. So the transmission of the electrical energy was started with the DC transmission system. Thomas Alva Edison built DC electrical central station in 1880 in New York. Of late the AC generator were invented and the generation switched to the AC generation. There were some disadvantages in the DC transmission system such as high power losses in the transmission line and it was impossible to change the voltage level of the DC voltage, hence DC transmission are avoided by the Alternating current (AC) system and it was possible to change the voltage level of the AC voltage by using transformer. These were the reasons that the DC transmission system was ignored and the transmission switched to the AC transmission system.

In the last four decades the Power Electronics went through a lot of inventions and developments, these made available Silicon Controlled Rectifiers (SCR), of the high ratings and one can change the voltage level of the DC voltage with the help of SCRs. At the high voltage the DC power can be transmitted with minimum losses. The HDVC system is eco friendly as well as economical too, to transmit the DC power over long distances at higher voltage. The first HVDC transmission line of India is from Rihand to Dadri of 1500 MW capacity and the length of the transmission line is approximately 816 KM, started transmission in December 1991.

2. The AC Systems: -

The AC transmission lines are familiar since majority of the transmission lines are AC transmission lines. All the industrial and domestic consumers are fed by the AC systems, but there are some limitations of these systems when these are used to transmit the power over long distance such as line losses, environmental effects, stability and cost. These limitations led to the emergence of the HVDC transmission system in the long distance transmission projects. The AC system has following components:

1. Generating Station
2. Step-up Transformer
3. Transmission line
4. Step-down transformer

The generating stations are employed to generate the AC power. The AC power can be generated from the Hydroelectric, Nuclear, Thermal and Wind generating stations. In order to minimize the transmission losses it is necessary to step-up the generated power. Hence the step-up transformers are employed. The transmission lines are the carrier of the generated power. For the distribution of the power it is necessary to step down the power, so the step-down transformers are connected to the transmission line at the substation/ load center.

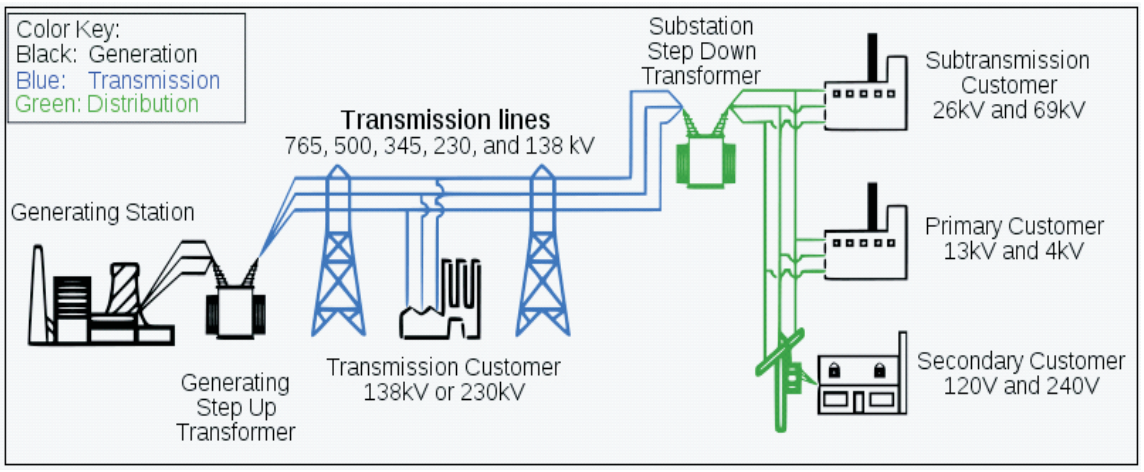

Fig: - Model of AC Power System

3. The HVDC system: -

The HDVC systems are build to transmit a huge amount of the electric power over a long distance. The HVDC system has the following components:-

1. Converting Station(AC to DC)
2. Transmission Line
3. Converting Station (DC to AC)
4. Filter

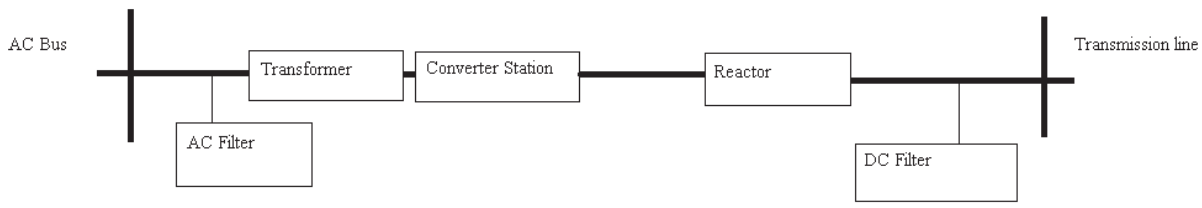

Fig:-2 Model of HVDC Power System

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The maximum power is generated in AC form, to transmit the power via DC transmission lines it necessary to convert the AC power into DC power, this is done by the first converter station. The transmission lines are employed to transmit the power from remote generating station to load center. At load center it is necessary to convert the DC into AC this is done by second converter station. To remove the harmonics filters are also used at the converter stations.

4. Economical Aspect: - Bulk power can be transmitted by both the AC and DC transmission Systemd from a remote generating station to the load center. For the decision making it is required to make cost comparison. In order to compare the cost it is necessary to consider the cost of all main component of the system. In case of the AC system capital cost of the step-up/step-down transformer, transmission line, reactive power compensation, light load compensation and circuit breaker must be accounted. Where in case of the DC system, the capital cost of converter, transmission line, AC input output equipment and filters used to remove the harmonics must be accounted. The cost of control system needs to be accounted for in both cases. However, the cost estimation is not easy because the cost of the components varies from place to place, manufacturer to manufacturer and time to time also. It is likely to conduct a new cost estimation study for the establishment of a new system

A.) AC Transmission Line Cost: - The cost of the AC transmission line depends upon many factors the power capacity to be transmitted, safety and environmental conditions. The AC transmission line needed more cost then that of the DC transmission line since a three phase AC transmission line has three conductors where as in DC transmission line has only two conductors due to this fact the cost of the AC transmission line is more in comparison to the DC transmission line.

B.) DC Transmission line Cost: - In case of the AC system the cost of the transmission line predominates and the cost of the station is less. In case of the HVDC system the cost of the transmission line is less than that of the AC system, but the cost of the converter station makes the total cost higher than that of the AC system.

5. Environmental Aspect: - The generated power by a remote generating station is transmitted to the load centers by the transmission lines. The load requirement is being increased day by day to satisfy the growing need of power. It is required to increase the capacity of the transmission line. These transmission lines have to cross all kind of places such as villages, cities, mountains and rivers. These transmission lines have harmful environmental effects which are making controversial issues since few year back. They have harmful environmental effects are RF interference, corona, magnetic field, electric field and danger of lighting storms. Let us have an eye-bird view of the same:

A.) RF interference: - There is fast current commutations incurrent and due to switching processes of the of the Thyristor value of converter this also causes change in voltage, which produces parasitic current. The parasitic current and operational

harmonics are of the order of kilohertz and megahertz portion of the radio frequency spectrum. These high frequencies propagates through the overhead transmission line through the converter station

B.) Corona:- When AC voltage is applied across two conductors, where spacing is large in comparison to diameter, and then the electrostatic stresses are setup in the atmospheric air surrounding the conductor. If the voltage is low, there will ne no change in the condition of air but in the case when voltage increases gradually, this produce ozone and air will start becoming conductive and after reaching a state of voltage a violet luminous glow will appear around the conductor with hissing noise. The phenomenon of appearance of violet luminous glow and production of hissing noise and ozone in overhead transmission line is known as corona. This is a function of the frequency the higher the frequency of supply, the higher are corona losses. Thus, corona losses are less in the DC transmission lines.

C.) Magnetic Field:- The magnetic field around the conductor is the function of current flowing through the conductor and distance from the conductor. The magnetic flux density is inversely proportional to the distance from the conductor. Magnetic field lines run in circles around the conductor (i.e. produces magnetic induction on objects and induced currents inside human and animal (or any other conducting) bodies causing possible health effects and a multitude of interference problems).The higher the current, the higher the strength of the magnetic field. Magnetic fields are typically measured in tesla (T) or more commonly, in gauss (G) and milli gauss (mG).

D.) Electric Field: - Electric field is produced by the voltage between the overhead conductor and earth. The amount of the flux can change with weather and relative humidity. The electric field problem is more in the AC transmission line, thus HVDC require much less right-of- way then horizontal AC configuration and less height then HVAC transmission line.

E.) Danger of Lighting Storms: -There is always a risk of lightning storms from the high voltage overhead transmission line. This is the reason we can't build a Extra High Voltage overhead transmission line.

F.) Skin Effect:-In the DC transmission lines, the current is distributed uniformly over the conductor and therefore use of the center of the conductor just as effectively as they use the periphery. However, AC owing to inductance effects within the conductor, crowd towards the outside of the conductor. This phenomenon is called skin effect. It raises the apparent resistance of the conductor. The skin effect is less in case of the DC transmission line.

G.) Ferranti Effect: -The long transmission line draws a substantial quantity of charging current. If transmission lines are open circuited or lightly loaded then voltage at receiving end will be greater than the voltage at the transmitting end, this effect is known as Ferranti effect. Since all electrical loads are inductive in nature hence they consume lot of reactive power from the transmission line which causes a voltage drop in transmission line. Capacitors which supply reactive power are connected parallel to the transmission line at receiving end so as to compensate the reactive power by the inductive loads.

The Ferranti Effect occurs when current drawn by the distributed capacitance of the transmission line itself is greater than the current associated with the load at the receiving end of the line. Therefore, the Ferranti effect tends to be a bigger problem on lightly loaded lines and especially on underground cable circuits where the shunt capacitance is greater than with a corresponding overhead line. This effect is due to the voltage drop across the line inductance (due to charging current) being in phase with the sending end voltages. As this voltage drop affects the sending end voltage, the receiving end voltage becomes greater. The Ferranti Effect will be more pronounced the longer the line and the higher the voltage applied. The Ferranti Effect is not a problem with lines that are loaded because line capacitive effect is constant independent of load, while inductance will vary with load. As inductive load is added, the VAR generated by the line capacitance is consumed by the load.

6. Advantages, Disadvantages and area of application of HVDC:-

A. Advantages: - The HVDC system has following advantage:-

- Ø Construction of transmission line is simpler.
- Ø Capable of carrying grater power per conductor.
- Ø No charging current.
- Ø No Skin effect.
- Ø Cables are capable of working at higher voltage gradient.
- Ø Ground return is possible.
- Ø Corona loss is less.
- Ø There is low short circuit current in DC system.
- Ø Power factor is unity.
- Ø DC system may connect the AC systems of different frequencies.
- Ø Distance is not limited by stability.
- Ø Less insulation is required.

B. Disadvantages:-Having these above advantages the HVDC system has some disadvantages also which are as following:-

- Ø Generation of DC power is not easy and economical.
- Ø Hence converters are used in HVDC are expensive.
- Ø Converters require much reactive power.
- Ø Harmonics are generated in the converters to remove these harmonics filter are used.
- Ø Network operation is not easy.
- Ø Reliable circuit breakers for high rating are not available.

C. Area of Application: - The HVDC systems are used in following application:-

- Ø The HVDC is used for the testing HVAC cables of long lengths.
- Ø It is also used in industries also such as:-Electrostatic painting, Cement industry and Communication system.
- Ø HVDC is also used in the Physics for particle acceleration and in medical equipment such as X-ray.

7. Advantages, Disadvantages and Application of HVAC:-

A. Advantages: - The advantage of the AC transmission system are as following:-

Ø An increase in the transmission voltage result increase in transmission line efficiency for a given amount of power over a given distance

Ø Voltage regulation is improved because of reduction in losses.

Ø The volume of the conductor material decreases because it is inversely proportional to the square of transmission voltage.

Ø Increase in the voltage decrease the per km insulation cost.

B. Disadvantages: - AC has a lot of disadvantages too as given below:-

Ø Corona loss and Radio interference.

Ø Insulation Requirement.

Ø Ferranti effect.

Ø Environmental and biological aspects

Ø Skin effect.

C. Area of Application:-The majority of the consumers are fed by AC system as given below:-

Ø Illumination.

Ø Electric Heating.

Ø Electric welding.

Ø Air conditioners

Ø and in majority of industries

8. Conclusion: -

In the Modern era there has been constantly increase in demand of electrical energy due to population explosion, modern life style, growing industrialization and urbanization etc. All these led demand of alternatives which increase the power transfer capacity of the new and existing transmission lines as well as. The power transmission by the AC transmission line is technically limited over the long distance because of the stability and reactive components problems in these systems. On other hand the HVDC system has no stability problem because there is no frequency components in the DC, thus, there is no limitation of distance in HVDC system. The cost the HVDC transmission line is less and there are less environmental effects of the DC system, which made it technically feasible to transmit the power by the HVDC transmission line but still both the HVAC and HVDC has their own advantages and limitations too.

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