EHV Transmission

EHV lines are used to move large amounts of power across long distances. The higher the voltage, the lower the losses. In addition, by being able to move more power across one line, fewer overall lines are needed for transmission. This reduces project costs and the right of way required.

EHV AC Transmission

Extra High Voltage (EHV) A.C. transmission may be considered to have come of age in 1952 when the first 380–400 kV line was put into service in Sweden. Since then, industrialized countries all over the world have adopted this and higher voltage levels. Very soon it was found that the impact of such voltage levels on the environment needed careful attention because of high surface voltage gradients on conductors which brought interference problems from power frequency to TV frequencies. Thus electrostatic fields in the line vicinity, corona effects, losses, audible noise, carrier interference, radio interference and TVI became recognized as steadystate problems governing the line conductor design, line height, and phase-spacing to keep the interfering fields within specified limits. The line-charging current is so high that providing synchronous condensers at load end only was impractical to control voltages at the sending-end and receiving-end buses. Shunt compensating reactors for voltage control at no load and switched capacitors at load conditions became necessary. The use of series capacitors to increase powerhandling capacity has brought its own problems such as increased current density, temperature rise of conductors, increased short-circuit current and subsynchronous resonance. All these are still steady-state problems.

However, the single serious problem encountered with e.h.v. voltage levels is the overvoltages during switching operations, commonly called switching-surge overvoltages. Very soon it was found that a long airgap was weakest for positive polarity switching-surges. The coordination of insulation must now be based on switching impulse levels (SIL) and not on lightning impulse levels only.

The reasons for adopting of EHV AC transmission:

1. Reduction of Electrical Losses, Increase in Transmission Efficiency, Improvement of Voltage Regulation and Reduction in Conductor Material Requirement:
For transmission of given amount of power over a given distance through the conductors of a given material and at a given power factor as the transmission voltage increases,

(a) Line losses are reduced since line losses are inversely proportional to the transmission voltage,

(b) Transmission efficiency increases because of reduction in line losses,

(c) Voltage regulation is improved because of reduction of percentage line drop, and

(d) Lesser conductor material is required being inversely proportional to the square of transmission voltage.

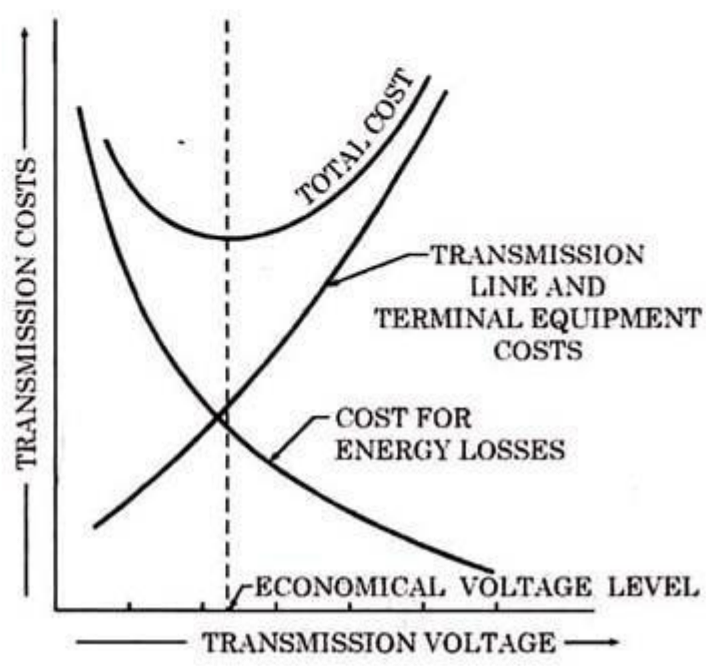
2. Economic considerations have led to the construction of power stations of large capacity and so need of transfer of bulk power over long distances arose. Transmission of bulk power from generating stations to the load centres is technically and economically feasible only at voltages in the EHV/UHV range.
3. Generating stations (Steam-, hydro- and nuclear-power stations) are located in remote areas (far away from load centres) because of the reasons of economy, feasibility and from the point of view of safety and environmental conditions. EHV transmission is, therefore, inevitable for transmission of huge blocks of power over long distances from these power plants to load centres.
4. Flexibility for Future System Growth:
There is flexibility of future system growth.

5. Increase in Transmission Capacity of the Line:

Power transferred is expressed as:

$$P = \frac{V_S \cdot V_R}{X} \sin \delta$$

where V_S and V_R are the two terminal voltages, δ is the load angle and X is the line reactance.
Thus the power transmission capacity of a transmission line increases with the increase in transmission voltage. No doubt the cost of transmission line and terminal equipment also increases with the increase in the transmission voltage but in general these costs are proportional to the transmission voltage rather than the square of the transmission voltage. Moreover there is also a saving in cost due to reduction in energy losses occurring in transmission lines. As a consequence the total cost of transmission decreases with the increase in transmission voltage, as depicted in Fig.



6. Possibility of Interconnections of Power Systems:
It is practically not possible to have interconnections of two or more power systems, which is necessary to achieve sharing of installed reserves and for development of integrated systems and grids, without EHV transmission.

7. Increase of Surge Impedance Loading:
Load carrying capability of a line is usually expressed in terms of "surge impedance loading" (SIL). Surge impedance loading (SIL) is the power that a line carries when each phase is terminated by a load equal to the surge impedance of the line.

For a transmission line, the surge impedance is given as $Z_C = \sqrt{L/C}$ where L and C are respectively the series inductance and shunt capacitance per unit length. The surge impedance loading (SIL), for a transmission line is given as $3V^2/Z_C$ where V is the line-to-neutral voltage.
It is evident that SIL varies as the square of the operating voltage, and, therefore, with the increase in voltage level, SIL itself increases. Thus power transfer capability of the line increases with the increase in voltage level.

The surge impedance of a line can be determined from its conductor configuration. The approximate values of surge impedances for lines with single, double, triple and quadruple conductors are 400, 300, 280 and 260 ohms respectively.

8. Reduction in Right-Of-Way:
In some countries 'rights-of-way' are paid for at a rate proportional to the total width of the transmission lines. Even in countries where right-of-way is not directly paid, there are usually strong pressures from the public towards fewer and fewer transmission lines.

Problem involved in EHV transmission

Although, there are many problems associated with EHV transmissions but some major problems are corona loss and radio interference. EHV transmission line requires heavy supporting structures and its is difficult to erect. There is one another major problem is, it require high insulation.

Problem 1. Corona Loss and Radio Interference.

The corona is not only a source of power loss but it is also a source of interference with radio and television. The corona loss depends on various factors such as system frequency, system voltage, air conductivity, air density, conductor radius, conductor surface, load conditions, atmospheric conditions etc. The problem is more acute in case of EHV transmission.

When the electric field at the surface of an energized conductor exceeds 2-3 kV/mm, audible and sometimes visible corona discharge takes place, causing a loss of power and radiation of electrical noise. Corona loss varies through the year depending upon weather conditions. The corona loss under bad weather conditions may be as high as 100 times the fair weather condition loss.

Corona inception voltage gradient is an important parameter for conductor design. For limiting the corona loss, audible noise and radio interference it is necessary to limit the electric stress at the surface of the conductor to 1.8 kV/mm (rms), preferably to 1.5 kV/mm (rms).

The corona loss can be reduced either by increasing the spacing between the conductors or the diameters of conductors but the spacing between the conductors cannot be increased to a large extent. Large diameter conductors (hollow conductors or ACSR conductors) have been used to bring down the corona loss and radio interference but the cost of manufacture of such conductors is high and their handling is both difficult and expensive.

Another difficulty with the use of such conductors is large wind and snow loadings. However, use of ACSR conductors is quite economical for line voltage up to 400 kV. Corona and radio-interference are also kept within permissible limits for such lines with this type of conductors. Bundled conductors, are invariably employed for EHV (400 kV or higher) lines.

The use of bundled conductors reduces the voltage gradient in the vicinity of line and thus, reduces the possibilities of corona discharge. Although the bundled conductors are used on EHV transmission lines primarily to reduce corona loss and radio-interference, but they have several other advantages.

The choice of configuration and cross-section of ac conductors with reference to corona considerations is generally above the economic cross-section based on thermal considerations or transient stability considerations i.e. the design of ac conductors based on corona limitations gives a cross-section much larger than that with respect to economical power transfer limit imposed by stability limit.

The corona loss is quite large in EHV transmission lines. For example, in a twin- Moose bundled conductor, 2×235 mm^2 (copper equivalent area) at 1.618 kV/mm of the 400 kV line, designed by UPSEB (Now U.P. P.C.L.) the annual corona loss per km of line is about 3,700 kWh. If the bundled-conductors were not having been employed in EHV lines, then corona loss would have been comparatively very high.
It is quite difficult to estimate corona loss with reasonable accuracy; as such loss depends on weather conditions. Attempts are made towards designing the transmission lines such that the fair weather corona loss is kept low and bad weather conditions do not seriously affect the line performance.

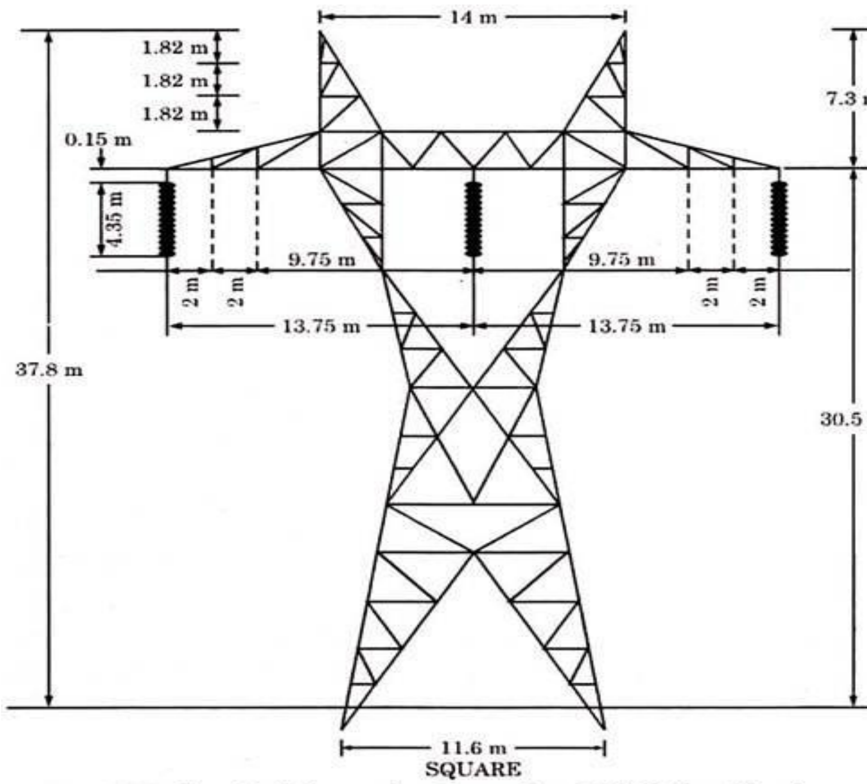
When bundled conductors are employed, spacers have to be installed at intervals of 80-100 m in each span to maintain the spacing between sub-conductors. This is necessary to prevent the conductors from getting stuck-up due to wind forces or electromagnetic induction introduced by heavy currents.

The increase in SIL with the increase in the spacing between the sub-conductors is small and, therefore, the intra bundle spacings are not very critical and 0.45 m is the most commonly used value.

Transmission lines with bundled conductors need somewhat stronger towers. It is due to the fact that bundled conductors are subjected to large wind and snow loadings.

Problem 2. Heavy Supporting Structures and Erection Difficulties.

EHV transmission lines have large mechanical loading on towers because of use of bundled conductors, large air and ground clearances, considerable dynamic forces due to broken conductors etc. Transmission line towers with fabricated steel members are usually employed in EHV transmission. A typical standard suspension tower for a 500 kV line is shown in Fig.



Standard Suspension Tower For 500 kV Line Showing Various Arrangements For Locations of Conductors and Ground Wires

The transmission lines are made more wind-resistant as they are to bear out the wind pressures during storms and cyclones.

Problem 3. Insulation Requirements.

The level of insulation required depends upon the magnitude of likely voltage surges due to internal causes (switching operations) or due to external causes (lightning etc.) The lines are usually protected against lightning etc. by use of ground wire and rapid auto-reclosing circuit breakers.

The ground wire, the line insulation and the tower footing are properly coordinated for adequate lightning protection. Switching surges are, however more dangerous as they may cause overvoltage's of 2-3 times the normal operating voltage. With the developments in the design of relay-breaker systems, however it is possible to control and minimise switching over-voltages.

Line insulation is designed to take care of switching overvoltage's, temporary overvoltage's and atmospheric overvoltage's. The insulation level of a transmission line is based on the switching surge expectancy on the system. The maximum switching surge overvoltage to the ground is taken as 2.5 pu and the insulation is designed for this voltage. In addition adequate protection against atmospheric overvoltage's is provided.

HV DC Transmission

Definition: High voltage direct current (HVDC) power systems use D.C. for transmission of bulk power over long distances. For long-distance power transmission, HVDC lines are less expensive, and losses are less as compared to AC transmission. It interconnects the networks that have different frequencies and characteristics.

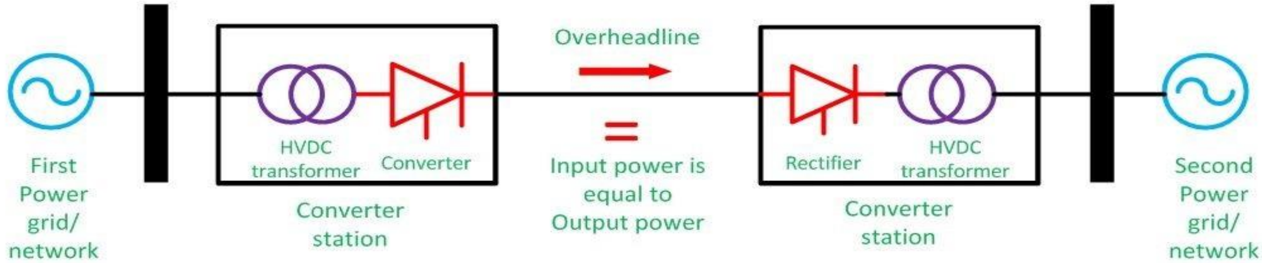
In AC transmission, alternating waves of voltage and current travels in the line which change its direction every millisecond; due to which losses occur in the form of heat. Unlike AC lines, the voltage and current waves don't change their direction in DC. HVDC lines increase the efficiency of transmission lines due to which power is rapidly transferred.

In a combined AC and DC system, generated AC voltage is converted into DC at the sending end. Then, the DC voltage is inverted to AC at the receiving end, for distribution purposes. Thus, the conversion and inversion equipment are also needed at the two ends of the line. HVDC transmission is economical only for long distance transmission lines having a length more than 600kms and for underground cables of length more than 50kms.

Working Principle

In generating substation, AC power is generated which can be converted into DC by using a rectifier. In HVDC substation or converter substation rectifiers and inverters are placed at both the ends of a line. The rectifier terminal changes the AC to DC, while the inverter terminal converts DC to AC.

The DC is flowing with the overhead lines and at the user end again DC is converted into AC by using inverters, which are placed in converter substation. The power remains the same at the sending and receiving ends of the line. DC is transmitted over long distances because it decreases the losses and improves the efficiency.

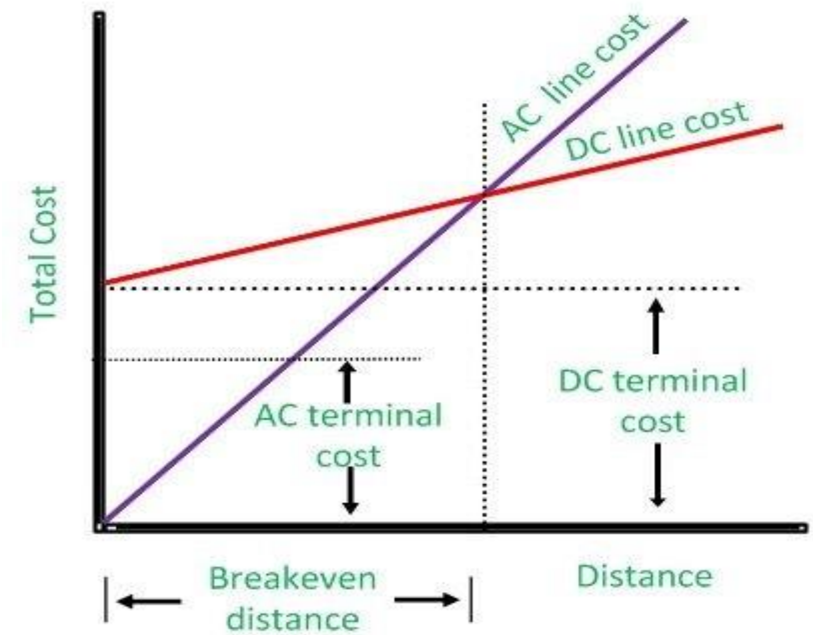


HVDC Substation Layout

A system having more than two converter stations and one transmission line is called a ‘two terminal DC system’ or a ‘point-to-point system’. Similarly, if substation has more than two converter stations and interconnecting DC terminal lines, it is called multiterminal DC substation.

Economic Distance For HVDC transmission lines

DC lines are cheaper than the AC lines, but the cost of DC terminal equipment is very high as compared to AC terminal cables (shown in the graph below). Thus, the initial cost is high in HVDC transmission system, and it is low in the AC system.



Comparision of the costs of AC and DC transmission

The point where two curves meet is called the breakeven distance. Above the breakeven distance, the HVDC system becomes cheaper. Breakeven distance changes from 500 to 900 km in overhead transmission lines.

Advantages of HVDC transmissions

1. A lesser number of conductors and insulators are required thereby reducing the cost of the overall system.
2. It requires less phase to phase and ground to ground clearance.
3. Their towers are less costly and cheaper.
4. Lesser corona loss is less as compared to HVAC transmission lines of similar power.
5. Power loss is reduced with DC because fewer numbers of lines are required for power transmission.

6. The HVDC system uses earth return. If any fault occurs in one pole, the other pole with ‘earth returns’ behaves like an independent circuit. This results in a more flexible system.
7. The HVDC has the asynchronous connection between two AC stations connected through an HVDC link; i.e., the transmission of power is independent of sending frequencies to receiving end frequencies. Hence, it interconnects two substations with different frequencies.
8. Due to the absence of frequency in the HVDC line, losses like skin effect and proximity effect does not occur in the system.
9. It does not generate or absorb any reactive power. So, there is no need for reactive power compensation.
10. The very accurate and lossless power flows through DC link.

Disadvantages of HVDC transmission

1. Converter substations are placed at both the sending and the receiving end of the transmission lines, which result in increasing the cost.
2. Inverter and rectifier terminals generate harmonics which can be reduced by using active filters which are also very expensive.
3. If a fault occurs in the AC substation, it may result in a power failure for the HVDC substation placed near to it
4. Inverter used in Converter substations have limited overload capacity.
5. Circuit breakers are used in HVDC for circuit breaking, which is also very expensive.
6. It does not have transformers for changing the voltage levels.
7. Heat loss occurs in converter substation, which has to be reduced by using the active cooling system.
8. HVDC link itself is also very complicated.

Application of HVDC Transmission

- Undersea and underground cables
- AC network interconnections
- Interconnecting Asynchronous system

Comparison of both HVAC and HVDC Transmission System

HVDC Transmission System	HVAC Transmission System
Low losses.	Losses are high due to the skin effect and corona discharge
Better Voltage regulation and Control ability.	Voltage regulation and Control ability is low.
Transmit more power over a longer distance.	Transmit less power compared to a HVDC system.
Less insulation is needed.	More insulation is required.
Reliability is high.	Low Reliability.
Asynchronous interconnection is possible.	Asynchronous interconnection is not possible.
Reduced line cost due to fewer conductors.	Line cost is high.
Towers are cheaper, simple and narrow.	Towers are bigger compared to HVDC.

ASSIGNMENT QUESTIONS

1.What is the requirement of high voltage transmission?

2. What is EHV AC Transmission?

3. Explain the problems involved in EHV Transmission System.

4. What is HVDC Transmission? Write down their application.

5. Write down the advantages of HVDC over HVAC Transmission system.