High Voltage Direct Current Transmission System

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Abstract-**Beginning with a brief historical perspective on the development of High Voltage Direct Current (HVDC) transmission systems, this paper presents an overview of the status of HVDC systems in the world today and also gives reviews the underlying technology of HVDC systems and explains the HVDC systems from a design, construction, operation and maintenance point of view. Here also discusses the recent developments in HVDC technologies. The paper also presents an economic and financial comparison of HVDC system with those of an AC system. The overall discussion concludes with a brief set of guidelines for choosing HVDC systems in today's electricity systems development. In today's electricity industry, in view of the liberalization and increased effects to conserve the environment.**

Key words -**HVDC, HVAC, Converters, AC circuit Breaker, Transformer.**

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I. INTRODUCTION

Power does not rely only on voltage, but is equal of voltage times current.

$$P=VI \quad \text{----------------- (1)}$$

For a given power a low voltage require a higher current and a higher voltage requires a lower current. However, since metal conducting wires have a certain resistance, some power is wasted, and transfer as heat. The power losses in a conductor are proportional to the square of current and resistance of conductor.

$$P=I^2R \quad \text{----------------- (2)}$$

Power is also proportional to voltage, so for given power level, higher voltage let decrease a current level. Higher level of voltage, give us also lower power loss. Power loss can be also reduced by decreasing resistance e.g. by increasing diameter of conductor, but it's demand higher economical costs.

High voltage transmission is used to reduce loss of power, but it cannot be used for lightning system and supplying motors. High voltage level has to be adjust to receivers. In AC are using transformers which decreasing or increasing voltage to required level. In DC does not exist such possibility. In those technologies manipulation is possible for more complicated way. To changing a level of voltage, electronic devices are used as mercury arc valves, such as semiconductors devices, thyristors, insulated-gate bipolar transistors (IGBTs), high power capable MOSFETs (power metal–oxide–semiconductor field-effect transistors) and gate turn-off thyristors (GTOs).

In AC voltage conversion is simple, and it demands little maintenance. Further three-phase generator is superior to DC generator in many aspects. Those reasons causes that AC technology is today common in production, transmission and distribution of electrical energy. However alternative current transmission has also drawback which can be compensate in DC links. It's the main reason why DC technology is chosen instead AC:

- inductive and capacitive elements of lines put limits to the transmission capacity and transmission distance
- It is not possible transmission between two points of different current frequency

Therefore electrical engineers research and applied DC technology which doesn't have such limitation.

II. INDIAN HVDC PROJECTS

1. 500 kV, 1500 MW Rihand- Dadri:

Date of commission: Dec-1991

Main Data:

1) Power rating : 1500MW
2) No. of poles : 2
3) AC Voltage : 400kV
4) DC Voltage : ±500 kV
5) Converter Transformer-
   Rihand Terminal : 6 × 315 MVA
   Dadri Terminal: 6× 305 MVA
6) Length of Over-head DC line : 816 km.

2. 2×250 MW HVDC Vindhyachal Back to Back:

Completion Date: April-1989

Main Data:

1) Power Rating : 2×250 MW
2) NO. of Blocks : 2
3) AC Voltage : 400kV
4) DC Voltage : ±70kV
5) Converter Transformer : 8×156 MVA

3. 2×500 MW HVDC Chandrapur-Padghe:

Start Date: November-1993

Completion Date: Decembeer-1997

Main Data:

1) Power Rating : 2×500 MW.
2) No. of Blocks : 2
3) AC Voltage : 400 kV
4) DC Voltag : 500kV
5) Converter Transformer : 12×234 MVA

4. 2000 MW, 500kV HVDC Talchar-Kolar:

Completion Date: June-2003

Main Data:

1) Power Rting : 2000 MW
2) No. of Blocks : 2
3) AC Voltage : 400 kV
4) DC Voltage : ±500 kV
5) Converter Transformer-
   Talcher : 6×398 MVA
   Kolar : 6×398 MVA
6) Length of Overhead DC line : 1369km.

III. SYSTEM COMPONENT

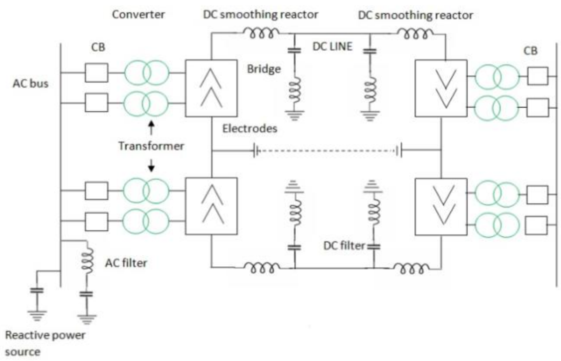

Fig.1.System component

Converters: The AC to DC and DC to AC conversion are done by the converters. It includes transformers and valve bridges.

Smoothing Reactors: Each pole consist of smoothing reactors which are of inductors connected in series with the pole. It is used to avoid commutation failures occurring in inverters, reduces harmonics and avoids discontinuation of current for loads.

Electrodes: They are actually conductors which are used to connect the system to the earth.

Harmonic Filters: It is used to minimise the harmonics in voltage and current of the converters used.

DC Lines: It can be cables or overhead lines.

Reactive Power Supplies: The reactive power used by the converters could be more than 50% of the total transferred active power. So the shunt capacitors provide this reactive power.

AC Circuit Breakers: The fault in the transformer is cleared by the circuit breakers. It also used to disconnect the DC link.

IV. TYPES OF DC LINK

The DC link may be classified into:

a) Monopolar DC link
b) Bipolar DC link
c) Homopolar DC link

a. MONOLAR DC LINK

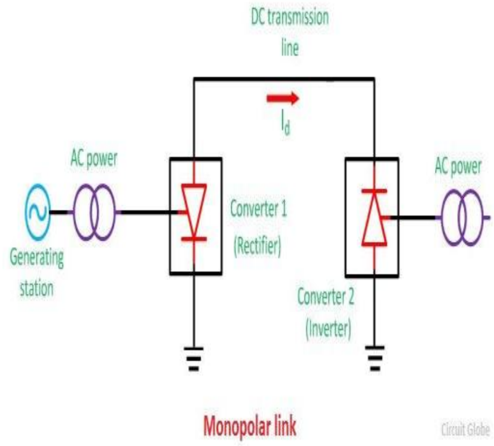

Fig.2. MONOPOLAR DC LINK

As the name suggests, monopolar link has only one conductor and return path is provided by permanent earth or sea. The line usually operates with negative polarity with respect to ground so as to reduce corona loss and radio interference. The earth electrodes are designed for continuous current operation and for any overload capacity required in the specific case. The sea or ground return path has low resistance and, therefore, low power loss in comparison with a metallic line conductor of economical and equal length provided the ground electrodes are of proper design. Monopolar line is more economical than a bipolar line because the ground return saves the cost of the one metallic conductor and losses in it. Monopolar HVDC links were used only for low power rating and mainly for cable transmission. In some cases the monopolar lines installed earlier are converted into bipolar systems by adding additional substation pole and transmission pole. Monopolar HVDC line has only the rating equal to half of corresponding bipolar line rating and is, therefore, not economically competitive with EHVAC schemes for submarine cables longer than 25 km and of power rating of 250 MW. For such cable transmission high voltage AC scheme is not technically feasible due to large charging currents with AC cables beyond thermal limits. Bipolar cable is not justified for rating up to about 500 MW. Recent HVDC cable schemes are bipolar.

b. BIPOLAR DC LINK

This link has two conductors, one positive and other is negative potential of the same magnitude (e.g. ±500 KV). At each terminal, two converters of equal rated voltages are connected in series on the DC side.

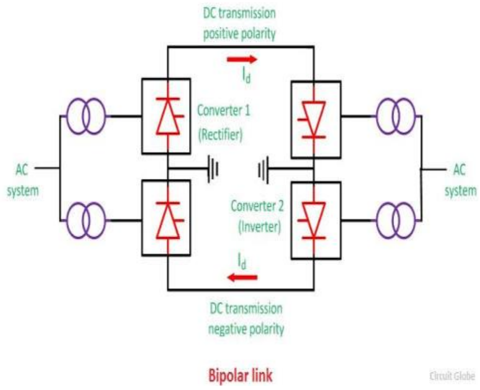

Fig.3 BIPOLAR DC LINK

The neutral points (i.e. the junction between converters) are grounded, at one or both ends. If both the neutrals are grounded, the two poles operates independently. If the currnt in the two conductors are equal, the ground current is zero. If one conductor ha fault the other conductor (along with ground return) can supply the half the rated load. The rated voltage of bipolar link is given as (say) ±500 KV. The bipolar trnasmission has two circuitswhich are almost independent to each other. A bipolar ink can be operated as a onopolar line in emergency. In some application contineous current through earth is not permitted, and the bipolar arrangement is the natural solution.

c. HOMOPOLAR DC LINK

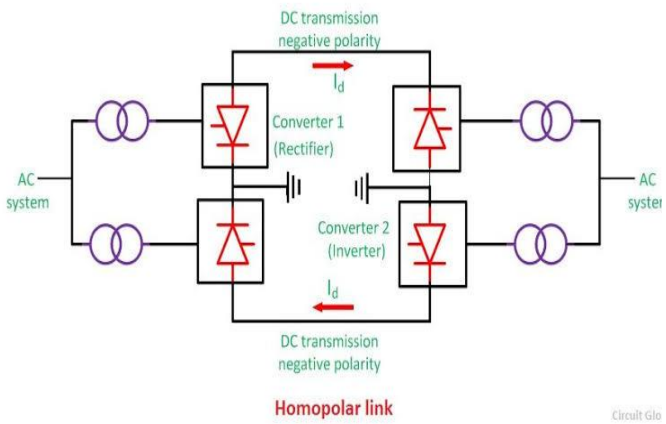

Fig.4 HOMOPOLAR DC LINK

A homopolar link shown in above fig. has two or more conductors, all having the same polarity (usually negative), as the corona losses and radio interfarance get reduced, and it always operates with ground return. If one of the conductors developes the fault, the converter equipment can be reconnected so that the healthy conductor (with some overload capacity) can supply more than 50% of the rated power. A two-conductor DC line is more reliable than a three conductor AC line, Because in the event of fault on one conductor, the other conductor can contineu to operate with ground return during the fault period. The same is not possible with AC line. Furthermore if a two pole (homopolar) DC line is compared with a double-circuit three phase AC line, the DC line cost would be about 45% less than the AC line.

In general, the cost advantage of the DC line increases at higher voltages.

V.COMPARISON BETWEEN HVDC VS HVAC

Sr. No	Characteristics	HVAC	HVDC
1.	**Capital cost** Line cost Substation cost Number of circuits Intermediate Substation	 Higer Lower More Required	 Lower Higher One Not Required
2.	Skin Effect	Present	Absent
3.	Ground Return	Not possible	Possible
4.	Line Losses	High	Low
5.	Power Transfer	Limits impossed by power angle and line inductive reactance	No limit
6.	Voltage Control	Difficult for long lines due to series inductance and shunt capacitance.	Easier
7.	Compensation Requirement	Series and shunt compensation in necessary	No compensation is required
8.	Corona and Radio Interface	More	Less
9.	Reliability	Lesser	More
10.	Short-circuit Current	Large	Small
Sr. No	Characteristics	HVAC	HVDC
11.	Control System	Simpler, cheaper and limitations of	Difficult, costlier but fast and

		control	accurate control
12.	Stability of network	Very low due to line inductive reactance	Much higher

VI. Economic Considerations

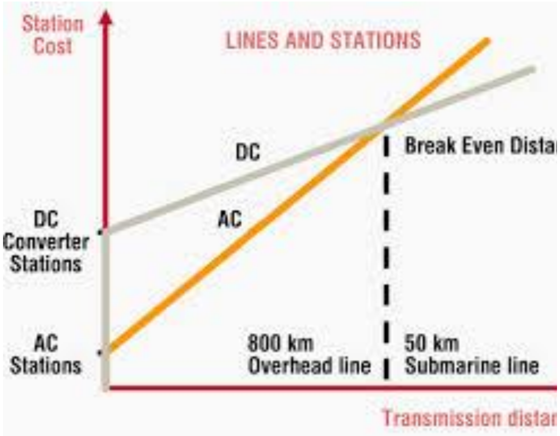

Fig.5 ECONOMIC COMPARISON BETWEEN DC AND AC TRANSMISSION LINE

From above graph we can see that the initial cost of HVDC transmission station is high as compared to HVAC transmission station.At break even distance the total cost of HVDC is equal to total cost of HVAC the break even distance in the range of 60 to 800 km and after the break even distance HVDC transmission system economic than HVAC

VII. Advatages Of Hvdc Transmission

1. Cheaper in Cost: Bipolar HVDC transmission lines required two-pole conductors while AC system requires 3 conductors. HVDC transmission system can utilize earth return and, therefore, does not require a double circuit while EHVAC transmission always required a double circuit. And because of lesser load on the supporting structures tower designs are simple and cheaper. EHVDC transmission needs intermidiate substation at an interval of 300 km for compensating but HVDC transmission system does not required any such intermidiate substation for compensation.

HVDC transmissionbecome economical over the ac transmission obove break-oven distance. The break-even distance is generally different for different projects. For overhead lines it may be about 600-800 km while for submarine cables and underground cables it may lie in the range of 20 to 30 km and 50 to 100 km respectively.

2. No Skin Effect: Thre is no skin effect in dc, so there is a unifor distribution of current over the section of the coductor. Thus y\tere is full utilisation of line coductor in case of dc transmission while it is not so in case of ac transmission.

3. Lower Transmission Losses: HVDC transmission systems needs only two conductor and, therefore, the powewr losses in line are lesser than the losses in ac of the same power transfer capability.

4. Voltage Regulation: There is no inductance, hence the voltage drop due to inductive reactance does not exist in dc transmission line. Thus voltage regulation is beter in case of dc transmission.

5. Line Loading: The permissibleloading on an EHVAC is limited by transient stability limit and line reactance to almost one-third of thermal rating of conductor. No such limits is exist in case of HVDC lines.

6. Surge Impedance Loading: Long HVAC lines are loaded to less than 80% of the natural load. No such condition is applicable to HVDC lines.

7. An HVDC line can be built in stages: The dc line can be built as a monopolar line with ground return in the initial stage and may be converted into bipolar line on a later date when the load requirement increases.

8. Greater Reliability: A two conductor bipolar dc line is more reliable than a 3-wire 3-phase ac line because the dc line may be operated in a monopolar mode with ground return when the other line developes a fault.

9. Rapid Change in Energy Flow: The control of thyristor valves permit rapid change in magnitude and direction of power flow when the two ac systems are interconnected by a dc link. Thus more flexible coordination of system control at the two ends, a more economical use of cheap power generetion in either of two ac systems, and reduction of system reserve and standby capacity are available. Transient satability is also increased.

10. Absence of Charging current and Limitation of Cable Lengths: Because of large charging current, the use of EHVAC for underground transmisssion over long distances is prohabited but because of absense of charging current in DC system there is no limit on the length of the cable. In ac systems there is limit on length of cable depending upon voltage about 60 km in case of 145 kV, 40 km in case of 245 kV and 25 km in case of 400 kV.

11. Low Short-Cuircuit Current: In ac transmission, addition of parallel line results in larger short circuit current in the system. This is due to reduce equivalent reactance. When an existing ac system is interconnected with other ac system by ac transmission line, the fault level of both the systems increases. Sometimes necessitates the replcement of the existing circuit breakers by the ones of higher rating. However, when the two ac systems are interconnected by a dc line, the contribution of dc line to the short circuit current is only up to the rated current of the dc line. During fault in dc line, grid control of converter can drastically reduced the fault current.

12. Lesser Corona Loss and Radio Interference: The corona loss is directly proportional to (f+25), where f is the supply frequency. So corona loss in dc system are lesser than those in ac system for the same conductor diameter and operating voltage. This is because in dc system f is equal to zero. Corona loss and radio interference are directly related and, therefore, radio interference in case of dc is less.

13. Higher Operating Voltages: Modern high voltage transmission line are designed on the basis of expected switching surge rather than lightning surges because the former are more severe in comparison to the latter. The level of switching surges due to dc is lower than that due to ac and, therefore, the same size of conductor and string insulators can be employed for higher voltages in case of dc as compare to ac.

14. Higher Current Carrying Capacity: The transmission cables have lesser dielectric power loss in dc in comparison with ac and, therefore, have higher current carrying cpacity.

VIII. Limitations Of HVDC Transmission

1. The systems are costly since installation of complicated converters and DC switchgear is expensive.
2. Converters require considerable reactive power.
3. Harmonics are generated which required filters.
4. Converters do not have overload capacity.
5. Lack of HVDC circuit breakers hampers multiterminalsor network operation. There is no DC device which can perform exellent switching operations and ensure protection. (Simultaneous control at all converters is difficult).
6. There is nothing like DC transformer which can change the voltage level in a simple way. Voltage transformation has to be provided on the AC sides of the system.
7. Reactive power required by the load is to be supplied locally as no reactive power can be transmitted over a DC link.
8. Contamination of insulators is polluted in some areas or along the sea coast. Pollution affects DC more thn AC. So frequent cleaning of insulators is required.

IX. Future Trends

Considerabile research and development is underway to provide a better understanding of the performance of HVDC link to achieve more effeicint and economic design of the thyristor-valve and related equipment and to justify the use of alternative AC/DC system configuration. Future power system would include a transmission mix of AC and DC. Future controllers would be more and more microprocessor based, which can be modified and updated without requiring hardware changes, and without bringing entire system down. While one cotroller is in action the duplicate controller is there as a ‘hot standby’ in case of sudden need. In near future it is expected that fibre optics system would be used to generate firring siganl and the direct light fired thyristor would be emplyed for HVDC converters. Currently a great deal of effort is being devoted to future research and development in solid state technology due to which one can hope that HVDC converters and multi- terminal DC (MTDC) system will play an even greater role in the power systems of the 21st century.

Conclusion

Today HVDC is very important issue in transmission energy. In near future this technology probably will be develop very intensive. Influence on future may have intensive spread of renewable energy source, also wind farm which need undersea connections. Also problem of cascade blackout, can be reduced by application of HVDC. Intensive, very large investments in e.g in China and India shows that high-voltage direct current will very important in the future, especially in big, new-industrial countries.

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