1.1 Introduction

Electric power transmission was originally developed with direct current. The availability of transformers and the development and improvement of induction motors at the beginning of the 20th century, led to the use of AC transmission.

DC Transmission now became practical when long distances were to be covered or where cables were required. Thyristors were applied to DC transmission and solid state valves became a reality.

With the fast development of converters (rectifiers and inverters) at higher voltages and larger currents, DC transmission has become a major factor in the planning of the power transmission. In the beginning all HVDC schemes used mercury arc valves, invariably single phase in construction, in contrast to the low voltage polyphase units used for industrial application. About 1960 control electrodes were added to silicon diodes, giving silicon-controlled-rectifiers (SCRs or Thyristors).

Today, the highest functional DC voltage for DC transmission is +/- 600kV. D.C transmission is now an integral part of the delivery of electricity in many countries throughout the world.

In large interconnected systems, power flow in AC ties (particularly under disturbance conditions) can be uncontrolled and lead to overloads and stability problems thus endangering system security. Strategically placed DC lines can overcome this problem due to the fast controllability of DC power and provide much needed damping and timely overload capability. The planning of DC transmission in such applications requires detailed study to evaluate the benefits. Example is the Chandrapur-Padghe link in India.

Presently the number of DC lines in a power grid is very small compared to the number of AC lines. This indicates that DC transmission is justified only for specific applications. Although advances in technology and introduction of Multi-Terminal DC (MTDC) systems are expected to increase the scope of application of DC transmission, it is not anticipated that the AC grid will be replaced by a DC power grid in the future. There are two major reasons for this:

First, the control and protection of MTDC systems is complex and the inability of voltage transformation in dc networks imposes economic penalties.

Second, the advances in power electronics technology have resulted in the improvement of the performance of AC transmissions using FACTS devices, for instance through introduction of static VAR systems, static phase shifters, etc.

Need for HVDC Systems

For long-distance transmission, HVDC systems may be less expensive and suffer lower electrical losses. For underwater power cables, HVDC avoids the heavy currents required to charge and discharge the cable capacitance each cycle. For shorter distances, the higher cost of DC conversion equipment compared to an AC system may still be warranted, due to other benefits of direct current links.

HVDC allows power transmission between unsynchronized AC transmission systems. Since the power flow through an HVDC link can be controlled independently of the phase angle between source and load, it can stabilize a network against disturbances due to rapid changes in power. HVDC also allows transfer of power between grid systems running at different frequencies, such as 50 Hz and 60 Hz. This improves the stability and economy of each grid, by allowing exchange of power between incompatible networks.

Brief History

HVDC technology first made its mark in the early under-sea cable interconnections of Gotland (1954) and Sardinia (1967), and then in long distance transmission with the Pacific Intertie (1970) and Nelson River (1973) schemes using mercury-arc valves. A significant milestone occurred in 1972 with the first Back to Back (BB) asynchronous interconnection at Eel River between Quebec and New Brunswick; this installation also marked the introduction of thyristor valves to the technology and replaced the earlier mercury-arc valves.

The first 25 years of HVDC transmission were sustained by converters having mercury arc valves till the mid-1970s. The next 25 years till the year 2000 were sustained by line-commutated converters using thyristor valves. It is predicted that the next 25 years will be dominated by force-commutated converters . Initially, this new force-commutated era has commenced with Capacitor Commutated Converters (CCC) eventually to be replaced by self-commutated converters due to the economic availability of high power switching devices with their superior characteristics.

The first commercially used HVDC link in the world was built in 1954 between the mainland of Sweden and island of Gotland. Since the technique of power transmission by HVDC has been continuously developed.

In India, the first HVDC line in Rihand-Delhi in 1991 i.e. I 500 KV, 800 Mkl, 1000 KM. In Maharashtra in between Chandrapur & Padaghe at 1500 KV & 1000 MV. Global HVDC transmission capacity has increase from 20 MW in 1954 to 17.9 GW in 1984. Now the growth of DC transmission capacity has reached an average of 2500 MW/year.

Table 1.1 List of HVDC Projects in India.

S.No	Project Name	Connecting Region	Commissioned On	Power Rating	AC Voltage	DC Voltage	Mode Of Operation	No. of Poles/ Blocks	Length Of Line
1.	**Rihand-Dadri**	ER-WR	December 1991	1500 MW	400 KV	500 KV	Bipole	2	816 Km
2.	**Talcher-Kolar**	ER-SR	June 2003	2000 MW	400 KV	500 KV	Bipole	2	1369 Km
3.	**Ballia-Bhiwadi**	ER-NR	Pole1: March 2010 Pole 2: March 2011	2500 MW	400 KV	500 KV	Bipole	2	780 Km
4.	**Chandrapur Padge**	CR-WR	1999	1500 MW	400 KV	500 KV	Bipole	2	752 Km
5.	**Mundra-Mohindergarh**	WR-NR	2012	1500 MW	400 KV	500 KV	Bipole	2	986 Km
6.	**Bishwanath-Agra**	NER-ER	2015	6000 MW	400 KV	800 KV	Multi-Terminal	2	1728 Km
7.	**Vidhyanchal**	WR-NR	April 1989	2x250 MW	400 KV	70 KV	Back To Back	2	-
8.	**Chandrapur**	WR-SR	December 1997	2x500 MW	400 KV	205 KV	Back To Back	2	-
9.	**Sasaram**	ER-SR	September 2002	1x500 MW	400 KV	205 KV	Back To Back	2	-
10.	**Gazuwaka**	ER-SR	March 2005	2x500 MW	400 KV	Block 1: 205 KV Block 2: 177 KV	Back To Back	2	-