VOLTAGE SOURCE CONVERTER BASED HVDC TRANSMISSION SYSTEM

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ABSTRACT

The ever increasing progress of high-voltage high power fully controlled semiconductor technology continues to have a significant impact on the development of advanced power electronic apparatus. Power electronic apparatus are used to support optimized operations and efficient management of electrical grids. In this paper, an overview of the recent advances technology in the area of voltage source converter (VSC) HVDC transmission system is provided. This paper also provides a list of VSC-basedHVDC installations worldwide is included.

It is confirmed that the continuous development of power electronics presents cost effective opportunities for the utilities to exploit, and HVDC remains a key technology. In particular, VSC-HVDC can address not only conventional network issues such as bulk power transmission, asynchronous network interconnections, back-to-back ac system linking, and voltage/stability support to mention a few, but also niche markets such as the integration of large-scale renewable energy sources with the grid and most recently large onshore/offshore wind farms.

Keyword : HVDC Links, HVDC System, VSC HVDC, Worldwide Project, Etc.

I INTRODUCTION

In recent year, DC power supply technology has been retarded again. As compared to basic and traditional High Voltage Direct Current (HVDC) technology has an effective and reliable way of transmitting electrical power over long distances [1]. HighVoltageDirectCurrenttechnology has certain characteristicswhichmakeitespecially attractive for transmission systemapplications.HVDC transmission systemis useful for bulk power delivery, long-distance transmission andlong submarinecablecrossings and asynchronousinterconnections. ThenumberofHVDC system projects committed and several under consideration globally have increased in recent years showing are newed interest in this High Voltage Direct Current technology. New converter design shave widened the voltage range of High Voltage Direct Current transmission systemtoincludeapplications for offshore, underground, economic replacement of reliability in generation, and voltagestabilization. The development includes higher transmission voltage range upto ± 800kV. For weak system applications capacitor-commutated converters and voltage-sourced converters withdynamicreactivepowercontrol. This broader technology range has increased the HVDC applications and contributed to the recent growth of HVDC transmission [2]. The voltage source converter based HVDC transmission technology is more flexible and more suitable for the constructionof multi-terminal DCtransmissionandDC grids constructionof multi-terminal DCtransmissionandDC grids. The voltage source converter based HVDC transmission system has broad applications in the fields of the integration of renewableenergy sources withthegrid, theinterconnection of urban electric grid and soon [3]. By connecting rectifier and inverter through DC cable or overhead transmission line, the power transmitted from sending end to the receiving end. MostprojectapplicationsofVoltage Source Converter HVDCadoptcables to reduce the high fault possibility, radio interference and audible noiseof overhead line [4].

HVDC systems is important technology, supporting in their own way the modern power systems, which in many cases are fully partially deregulated in several countries [6]. In the near future, even higher integration of electrical grids and market driven developments are expected as, for instance, countries in the Middle-East, China, India and South America require infrastructure to power their growth [7]-[11]. Today, there are more than 92 HVDC projects worldwide transmitting more than 75GW of power employing two distinct technologies as follows [12]:

1. Line-commutated Current-Source Converters (CSCs) using thyristors. This technology is well established for high power, typically around 1000MW, with the largest project being the Itaipu system in Brazil at 6300MW power level [12].

2. Forced-commutated Voltage-Source Converters (VSCs) using gate-turn-off thyristors (GTOs) or in most industrial cases insulated gate bipolar transistors (IGBTs). It is well established technology for medium power levels thus far, with the largest size project being the latest one named Estlink at 350MW level (Table 2) [12].

CSC-HVDC systems represent mature technology today (i.e., also referred to as “classic” HVDC) and recently, there have been a number of significant advances [13]. Table 1 gives the various types of Fully-Controlled High-Power Semiconductors.

Table 1 Fully-Controlled High-Power Semiconductors.

Acronym	Type	Full Name
IGBT	Transistor	Insulated Gate Bipolar Transistor
IEGT	Transistor	Injection Enhanced Gate Transistor
GTO	Thyristor	Gate Turn-off Thyristor
IGCT	Thyristor	Integrated Gate Commutated Thyristor
GCT	Thyristor	Gate Commutated Turn-off Thyristor

II BASIC HVDC SYSTEM

High Voltage Direct Current transmission system classified into two types such as Line Commutated Converter HVDC transmission system and Voltage Source Converter HVDC transmission system. The Line Commutated Converter (LCC) based HVDC system is also known as classical HVDC [14]. Voltage Source Converter HVDC is a new power transmission technology and Self turn-off devices. Voltage source converter provides a new choice for grid inter-connection [4].

2.1 ComponentsofBasicHVDC System

A basic structure of High Voltage Direct Current transmission system is as shown in figure 1. This system consists of AC side filters, converters, transformers, DC side filters, reactors and DC transmission lines or cables[5].

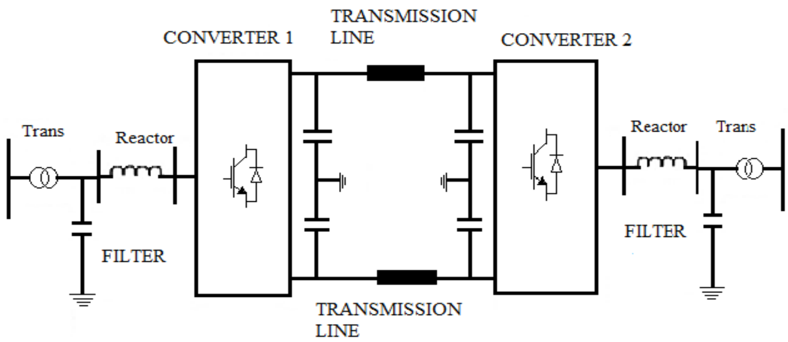

Fig.1 A Basic Structure of HVDC System

Converters- The converters play an important role in HVDC Transmission system. It performs two operations at sending end and at receiving end such as conversion from AC to DC like rectifier and DC to AC like inverter respectively. These converters are connected to the AC system through transformers at the sending end and at the receiving end. The current source converters with line commutated thyristors switches are used in basic HVDC converters system. For both conversions, i.e., rectification and inversion process a six-pulse valve bridge is used in basic HVDC system. Similarly, twelve pulse converter bridge circuits can be made by connecting two six pulse bridges circuit to each other. These bridges are connected separately to the sending end and at the receiving end of the AC system through transformers. These transformers are connected to AC system, one with Y-Δ winding structure and the other with Y-Y winding structure. Due to this, the distortion decreases in the AC systems which are caused by the HVDC converters[5].

Transformers- The transformers connect the AC transmission network to the six-pulse valve bridge or twelve pulse Valve Bridge. The transformers adjust the AC voltage to a suitable level of the converters. The design of these transformers can be depending on the power to be transmitted in the system.

AC Side Filters- The converters of HVDC transmission system produce harmonic currents on the AC side. These harmonic currents entering into the AC system. These harmonic currents are limited by AC filters on AC side. In the process of conversion, the converters consume reactive power of the HVDC system. This reactive power is partly compensated in the filter banks and remaining is provided by capacitor banks connected in the HVDC transmission system[5].

DC Side Filters- The converters of the HVDC transmission system produce ripple on the DC voltage. These voltage ripples cause the interference to telephone lines near the DC line. There is no need of DC filters for pure cable transmission or for back to back HVDC stations but if overhead transmission lines are used in HVDC

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system, it is necessary to install DC filters. Tuned filters and active DC filters are commonly used on DC side of HVDC transmission system[5].

HVDC Overhead Transmission Lines or HVDC Cables- For submarine and underground transmission system normally HVDC cables are used. There is no length limitation exists for HVDC cables transmission system. There is no need of DC cables or overhead lines for a back to back HVDC transmission system. Due to environmental concern cables are used for connections over land[5].

2.2 HVDC SCHEMES

Thereare mainlythreetypesof HVDCschemes.The selection ofeachschemeatplanningstagedependson the operationalrequirements,flexibilityof demand,reliabilityissue andcost. ThefollowingarethemostcommonHVDC configurationschemes [14].

2.2.1 MonoPolar HVDC Scheme

In this scheme, a single line is used between the two converters. In mono polar HVDC scheme, either a positive or negative voltage is used for the transmission of voltage [14]. The ground or sea or metal can be generally used as return path. The mono polar HVDC scheme is shown in figure 2.

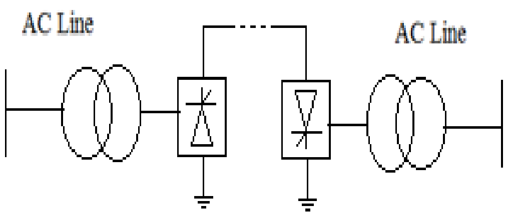

Fig.2 Mono polar HVDC system

2.2.2 Bi Polar HVDC Scheme

In this scheme, power transmission is carried out using two conductors of opposite polarity. It is a combination of two mono polar HVDC systems. Due to this combination reliability of the system is increased. When on epole of the transmission system is removed, the other part resumes the normal operation using groundas a return path [14]. This scheme is as shown in figure 3.

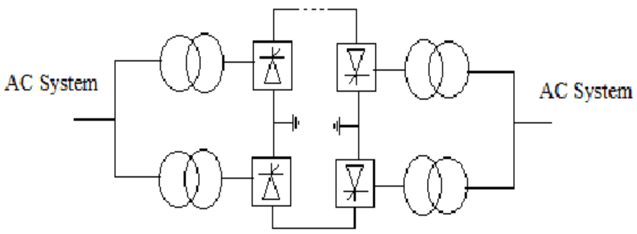

Fig.3 Bi Polar HVDC System

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2.2.3 HomoPolar HVDC Scheme

Thisisazero-distance transmission system.The two converters areconnectedto eachother withoutany DC line [14]. This scheme is as shown in figure 4.

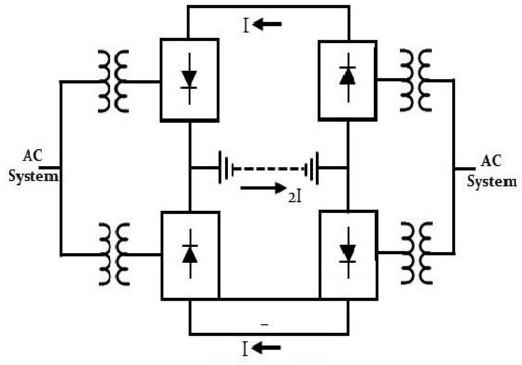

Fig.4 Homo PolarHVDC System

III WORLDWIDE INSTALLATIONS OF VSC-HVDC PROJECT

VSC-HVDCcanbeeffectivelyusedina numberofkeyareas asfollows[15]:

1) Small,IsolatedRemoteLoads;

2) PowerSupplytoIslands;

3) InfeedtoCityCenters;

4) RemoteSmall-ScaleGeneration;

5) OffshoreGenerationandDeep-SeaCrossings;

6) Multi-terminalSystems;

7) Independent control of both active and reactive power;

8) Supply of passive networks and black-start capability;

9) High dynamic performance.

The various projects worldwide where VSC-based HVDC systems have been successfully exploited are discussed. The projects have been designed and delivered by ABB [16] and are summarized in Table 2. They involve back-to-back systems (Eagle Pass, USA), wind energy applications (Gotland, Sweden), two controlled asynchronous connections for trading of electricity (Murray link and Direct link, Australia), power enhancement (Cross Sound link, USA) and the powering of an off-shore platform (Troll A, Norway). It should be noted that the DC voltage has reached ±150kV and the largest system is at 350MW, making the VSC-HVDC a well-established technology in the medium power levels. Moreover, the experiences gained from the projects so far ensure that VSC-HVDC technology remains competitive and assists utilities worldwide in order to deliver efficient, reliable, economic, and where possible renewable energy to customers irrespective of how challenging the applications are.

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Table 2 Summary of worldwide VSC-HVDC projects

Project Name	Commissioning year	Power rating	Number of circuits	AC voltage	DC voltage	Length of DC cables	Comments and reasons for choosing VSC-HVDC
Hallsjon, Sweden	1997	3 MW	1	10 kV (both ends)	± 10 kV	10 km Overhead lines	Test transmission. Only project where overhead lines were used.
Gotland HVDC light, Sweden	1999	50 MW	1	80 kV (both ends)	± 80 kV	2 × 70 km Submarine cables	Wind power (voltage support). Easy to get permission for underground cables.
Eagle Pass, USA	2000	36MW	1	132 kV (both sides)	± 15.9 kV		Controlled asynchronous connection for trading. Voltage control. Back-to-back HVDC light station
Tjaereborg, Denmark	2000	8 MVA 7.2 MW	1	10.5 kV (both sides)	± 9 kV	4 × 4.3 km Submarine cables	Wind power. Demonstration project.
Direct Link, Australia	2000	180 MW	3	110 kV (Bungalora) 132 kV (Mullumbimby)	± 80 kV	6 × 59 km Underground cable	Controlled asynchronous connection for trading. Easy to get permission for underground cables.
Murray Link, Australia	2002	220 MW	1	132 kV (Berri) 220 kV (Red Cliffs)	± 150 kV	2 × 180 km Underground cable	Controlled asynchronous connection for trading. Easy to get permission for underground cables.
Cross Sound, USA	2002	330 MW	1	345 kV (New Heaven) 138 kV (Shoreham)	± 150 kV	2 × 40 km Submarine cables	Controlled connections for power enhance. Submarine cables.
Troll offshore, Norway	2005	84 MW	2	132 kV (Kollsnes) 56 kV (Troll)	± 60 kV	4 × 70 km Submarine cables	Environment, long submarine cable distance, compactness of converter on platform.
Estlink, Estonia Finland	2006	350 MW	1	330 kV (Estonia) 400 kV (Finland)	± 150 kV	2 × 31 km Underground 2 × 74 km Submarine	Length of land cable, sea crossing and non-synchronous AC systems.
Valhall offshore, Norway	2009	78 MW	1	300 kV (Lista) 11 kV (Valhall)	150 kV	292 km Submarine cables	Reduce cost and improve operation efficiency of the field. Minimize emission of greenhouse gases.

IV CONCLUSION

In this paper, recent advances of the VSC-based HVDC technology and an overview of state-of-art of VSC HVDC technology is introduced. It not only further enhances the advantage of VSC-HVDC, such as the fast dynamic response, independent active and reactive power control, and ability of connecting to "black" network, but also eliminates some well-known drawbacks, like high switching losses and harmonics.. It is confirmed that developments associated with VSC-based HVDC technology have delivered systems at voltage levels up to 350 kV and power levels up to 400 MW. VSC-HVDC undoubtedly will continue to provide solutions in many areas of the power systems where installations necessitate proven solutions.

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