VSC-Based HVDC Power Transmission Systems

Tushar Sakarwal[1], Mr. Ravishankar[2], Dr.Deepika Chouhan[3], Md. Asif[4]
[1,2,3,4]Dept of Electrical Engineering
[1,2,3,4]Poornima College of Engineering, Rajasthan Technical University, Jaipur, India

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 used to support optimized operations and efficient management of electrical grids, which, in many cases, are fully or partially deregulated networks. Developments advance both the HVDC power transmission and the flexible ac transmission system technologies. In this paper, an overview of the recent advances in the area of voltage-source converter (VSC) HVDC technology is provided. Selected key multilevel converter topologies are presented. Control and modeling methods are discussed. A list of VSC-based HVDC installations worldwide is included. VSC-HVDC is ever to effectively compete with classical HVDC*

Keywords- HVDC, VSC, HVDC CB, Fault Analysis.

I. INTRODUCTION

HVDC POWER transmission systems and technologies Associated with the flexible ac transmission system (FACTS) continue to advance as they make their way to commercial applications[1]-[30] Both HVDC and FACTS systems underwent research and development for many years, and they were based initially on thyristor technology and more recently on fully controlled semiconductors and voltage-source converter (VSC) topologies[1].

The ever increasing penetration of the power electronics technologies into the power systems is mainly due to the continuous progress of the high-voltage high power fully controlled semiconductors [31]-[36].The fully controlled semiconductor devices available today for high-voltage high-power converters can be based on either These devices can be used for a VSC with pulse width modulation (PWM)[1].

HVDC transmission allows efficient use of energy source remote from load centers. Depending on voltage level and construction details, losses are quoted as about 3% per 1,000 km. Today, there are approximately 100 HVDC installations worldwide (in operation or planned for the very near future) transmitting more than 80 GW of power employing two distinct technologies as follows. The HVDC transmission is better as compared to HVDC transmission as the total transmission cost of the system is reduced for long range transmission. The HVDC Transmission required less number of conductors as compared to the HVAC transmission.

II. HVDC SYSTEM CONFIGURATION

2.1 Common System Topologies

Depending upon the function and location of the converter Stations, various configurations of HVDC systems can be identified. The ones presented in this section involve VSC-HVDC configurations but similar types of configurations exist for VSC-HVDC with or without transformers depending upon the project in question.

A. Back-to-Back VSC HVDC System

In this case, two converter stations are located at the same site there is no transmission of power with a dc link over a long distance. The two interconnected ac system may have same or different frequency[1].

B. Monopolar VSC HVDC System

In this configuration, two converter are used that are separated by a single pole line, and a positive or a negative dc voltage is used. Many of the cable transmission with submarine connection use a monopole system[1].

C. Bipolar VSC-HVDC System

This is the most commonly used configuration of a VSC-HVDC system in application where overhead line is used to transmit the power. The advantage of such system is that one pole can continue to transmit power in case the other one is out of service[1].

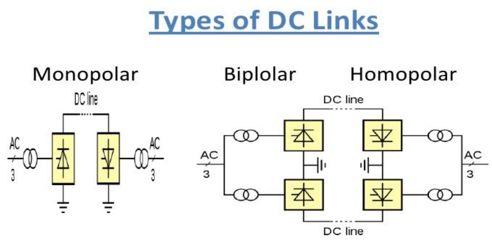

Fig1.types of DC Links

D. Multiterminal VSC-HVDC System

In this configuration, there are more than two sets of converters. A multi terminal VSC-HVDC system with 12-pulse converter is used. The multi terminal VSC-HVDC system use two or more monopole system[1].

2.2 Difference Between VSC-HVDC & LLC-HVDC

There are some brief difference between classic LLC (Line load commutated) HVDC and VSC (Voltage source converter) HVDC given below [11]-

Table-1.Difference between VSC-HVSC & LLC-HVDC

Technology	HVDC (LLC)	HVDC (VSC)
Semiconductor (Control)	Thyristor (Turn On Only)	IGBT(Turn On Only)
Power Control	Active Only	Active/Reactive
AC Filter	Yes	No
Min Short Circuit Ratio	Greater Than 2	Zero
Black Start Capablity	No	Yes

III. VSC-HVDC INSTALLATION

In this section, the various projects worldwide where VSC based HVDC systems have been successfully exploited are discussed. The projects are summarized in Table II. They involve back-to-back systems (Eagle Pass, USA), wind energy applications (Gotland, Sweden, and NORD E.ON 1, Germany), two controlled asynchronous connections for trading of electricity (MurrayLink and DirectLink, Australia), power enhancement (CrossSound link, USA, and Caprivi link, Namibia), and the powering of offshore platforms (Troll A and Valhall, Norway).

It should be noted that the dc voltage has reached 350 kV and the largest system is at 400MW, making the VSC-HVDC a wellestablished technology in themedium power levels. Irrespective of how challenging the applications are, the VSC-HVDC technology remains competitive and assists utilities worldwide in order to deliver efficient, reliable, economic, and (where possible) renewable energy to customers[8].The installation on VSC-HVDC is not very costly as it only required to create a converter station where the power is converted into dc and at distribution it again converted[8].

IV. COMPARION OF HVAC & HVDC

Table-2.HVDC vs HVAC

HVAC	HVDC
High Investment Cost	Low Investment Cost
Skin Effect And Corona	No Skin Effect and Corrona
Lower Voltage Regulation	Better Voltage Regulation
Impossible to Interconnect Two Power Grid with Different Frequency	Possible To Interconnect Two Power Grid With Different Frequency
Interference With Nearby Communication Lines is Higher	Interference With Nearby Communication Line Is Lesser
High Short Circuit Current	Low Short Circuit Current
Works On Same Frequency	Works On Different Frequency

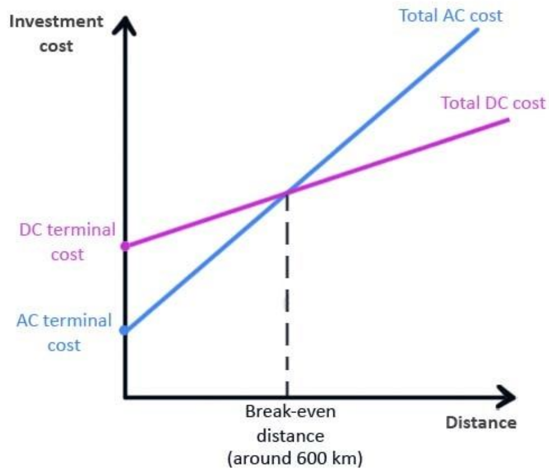

Fig2. Cost Comparison

V. MODELING AND CONTROL

The large number of technical papers associated with VSC-HVDC systems, in the area of modeling and control, is not limited to. A dc bus voltage control system using equivalent continuous-time state-space average modeling was presented in. It is shown in that including a back-to-back VSC-HVDC system at the midpoint of a transmission line can increase the transmissibility of the line by a factor of 1.68[1]-[9]. It is shown in that the VSC-HVDC system can be operated as a static synchronous series compensator (SSSC). Recently, a control system for the VSC-HVDC during island operation and under three-phase balanced faults was investigated in and it has been found that the current limit of the converters has a significant influence on the dynamic response of the system. Finally, a dynamic model for a back-to-back HVDC system based on the three-level NPC topology was presented in[9].

VI. HVDC CIRCUIT BREAKER

The availability of dc CBs is limited. DC CBs are commonly used in traction applications but the voltage and current ratings of these devices are considerably lower than what would be required in HVDC and multi terminal applications. The use of the dc CBs is feasible if a number of breakers are connected in series. Series connection of the dc breakers implies that all breakers should commutate simultaneously. Any time delays or breaker mismatching will result in breaker failure[4]-[6].

A plethora of publications exists in the literature concerning mechanical, solid-state, and hybrid ac CBs. On the other hand, only a few scientific publications are available studying the feasibility of different solutions concerning dc CBs. The different dc CBs topologies can be divided into three categories as follows

1) A configuration employing a conventional ac CB and:
   a) a charged capacitor is connected in parallel with the breaker.
   b) a resonance circuit is connected in parallel with the breaker.

2) A solid-state CB that can consist of:
   a) a controllable device such as IGBT, integrated gate commutated thyristor (IGCT), GTO, with an antiparallel diode.
   b) a bidirectional switch that consists of devices and diodes.

VII. EMERGING APPLICATION

VSC-HVDC can be effectively used in a number of key areas
As follows –

1) Small, isolated remote loads;
2) Power supply to islands;
3) Indeed to city centers;
4) Remote small-scale generation;
5) Offshore generation and deep-sea crossings;
6) Multi-terminal systems.

As a way of example, a five-terminal VSC-HVDC and a Multi-terminal. From the technology point of view, wind farms and offshore wind farms in particular are well suited for VSC-HVDC application. The discussion continues as to whether the dc is more cost-effective to the ac counterpart as a means to connect wind farms with the main grid. Evaluation of grid connecting offshore wind farms through a dc link and their technical and economic analyses are recently presented in The opportunity to use dc systems based on permanent-magnet generators and medium-frequency transformers, as opposed to 50/60 Hz generators and transformers, has been presented offering more compact and light solution for offshore wind farms[4]-[6].

VIII. ADVANTAGES OF HVDC

There are so many advantages of using HVDC instead of classic AC transmission system some of them are listed below[1]-[3]-

- A long distance point to point HVDC transmission scheme generally has lower overall investment cost and lower losses than an equivalent AC transmission scheme.

- HVDC transformation hardware at the terminal stations is exorbitant; however the aggregate DC transmission line costs over long separations are lower.
- Endpoint-to-endpoint long-haul bulk power transmission without intermediate 'taps', usually to connect a remote generating plant to the main grid.
- Integration of renewable resources such as wind into the main transmission grid.

IX. CHALLENGES IN USE OF HVDC

- The challenges of HVDC are in conversion, switching, control, availability, and maintenance.
- HVDC is less dependable and has brought down accessibility than classic (AC) networks, primarily because of the additional change hardware.
- Single-pole system has accessibility of around 98.5%, with about 33% of the downtime unscheduled because of deficiencies.
- Fault-tolerant bipole frameworks give high accessibility for 50% of the link capacity, but the availability of the full capacity is about 97% to 98%
- HVDC scheme requires many spare parts to be kept, often exclusively for one system.

X. CONCLUSION

Long distances are technically unreachable by HVAC line without intermediate reactive compensations. The frequency and the intermediate reactive components cause stability problems in AC line. On the other hand HVDC transmission does not have the stability problem because of absence of the frequency, and thus, no distance limitation. The cost per unit length of a HVDC line lower than that of HVAC line of the same power capability and comparable reliability, but the cost of the terminal equipment of a HVDC line is much higher than that of the HVAC line. The breakeven distance of overhead lines between AC and DC line is range from 500 km (310 miles) to 800 km (497 miles). The HVDC has less effect on the human and the natural environment in general, which makes the HVDC friendlier to environment.

REFERENCES

[1] ““VSC-Based HVDC Power Transmission Systems” Nikolas Flourentzou, VassiliosG. Agelidis, GeorgiosD. Demetriades.

[2] “.Wavelet-Based Protection Strategy for dc Fault in Multi-terminal HVDC” K.De Kerf, K.Srivastava 2014

[3] “Multi-Terminal HVDC System for Integration of Offshore Wind Farm and Green Electrification ”, Christian Feltes, Holger Wrede, 2014.

[4] “Protection of VSC-Multi Terminal HVSC against DC Fault

[5] “New Technologies of Voltage Source Converter For HVDC Transmission System” , Dr RL Sellick, M Åkerberg, 2013.

[6] “Modeling, Control design and Analysis of VSC based HVDC Transmission ”, R. Feldman , A.J. Watson, J.C. Clare, 2010.

[7] “Evaluation of Losses in VSC-HVSC Transmission System”, Yifei Guo, Houlei Gao, 2009

[8] “Analysis of Stability Limitation of a VSC-HVDC Link Using Power Control” Oluwole Daniel Adeuy, 2013.

[9] “Modeling and Control of VSC-HVDC Link Connected to Island System”, Sotirios I. Nano, 2011

[10] “Interconnection of Two Very Weak AC System by VSC-HVDC”, Temesgen M. Haileselassie, Marta Molina, 2010.

[11] “Economic Comparison of VSC HVDC and HVAC” , Grain Philip Adam, 2014.

[12] “Comparison of HVSC light and HVDC Classic site”, Guanjun Ding, Guangfu Tang, Zhiyuan He, and Ming Ding, 2015

[13] “AC Grid with embedded VSC-HVDC for Secure and Efficient Power Delivery”, Pinaki Mitra, 2013.

[14] “Main Grid Frequency Support Straegy for VSC-HVDC Connected Wind Farm”, Chunyi Gu, 2008.

[15] Improvement of Subsynchronous Torsional Damping using HVDC”, Benish Peiny, 2013