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HVDC Power Transmission& Technology in India

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Abstract - Necessity of efficient electric transmission on electricity to make sustainable generation of energy possible. In this respect High Voltage Direct Current has a important role**.** There is a considerable interest in future applications of HVDC grids, as overlaying backbone systems for existing AC networks. Such backbone systems may be needed for transporting large amounts of power over long distances or for fulfilling the increasing demand for cross border power trading. HVDC is seen as a natural choice over EHVAC for a backbone system since the power flow can be easier controlled, the overhead lines are less costly to build, and underground cables can be used without concerns about reactive power. Rapid development in the field of power electronic devices with turn off capability like Insulated Gate Bipolar Transistors (IGBT) and Gate Turn-Off Thyristor (GTO), makes the Voltage Sourced Converters (VSC) getting more and more attractive for High Voltage Direct Current Transmission (HVDC).This new innovative technology provides substantial technical and economic advantages for different applications compared to conventional HVDC transmission systems based on thyristor technology. This paper focuses on VSC application for HVDC systems with IGBT of high power ratings, which are currently in discussion for several projects. After a brief description of the main circuit components an overview on basic design aspects of VSC based HVDC systems is given.

I. INTRODUCTION

High Voltage Direct Current (HVDC) with Line Commutated Converters (LCC) was developed and put in commercial operation already in the 1950's, with mercury arc valve technology. In the 1970's,HVDC applications evolved with the introduction of thyristor based valves, which have over the years proven highly reliable, and well-studied in Cigre's collected statistics and sessions. HVDC's typical applications are long-distance "bulk-power" transmission inter-connectors and long submarine cable systems. The development of power electronics technology resulted in the mid
1990's of a new type of valves for the HVDC converters based on transistors (e.g. utilizing Insulated-gate Bipolar Transistor, IGBT), called Voltage Source Converter, VSC.

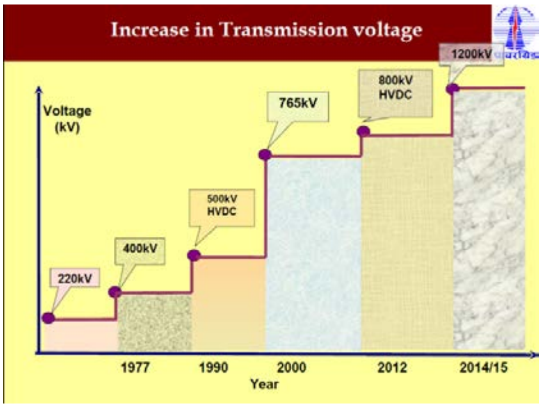


Fig. 1.1 HVDC Voltage Source Converter (HVDC VSC)

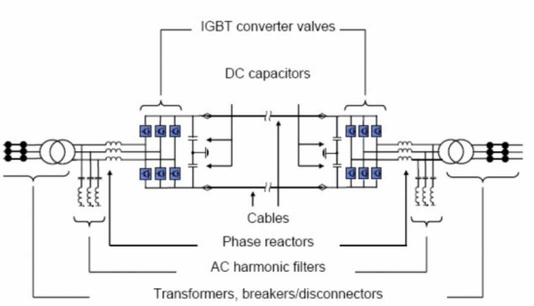
The developed HVDC VSC technology can be utilized for a much more elaborate and fast control of the valves. One of the most important new features compared with LCC is the functionality to not only control the real power flow MW but also the reactive power, i.e. the voltage level, at both connections, also referred to as the STATCOM or SVC (Static Var Compensator) functionality. HVDC VSC even allows for startup of complete "dead" AC systems ("black-start capability"). The global trend shows VSC projects with continuously increased capacities up to 1,200 MW. New applications include large wind farm connections, supply to urban load centers, and connections to remote "weak" AC systems. HVDC VSC technology allows overhead lines or land cable systems, i.e. underground solutions, the latter application of special interest for environmental reasons and easement of the permit process. A number of HVDC VSC transmission installations, both globally as well as here in Australia, have now been in operation for quite a few years. This paper, to our knowledge, covers the first study of the operation experiences from this relatively new technology. Two HVDC VSC transmission links have been studied, both with 7 years of operation, although in quite different conditions. The two VSC links comprise one installation in the US with submarine cables and one in Australia with land cables ,thereby widening the areas of interest. The available statistics for the 7 years operation for the respective installations' availability and reliability are presented as a measurement of the operation performance. This presentation of HVDC VSC performance provides useful information for system planners to compare available transmission solutions based on actual operation experience. In addition, it should be of interest for the requirements for new HVDC VSC projects.

II. HVDC

In view of the increasing power demand over the world or in India, so many technologies had been developed and are in operation. FACT, SVC, SSC are one of them. For making Bulk Power transmission economical & reliable, transmission technology further developed and now HVDC could be the same. High Voltage Direct Current (HVDC) technology has characteristics which makes it especially attractive for certain transmission applications. HVDC transmission is widely recognized as being advantageous for long-distance, bulk power delivery, asynchronous interconnections and long submarine cable crossings. Now in India number of HVDC projects have already been commissioned or under consideration has increased in recent years reflecting a renewed interest in this mature technology. HVDC further classified as HVDC LCC and HVDC VSC. New converter designs have broadened the potential range of HVDC transmission to include applications for underground (Cable System), economic replacement of reliability-must-run generation, and voltage stabilization. From EAST to WEST and NORTH to SOUTH, so many projects have launched by Government of India for improvement of Power transmission all over the India. Those projects are listed in Table 1. All of those projects are HVDC LCC (Thyristor) Based. Capacitor-commutated converters (CCC) for weak system applications and voltage-sourced converters (VSC) with dynamic reactive power control. This broader technology range has increased the potential HVDC applications and contributed to the recent growth of HVDC transmission.

VSC-based Transmission Importance

1. Asynchronous Link
2. Independent control of reactive and active power
3. Reactive control independent of other terminal(s)
4. Controlled Power Exchange
5. Simpler interface with ac system
6. Compact filters
7. Provides continuous ac voltage regulation
8. No minimum power restriction
9. Operation in extremely weak systems
10. Improve Stability of AC System
11. No commutation failures
12. No restriction on multiple in feeds
13. No polarity reversal needed to reverse power
14. Black-start capability
15. Variable frequency



Main circuit diagram of HVDC Light

Fig. 2.1

VSC-based HVDC transmission Technology

1. High voltage valves with series-connected IGBTs
2. Compact, dry, high-voltage dc capacitors
3. High capacity control system
4. Solid dielectric DC cable

III. HVDC VSC TECHNOLOGY ADVANTAGES

The most attractive technical advantages of VSC-HVDC system for embedded applications in ac networks include

1. Power flow control flexibility
2. Fast response to disturbances
3. Multi Terminal configurations

Power Flow Control Flexibility

The power flow on the VSC-HVDC links can be optimally scheduled based on system economics and security requirements. It is also feasible to dispatch VSC-HVDC systems in real-time operations. Thus, the power grid operation will benefit from embedded VSC-HVDC systems due to increased flexibility to utilize more economic and less pollutant generation resources and effective congestion management.

Fast Response to Disturbances

Fast control of active and reactive power of VSC-HVDC system can improve power grid dynamic performance under disturbances. For example, if a severe disturbance threatens system transient stability, fast power run-back and even instant power reversal control functions can be used to help maintain synchronized power grid operation. VSC-HVDC system can also provide effective damping to mitigate electromechanical oscillations by active and reactive power modulation.

Multi Terminal Configurations

A multi Terminal VSC HVDC system consists of several converters whose dc terminals are connected in shunt across the buses of a dc network. The VSC-HVDC terminals can be connected to different points in the same ac network or to different ac networks. These dc grids can be radial, meshed or a combination of both. Multi Terminal configurations are being considered as feasible alternative for ac network reinforcement to fully exploit the economic and technical advantages of VSC-HVDC technology.

IGBT has quick switching characteristics and A special gate unit and voltage divider across each IGBT maintain an even voltage distribution across the series connected IGBTs. The gate unit not only maintains proper voltage sharing within the valve during normal switching conditions but also during system disturbances and fault conditions.

Project NAME	POWER	TYPE	YEAR
Vindhyachal	2X250 MW	Thyristor	1889
Chandrapur	2X500 MW	Thyristor	1997
TalcharKolar	2000 MW	Thyristor	2003
Sasaram	1X500 MW	Thyristor	2002
Gazuwaka	2X500 MW	Thyristor	2005
BalliaBhiwadi	2500 MW	Thyristor	2010

Table 3.1 HDVC Power Transmission in INDIA

System Salient Features

I. ± 500 kV , 1500 MW Rihand – Dadri HVDC Project.

±500kV,1500MW HVDC Bi-Pole Transmission link supplies Bulk Power from Thermal Power Plant of Rihand (Eastern part of Northern Grid) to Dadri (Western part of Northern Grid).

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1. Each pole continuous power carrying capacity is 750 MW with 10% two hours overload and 33% five seconds overload capability.
2. Reverse power flow capability available.
3. During inclement weather condition power
4. transmission is possible at ±400 kV DC voltage.

II. 2 x 250 MW HVDC Vindhyachal Back to Back Station.

(i) It connects Vindhyachal Super Thermal Power Stations (WesternRegion) to Singrauli Super Thermal Power Stations (Northern Region) in Indian Grid.
(ii) Each Block power carrying capacity is 250 MW.
(iii) Bidirectional power flow capability is available.
(iv) The project achieve load diversity of Northern and Western region in Indian Grid by meeting high demand from surplus power available in either regions
(v) First commercial Back to Back HVDC Station in India

III. Up gradation of + 500 kV HVDC Talchar – Kolar link from2000 MW to 2500 MW

1. HVDC Talchar – Kolar link was designed for 2000 MW continuous rating with inherent short term overload capacity depending on-
2. Ambient temperature
3. Prevailing voltages at Talcher and Kolar
4. Cooling mechanism.
5. Further, DC Bipole lines with quad conductor was capable to transmit 1250MW continuously with marginal incremental loss.
6. The inherent overload capability was utilized to meet the system contingencies by up gradation of Talcher – Kolar HVDC link capacity from2000 MW to 2500 MW .
7. This enhanced capacity is to be used only under contingency and not for increasing HVDC Capacity for firm transfer of 2500 MW

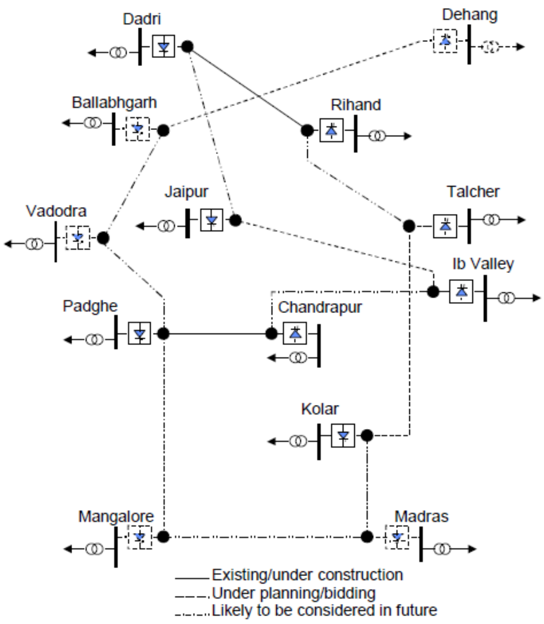

Figure 1: Conceptual HVDC ring-main scheme

IV. 2 x 500 MW HVDC Gazuwaka Back to Back Station.

(i) It connects Jeypore (Eastern Region) to Gazuwaka (Southern Region)Thermal Power Stations of Indian Grid.
(ii) Each Block power carrying capacity is 500 MW.
(iii) Bidirectional power flow capability available.
(iv) The project achieve load diversity of Eastern and Southern region in Indian Grid by meeting high demand from surplus power available.

V. + 500 kV, 2500 MW HVDC Ballia – Bhiwadi Transmission Link

(i) Bi-Pole + 500 kV, 2500 MW HVDC 780 km Transmission lines from Ballia (Eastern part of India) to Bhiwadi (Northern part of India)of Indian Grid.
(ii) Each pole power carrying capacity is 1250 MW.(iii) During unfavorable weather condition, operation at 70% to 80% DC voltage is possible.
(iv) Reverse power flow capability is available.

III. HVDC FUTURE IN INDIA

The thyristor as the key component of a converter bridge continues to be developed so that its voltage and current rating is increasing. Gate-turn-off thyristor (GTOs) and insulated gate b pole transistors (IGBTs) are required for the voltage source converter(VSC) converter bridge configuration. Some of the ongoing projects are Talcher Kolar, Dadri Rihad, BallabhgarhDehang, Manglore Madras in India, which could be implemented as per the Power Demand. It is the VSC converter bridge which is being applied in new developments. Its special properties include the ability to independently control real and reactive power at the connection bus to the ac. system. India has covered form three sides by sea water and we can propose to set up the Wind Power Plant all over the Sea around for getting better power generation. Since we are having very wide transmission network all over the country so that this could be possible to supply the power from any cost to the load center with the minimum losses or reactive power. Reactive power can be either capacitive or inductive and can be controlled to quickly change from one to the other. A voltage source converter as in inverter does not require an active a.c. voltage source to commutate into as does the conventional line commutated converter. The VSC inverter can generate an a.c. three phase voltage and supply electricity to a load as the only source of power. It does require harmonic filtering, harmonic cancellation or pulse width modulation to provide an acceptable a.c. voltage wave shape. Two applications are now available for the voltage source converter.

800 KV HVDC Multi Terminal System

POWERGRID is installing +/-800 kV,6000 MW HVDC multi-terminal system of approx length of 1728 km from North Eastern Region to Agra One Rectifier station in Biswanath Chariali (in North Eastern Region), second one in Alipurduar (in Eastern Region) and Inverter station at Agra (in Northern Region)

1. Converter stations at Biswanath Chariali and Alipurduar each handles a power of 3000 MW and Converter station at Agra handles 6000 MW
Power.
2. This Tr. System originates from Assam and passes through West Bengal ,Bihar and terminates in Uttar Pradesh.
3. First Multi Terminal project in India.

Salient features

1. First ±800 KV Multi-Terminal HVDC project in the world.
2. First 12 pulse 800 KV terminal of the world
3. First Multi-Terminal with continuous 33% overload feature
4. After considering the continuous 33% overload feature, this will be the highest capacity HVDC project of the world.
5. Each pole of the Multi-terminal shall be designed for 2000 MW which is the highest capacity poles in the world.
6. The Earth electrode shall be designed for 5000 A DC continuous current which shall be 1st of its kind in the world.

IV. FUTURE DEMAND IN TRANSMISSION

1. Need of long distance Transmission system
2. Minimum use of land and Right-of-Way
3. Optimal cost per MW transmission
4. Optimal Transmission Losses

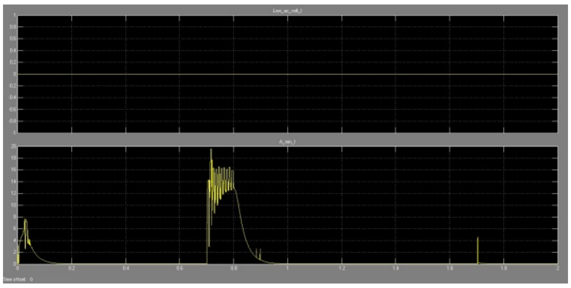

Fig. 4.1 Vd& Id Characteristics

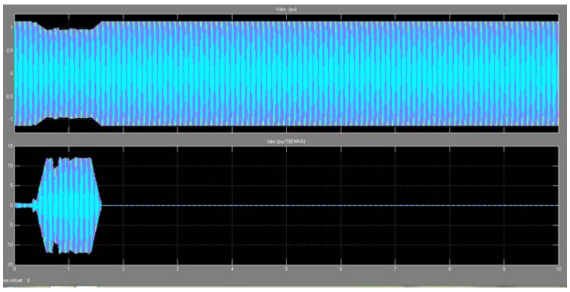

Fig. 4.2 Inverter Control for IGBT Based HVDC System

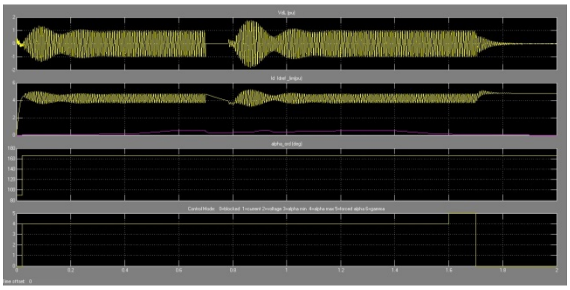

Fig. 4.3 Rectifier Control for IGBT Based HVDC System

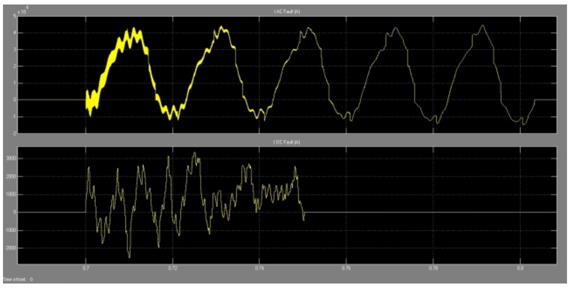

Fig. 4.4 Line to Ground Fault for IGBT HVDC System

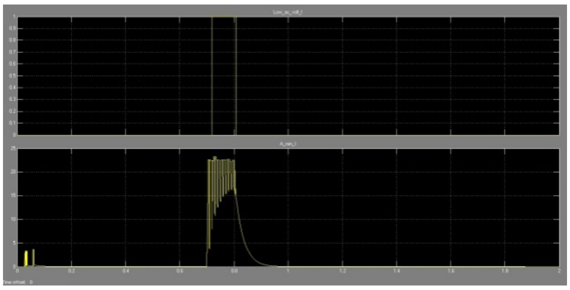

Fig. 4.5 Inverter Protection for Thyristor Based HVDC

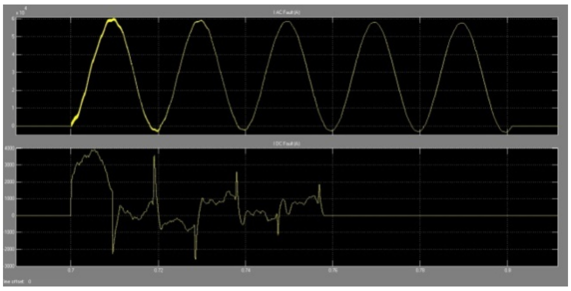

Fig. 4.6 Line to Ground Fault Thyristor HVDC System

V. CONCLUSION

Several interesting features of VSC-HVDC have shown to be very useful in improving the transfer capability and reliability of power systems. The Transmission Technology has been used right now in India is based on Thyristor. Now there should be change from Thyristor to IGBT for getting batter system performance and good results.

Now so many new technologies with Power Electronics has been developed and used by other countries and they have very reliable performance. The development work for VSC HVDC systems has been discussed. The progress in four key technical aspects of VSC HVDC system indicates that, future aspect of the Indian Transmission system could be based on off shore wind farm, as per the current Transmission situation of the world. The VSC HVDC system provides a solution for adding new transmission lines of distance longer than 100 km. Compared to AC, VSC HVDC has additional advantages such as full power flow control in both directions, voltage stabilization via continuous reactive power control and minimized disturbances by preventing fault propagation.

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