A Review: High Voltage Transmission System

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Abstract- As the demand of electricity increasing day by day we cannot dependent on the conventional power system like: long distance distributed generating stations as well as complex & heavily loaded transmission and distribution network. High Voltage Direct Current (HVDC) transmission systems have a very important role in power system. Without proper study of HVDC system obtaining an accurate mathematical model of the system is not possible and without proper modeling Power transmitted in a HVDC system cannot be calculated. Power transmitted through the HVDC system is depends upon the efficiency of the controller as well as the converter station. Traditionally PID controllers are employed for rectifier pole current control and inverter side excitation control. This paper is the review of the HVDC system covers up the introductory part of fundamentals of the HVDC system. Due to the growing demand for electrical power at load centers and attentiveness of electrical generation at a scattered manner, a number of high capacity long distance HVDC systems are needed and also shouled be planned to achieve various advantages. As the advancement done in power electronics field going on , HVDC system will be more attractive and reliable.

Keywords*: HVDC, converter station, advantages, problems and applications*

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1. INTRODUCTION

High voltage direct current (HVDC) convert AC voltage to DC voltage through the rectifier and transmits DC power through the transmission lines. Then reconverts DC into AC power in inverter and supplies the ac power to the existing power system [1]. The power flow control in AC system is quiet difficult to control but in the DC transmission can be controlled rapidly. The controllability of HVDC links is one another advantage of DC systems. As the controllability concern, as its more the dynamic performance of large system is definitely be more. To achieve the promised advantages the control systems must be efficient and perform appropriately for various disturbances and system condition. Due to various advantages of HVDC technology its applications are wide like: under water cable, and in the interconnection of differently managed power systems, either operated in synchronously or asynchronously mode of operation[2,3].

HVDC Technology is a most attractive power transmission technology, when power has to be transmitted over a long distances with most efficient economic conditions.

The first commercial HVDC transmission project has been installed in Sweden in 1954. A total of around 70000MW of power transmission capacity is transmitted around the world through 95HVDC projects [1].

High Voltage DC Transmission:

AS per history of electricity, the first commercial electricity generated (by Thomas Alva Edison) in which direct current (DC) was used for electrical power and also the very first electrical power transmission systems were also direct current systems. The main drawback mainly incorporated the fact that DC power at low voltage was difficult to be transmitted over long distances, hence giving rise to extra high voltage (EHV lines) carrying alternating current. By introducing of high voltage rating valves, make possible to transmit DC power at very high voltages over long distances, known as the HVDC transmission systems.

HVDC transmission system was first installed in the year 1954, (100kV, 20MW DC link) between Swedish mainland and the island of Gotland, since then a huge amount of HVDC transmission systems have been installed and growing day by day.

Due to following reasons HVDC transmission systems have become desirable:

- Environmental benefits
- It is more economical (cheapest solution)
- Asynchronous ties are feasible
- Control on the power flow
- Sublime benefits to the transmission including stability, power quality etc.

HISTORY OF HVDC SYSTEM:

The first transmission of direct current was in 1882 of the distance of 50 km long (distance between Miesbach-Munichbut) and voltage level was only 2 kV. The DC transmission system was developed by the scientist Rene Thury, he also created own method, which based on series-connected generator and was used in practice by 1889 in Italy. Further on Thury's idea transmitted 630 kV at 14 kV over distance 120 km DC transmission was estabilished. Also the most important project was line Mountiers-Lyon in France which wasworking between 1906 until 1936. Another major project is the Line of Mountiers-Lyon connected hydroelectric power plant, transmitted 8600 kW, had 200 long kilometers and voltage between two poles was 150 kV.

In 1930 another project of 100 kV DC was developed with economical and technical low efficiency caused that Thury's systems was withdrawal, but despite those reasons – it was little commercial success. Now the time was to attempts with mercury arc valve, and the technology was put in 1932 by General Electric, which tested mercury-vapor valves in 12 kV DC line with the system could convert current from 40 Hz to 60 Hz frequency at Mechanicwille, New York. In 1941 now project of underground DC (with mercury arc

valves) connection in Berlin but due to war project was never completed. 1954 was the crucial moment in development of HVDC, in this era of static mercury arc valve. Next between Sweden with island Gotland, a new project was created by ASEA. After and near of the time of 2000, thyristor valves ware introduced and further more advancement are going on [4, 5].

Background of HVDC transmission

The HVDC transmission system is a basically the power electronics technology based system used in power system; it is having high capability of power handling and transmission over long distance with considerable economic strength. At present interest on the renewable energy sources had emerged Thus, the wind power industry, one of the most powerful and successful industry in the last four decades had appeared. Since then, the development in this industry is continuous and at a high rate, fact which can be observed from Figure 1.1which presents the development of the wind turbines during last three decades [4, 5, 6].

2. PROBLEMS ASSOCIATED WITH HVDC

- Converter stations needed to connect to AC power grids are very expensive. The cost of installation at the Converter Stations is quite high, required at each end of a D.C. transmission link, whereas in an A.C. link only transformer stations are required.
- Reactive power requirement: Both in rectification and in inversion reactive power is required.
- Difficulty of circuit breaking: In the case of D.C. natural zero crossing is not present, hence DC circuit breaking is difficult.
- High power generation difficult: Due to the problems associated with commutation in D.C. machines, voltage and speed are limited. Comparitively, lower power can be generated with D.C.
- In contrast to AC systems, designing and operating multi-terminal HVDC systems is complex.
- Converter substations generate current and voltage harmonics
- During short-circuits in the AC power systems close to connected HVDC substations
- The number of substations within a modern multi-terminal HVDC transmission system can be no larger
- The high-frequency constituents found in direct current transmission systems can cause radio noise
- Grounding HVDC transmission involves a complex and difficult installation
- The flow of current through the Earth in monopole systems can cause the electro-corrosion of underground metal installations, mainly pipelines.
- Absence of overload capacity: Converters cannot be overload as in transformers.

3. ADVANTAGES OF HVDC OVER AC TRANSMISSION

- **Economical Aspects of transmission:**

It is quiet difficult to estimate a cost of buildings HVDC transmission system and its operating unit. Cost factor is different and depends on power of line, length connection, environment of track wires etc. Usually the biggest producers of HVDC transmission are Siemens or ABB don't reveal financial information about investments, means no strong estimation can be done. Despite narrow basement of information, we can estimate some costs of built DC line, which is show on Fig.1

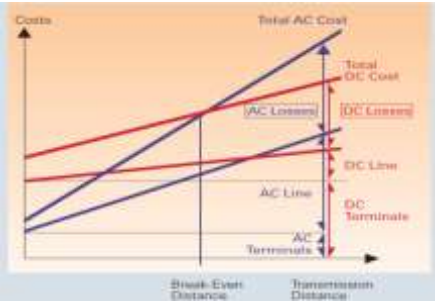

Figure 1 variation of cost in AC & DC with distance

- **Technical aspects of transmission:**

In the technical aspects HVDC is having following positive features with long distance power transmission due to fast controllability of power using converter control:

- Full control over transmission of power
- Enhanced transient and small signal stability
- Fast control to limit fault current in DC Line.

- **Reliability aspects of transmission :**

The reliability of HVDC system is quiet good and comparable to that of AC system and it is more due to high reliability of thyristor valve compared to the mercury valves. As the enhancement is done in power electronics, reliability is more.

4. APPLICATIONS OF HVDC TRANSMISSIONS

The HVDC transmissions are basically used in following four applications [4, 5, 6, 7]:

- underground/submarine cable transmissions: In the case of underground or submarine HVDC cables there is no physical restriction concerning the distance, the power level and also there are considerable savings in installed cable costs. Furthermore, in the case of the underground

cables, these ones can be used on shared Right-of-Way with other utilities.

- Long distance bulk power transmissions: The HVDC transmission systems provide an economical alternative to AC transmission systems regarding the bulk power delivery from remote locations such as hydroelectric developments or large scale wind farms whenever the breakeven distance is exceeded.
- Asynchronous connections of AC power systems: The HVDC transmissions systems o_er a reliable and economical way of interconnection between two AC asynchronous networks. Usually, these interconnections are realized using back-to-back converters with no transmission line.
- Stabilization of power lows in integrated power systems: According to [7], due to the fast controllability of dc power, strategically placed DC lines can solve issues like power flow in AC ties which can be uncontrollable and can lead to overloads and stability problems.
- Offshore transmission: Due to their advantages, such as: self-commutation, black-start capability and dynamic voltage control, VSC-based HVDC transmissions can be used to serve isolated load son islands or offshore platforms over [10].

5. HVDC SYSTEM CONFIGURATION

Configuration of HVDC transmission system is can be defined as per the locations of the converter station, mainly four HVDC transmission system configuration are used in HVDC power transmission. These four HVDC transmission system configuration can be used for both VSCs and CSCs converter topologies [3].

- **Components of HVDC configuration:**

HVDC system can use mercury arc rectifiers but in the latest technology thyristors are used. Thyristor is a solid- state semiconductor device, similar to the diode, but has particular property in control of AC throughout the cycle. Now a day IGBT, IGCT and MOSFET are implemented, because their operation is simpler and efficient way of control.

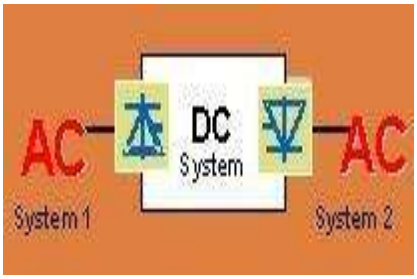

Figure 2 Components of HVDC configuration

In HVDC transmission at both sides (system 1 & 2) a set of transformers, often three physically separate single-phase transformers with converter system are used. Both Rectifying and inverting systems usually use the same devices but different firing angles. Enhancement in conversion characteristics of this configuration uses 12 valves (often known as a twelve-pulse system). With twelve valves connecting each of the two sets of three phases to the two DC rails, there is a phase change every 30degrees, and harmonics are considerably reduced. In elements which take share in conversion, are applied filters which limit harmonic in DC cycle [8].

- **Monopolar HVDC System**

In this configuration, two converters separated by a single pole line are used. Positive or negative DC voltage can be used (one through the conductor and ground as return path), but in the case of using negative polarity the corona effects in the DC line are less [5]. Depending on the application, in the case of the monopolar line, ground or a metallic conductor can be used as return path, as illustrated in Figure3.

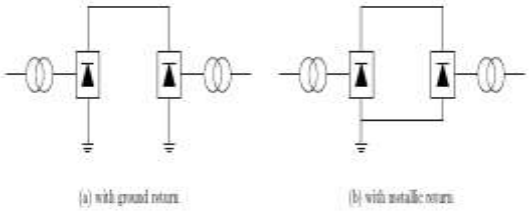

Figure 3 Monopolar HVDC system

- **Bipolar HVDC System**

In this case, the configuration uses two conductors, one positive and the other negative (both are the metallic conductor, ground is used as return path). The connection between the two sets of converter is grounded at one or at both ends [5]. The Major advantage of this configuration is given by the fact that one of the poles can continue to transmit power in case the other one is out of service [3, 5]. Thus, the two poles may be used independently, if both neutral points are grounded [10]. The bipolar HVDC system configuration is illustrated in Figure 4.

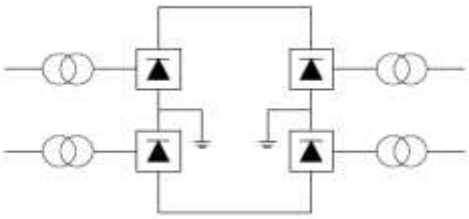

Figure 4 Bipolar HVDC system

- **Back-to-back HVDC System**

In back to back configuration, the two converters stations are placed at the same site and there is no transmission of power with a DC link over a long distance [3]. The block diagram of a back-to-back system is presented in Figure 5.

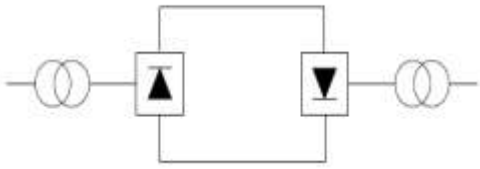

Figure 5 Back to back HVDC system

- **Multi-terminal HVDC System**

A multi-terminal HVDC transmission system consists of three or more converter substations, some of them working as inverters while the other ones as rectifiers [7]. Depending on the positioning of the converter substations, two basic arrangements of the multi-terminal HVDC system can be obtained: series multi-terminal HVDC system and parallel multi-terminal HVDC system. These two arrangements are presented below.

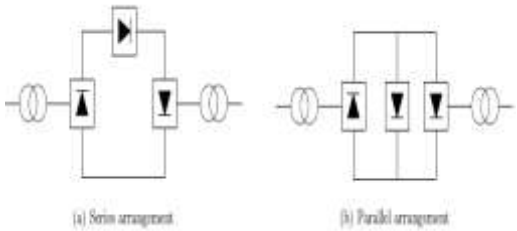

Figure 6 Multi terminal HVDC system

6. MODERN TRENDS IN HVDC TECHNOLOGY

- Power semiconductor and valves
- Converter control
- DC breakers
- Conversion of existing AC lines
- Operation with weak AC systems
- Active DC filters
- Capacitor commutated converter
- UHV DC transmission

7. FEW OPERATING PROBLEMS

- **Converter transformers:** CIERE AG 04 statistics reveal many failures in converter transformers have been occurring due to the major problematic areas like turn to turn failure in valve side windings, leads and cleats failures, DC bushing failures etc.
- **Flashover performance of HVDC converter station insulators:** Insulators such as bushings, capacitive voltage dividers and potential transformers suffers from external flashover due to rain, snow and ice.
- **Valve Hall Fires:** In the system converters stations are failure due to problems like loos connections, smokes and cooling.
- **Problems of ground returns:**Ground return is very important in monopolar operationbecauseit may cut down power losses but due to ground return problems with buried metallic structure and three phase transformers with neutral grounded.

8. CONCLUSION & FUTURE SCOPE

This paper covers the basic review of the HVDC transmission system and also comparison with the conventional AC transmission system. Authors can put the future scope of HVDC transmission like, deeper insight into the functioning of complex HVDC transmission system converter can be obtained by analytical modelling. Further easy to comprehend analytical model in universally available software like Matlab/Simulink can help in fast spread of complex HVDC system knowledge also to those who are responsible for operation and maintenance of these systems thus bringing large benefits.

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