Prabha uikey 2019, 7:4
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology

An Open Access Journal

Performance Improvement of VSC Based HVDC Transmission Techniques

Prabha uikey, Dr. Anil Kori
Jabalpur Engineering College,
Jabalpur, India

***Abstract*- This papers deals with a new three-level Voltage Source Converter (VSC) with its dynamic control and power quality improvement for High Voltage Direct Current (HVDC) system. The proposed three-level voltage source converter (VSC) topology for HVDC system consists of two converter stations fed from two different ac systems. The active power is transferred between the stations either way. The reactive power is controlled independently in each converter station. The three-level VSC is operated at optimum dead angle which gives the harmonic performance equivalent to a two-level 24-pulse voltage source converter. Both converters stations can be operated as either a rectifier or an inverter according to their direction of active power flow. These VSC based converters are operated at Fundamental Frequency Switching (FFS) to reduce the losses in the system. A control algorithm is developed for bidirectional active power flow, independent reactive power control for both rectifier and inverter stations. The proposed converter topology is found highly suitable for high power rating systems and this result in a substantial reduction in switching losses and avoiding additional reactive power plant and filter arrangements. Simulation is carried to verify the performance of the proposed VSC topology and control method for bidirectional active power flow and their independent reactive power control. Index Terms – HVDC System, Three-level Voltage Source Converter, Dead Angle, Fundamental Frequency Switching, Active Power Flow, Reactive Power Control, Power Quality, and Total Harmonic Distortion.**

***Keywords*- HVDC System, Three-level Voltage Source Converter, Dead Angle, Fundamental Frequency Switching, Active Power Flow, Reactive Power Control, Power Quality, and Total Harmonic Distortion.**

I. INTRODUCTION

At the beginning of the electricity supply industry there was a great battle between the proponents of Alternating Current and Direct Current alternatives for electricity distribution. This eventually played out as a win for AC, which has maintained its dominance for almost all domestic, industrial and commercial supplies of electricity to customer. As the size of electricity supply systems increased several major challenges for AC systems emerged.There were major difficulties in increasing the voltage and the range of under-sea cables. Also the development of very large hydro-electric projects in areas quite remote from their load centres became an increasing challenge for AC systems to transport vast quantities of electricity over very great distances. For very large transmission schemes High Voltage Direct Current (HVDC) is both more efficient and has a greater capability than AC systems. It was recognised as early as the 1920's that there were advantages in the use of DC transmission systems for these more challenging applications. Hence the concept of HVDC emerged, however development was held back by the lack of a suitable technology for the valves to convert AC to DC and vice versa High Voltage Direct Current Technology is a most attractive transmission technology when power has to be transmitted over long distances. The first commercial HVDC transmission project has been installed in Sweden in 1954. In last half century, its application has widely increased. A total of around 70000MW of transmission capacity is transmitted around the world through 95 HVDC projects [1].

Due to the burgeoning demand for electrical power in one area and concentration of electrical generation in another area, a number of high capacity long distance HVDC systems are planned where bulk power from one region to another region is being transmitted. Advancement in power electronics is making High Voltage Direct Current Transmission Systems (HVDC) more and more attractive and reliable. Developing countries like India and China with their ambitious power capacity enhancement program are installing more HVDC systems for long distance transmission. More can be obtained from investments in complex HVDC systems if operation and maintenance personnel have deeper understanding about the functioning of these systems.

Further commissioning/ maintenance errors may be minimized if the consequences of such errors are known and appreciated by the concerned personnel. Easy to comprehend, simple analytical HVDC converter model as developed in universal software Mat lab/ Simulink in this paper can prove to be very useful for operation and maintenance personnel. The model illustrates steady state operation of HVDC system converter and can be used to comprehend commutation and overlap, valve firing sequence, AC current and voltage waveforms in converter transformer & thesource, and DC current including ripple. The model also helps in understanding the role and importance of AC filters.

1. Converter Station

An HVDC converter station is a specialised type of substation which forms the terminal equipment for a high-voltage direct current (HVDC) transmission line. It converts direct current to alternating current or the reverse. In addition to the converter, the station usually contains:

- Three-phase alternating current switchgear
- Transformers
- Capacitors or synchronous condensers for reactive power
- Filters for harmonic suppression
- Direct current switchgear

2. Three-phase alternating current switch gear

The three-phase alternating current switch gear of a converter station is similar to that of an AC substation. It will contain circuit breakers for over current protection of the converter transformers, isolating switches, grounding switches, and instrument transformers for control, measurement and protection. The station will also have lightning arresters for protection of the AC equipment from lightning surges on the ACsystem.

3. Transformer

The converter transformers step up the voltage of the AC supply network. Using a star-to- delta connection of the transformer windings, the converter can operate with 12 pulses for each cycle in the AC supply, which eliminates numerous harmonic current components. The insulation of the transformer windings must be specially designed to withstand a large DC potential to earth. Converter transformers can be built as large as 300 megavolt-amperes (MW) as a single unit. It is impractical to transport larger transformers, so when larger ratings are required, several individual transformers are connected together. Either two three-phase units or three single-phase units can be used. With the latter variant only one type of transformer is used, making the supply of a spare transformer more economical.

4. Converter

The converter is normally used on a building which called valve hall. Converters using thyristors or valves are known as line commutated converters. Here thyristor-based converters are connected in series to form a thyristor valve and the converter consists of twelve thyristor valves. The thyristor valves are usually grouped in pairs or groups of four and can stand on insulators on the floor or hang from insulators from the ceiling.

5. Reactive Power

When line commutated converters are used, the converter station will require between 40% and 60% of its power rating as reactive power. This can be provided by banks of switched capacitors or by synchronous condensers, or if a suitable power generating station is located close to the static inverter plant, the generators in the power station. The demand for reactive power can be reduced if the converter transformers have on-load tap changers with a sufficient range of taps for AC voltage control. Some of the reactive power requirement can be supplied in the harmonic filter components. Voltage sourced converters can generate or absorb reactive as well as real power, and additional reactive power equipment is generally not needed.

6. Harmonic Filter

Harmonic filters are necessary for the elimination of the harmonic waves and for the production of the reactive power at line commutated converter stations. At 12 pulse converter Stations, only harmonic voltages or currents of the order 12n+1and 12n-1(on the AC side) or (on the DC side) result. Filters are tuned to the expected harmonic frequencies and consist of series combinations of capacitors and inductors. Voltage sourced converters generally produce lower intensity harmonics than line commutated converters.

7. DC equipment

The direct current equipment often includes a coil (called a reactor) that adds inductance in series with the DC line to help smooth the direct current. The inductance typically amounts to between 0.1 H and 1 H. The smoothing reactor can have either an air-core or an iron-core. Iron-core coils look like oil- filled high voltage transformers. Air-core smoothing coils resemble, but are considerably larger than, carrier frequency choke coils in high voltage transmission lines and are supported by insulators.

Air coils have the advantage of generating less acoustical noise than iron-core coils, they eliminate the potential environmental hazard of spilled oil, and they do not saturate under transient high current fault conditions. This part of the plant will also contain instruments for measurement of direct current and voltage. Special direct current filters are used to eliminate high frequency interference. Such filters are required if the transmission line will use power-line communication techniques for communication and control, or if the overhead line will run through populated areas. These filters can be passive LC filters or active filters, consisting of an amplifier coupled through transformers and protection capacitors, which gives a signal out of phase to the interference signal on the line, thereby cancelling it.

II. ADVANTAGES OF HVDC COMPARED WITHAC

- The AC transmission encountered both efficiency and economic problems with long Distances, represented chiefly by the use of cables but also by overhead lines. Due to Inductive and capacitive elements, the AC cables exchange too much reactive power, Phenomena known as Ferranti effect. Putting the limit of roughly 40-100 km for AC Overhead lines.
- Furthermore, the connection between two AC systems may be impossible, due to different Frequency, instability or undesired flow scenarios. DC transmission does not suffer with charging current neither skin effect; thus it’s not limited by distances and its preferred for distances higher than 40km.
- The DC has the further advantage to comply with fast power control improving the system stability. Also economic aspect has to be taken in consideration. Summing the cost of terminals and line, a break-even distance has been recognized, beyond which the DC system is cheaper than the AC one. The break-even distance lies usually between 500 and 800km.figure 2 shows the comparison of total cost over distance for AC-DC system.

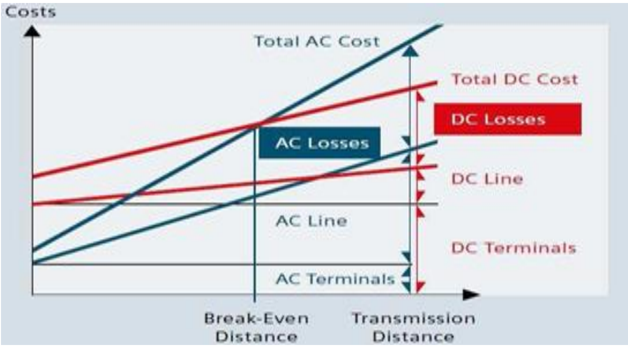

Figure 1 Comparison of Total Cost over Distance for AC and DC System.

- The PWM operates at a high frequency value, it allows a fast response to disturbances and the design of small high frequency filters. Moreover, along with IGBT, it makes VSC operation independent of the grid strength, being even able to feed a passive load or energize a dead network during a black start.

- The VSC doesn't require any external AC source, absorbing then lesser active power.
  The converter operation in 4 quadrants allows the fast control of active and reactive power independently and helps the creation of multi-terminal systems, thanks to the power flow reversal without changing the Vdc polarity.
- In case of fault, Power level of HVDC system can be controlled electronically i.e. very fast.
- HVDC has minimum audible noise, as well as minimum radio, TV interference.
- Cost of Transmission is less, since only two conductors are used for transmission.
- There is no reactive power so transmission losses are reduced.
- There is no skin effect.

III. INHERENT PROBLEMS ASSOCIATED WITHHVDC

1. Complexity

In contrast to AC systems, designing and operating multi-terminal HVDC systems is complex. Controlling power flow in such systems requires continuous communication between all terminals, as power flow must be actively regulated by the control system instead of by the inherent properties of the transmission line.

2. Expensive Converter

Converter stations needed to connect to AC power grids are very expensive. Converter substations are more complex than HVAC substations, not only in additional converting equipment, but also in more complicated control and regulating systems.

3. Power Faults

During short-circuits in the AC power systems close to connected HVDC substations, power faults also occur in the HVDC transmission system for the duration of the short-circuit. Inverter Substation are most affected. During short-circuits on the inverter output side, a full HVDC transmission system power fault can be caused. Power faults due to short-circuits on the rectifier input side are usually proportional to the voltage decrease.

4. Radio Noise

The high-frequency constituents found in direct current transmission systems can cause radio noise in communications lines that are situated near the HVDC transmission line.

IV. METHODOLOGY

1. Voltage Source Converters

A VSC has a voltage source connected on the dc side in the form of a large capacitor appropriately charged to maintain the required voltage. A constraint imposed on the circuit of a power converter is that one side needs to be inductive and another capacitive to prevent a loop consisting of voltage sources. On a VSC, the ac side has an inductance connected, Which has two purposes: first, it stabilizes the ac current and second, it enables the control of active and reactive output power from the voltage source converter. A VSC requires self-commutating switches such as gate turn off thyristors (GTO) or insulated-gate bipolar transistors (IGBT), which has a turn-on and turn-off capability so the position and frequency of the on and off switching instants can be altered to provide a specific voltage and current waveform. The world of converters may be divided in to two groups that are to be distinguished by their operational principle.

One group needs an AC system to operate and called as line commutated converter. Conventional HVDC systems employ line commutated converters. The second group of converters does not need an AC system to operate and is therefore called as self-commutated converters. Depending on the design of the DC circuits this group can be further divided in to current source converters and voltage source converters. A current source converter operates with a smooth DC current provided by a reactor, while a VSC operates with a smooth DC voltage provided by storage capacitor. Among the self-commutated converters it is especially the VSC that has big history in the lower power range for industrial drive applications.

2. VSC-HVDC Transmission

The use of HVDC technology has traditionally been limited to point-to-point interconnections. However, there is an increasing interest of more inter connection points constituting to a dc grid. This is because of technological advances in power electronics and VSC system but also due to grid integration challenges from remotely located generation sites. Since there are two types of HVDC conversion methods, two types of dc grids are possible. However, this work will only consider the VSC type.

V. SIMULATION CIRCUIT FOR HVDCTRANSMISSION

The circuit diagram of figure 3 shows the simulation circuit diagram of HVDC Transmission.

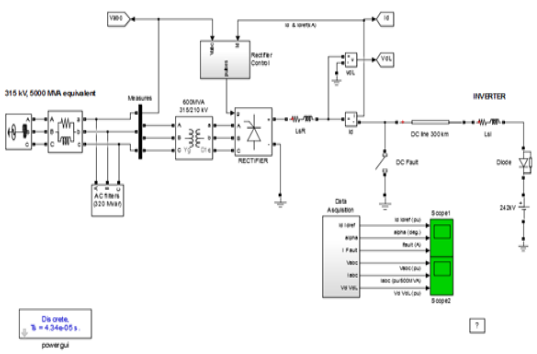

Figure 2 Simulation model of HVDC Transmission 1.

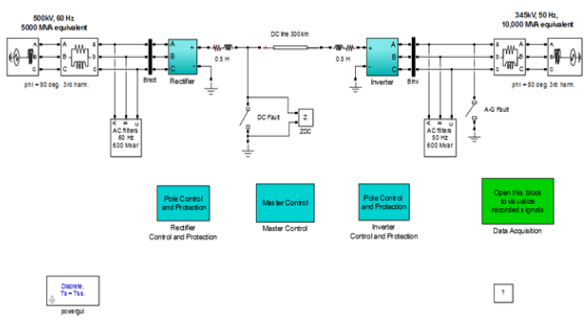

Figure 3 Simulation model of HVDC Transmission 2.

VI. PROPOSED WORK

- Design a combination of a HVDC transmission system with the proper combination of the converter with PWM and VSC for Inverter and Thyristor for the Source is used.
- Simulation study is carried out on PSCAD/EMTDC Software package. Run the model in a PSCAD simulation tool.
- Find the simulating results with analysis of the thermal limit and transient in system.
- Analysis of the fault problem and their solutions.

Using MATLAB Simulink, the circuit of high voltage direct current electric power transmission is simulated both at normal and faulty conditions. The simulation result shows separately by alternating current circuit, direct current circuit and simultaneous ac-dc circuit.

1. Source Output

The power source of the transmission line is 500kv at 50Hz frequency. The output power of the source is three phase power supply which are Va, Vb,Vc.. We can see on the below figure the output of the source is on the form of Alternating Current.

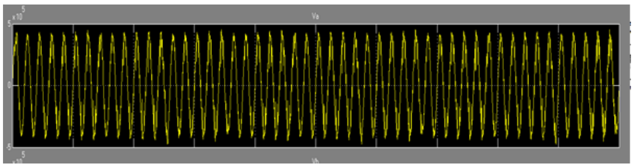

Figure 4 Source Output Voltage and Current at phase a.

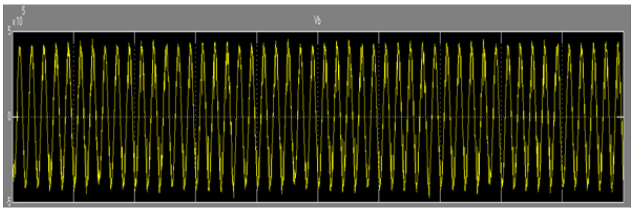

Figure 5 Source Output Voltage and Current at phase b.

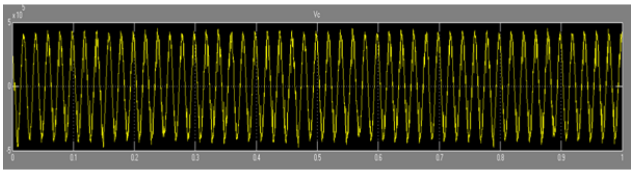

Figure 6 Source Output Voltage and Current at phase c.

2. Transmission Output

The Output of DC Transmission line at the sending end and receiving end voltage is on the form of a direct current. The amplitude value of Vsending is x105 and the amplitude of Vreceiving is x107. And the transmission line the DC power is transmitted.

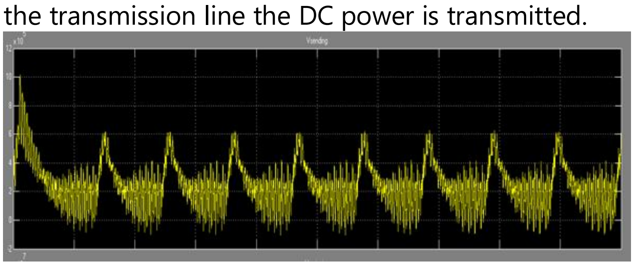

Figure 7 Transmission Output Voltage and Current at sending end.

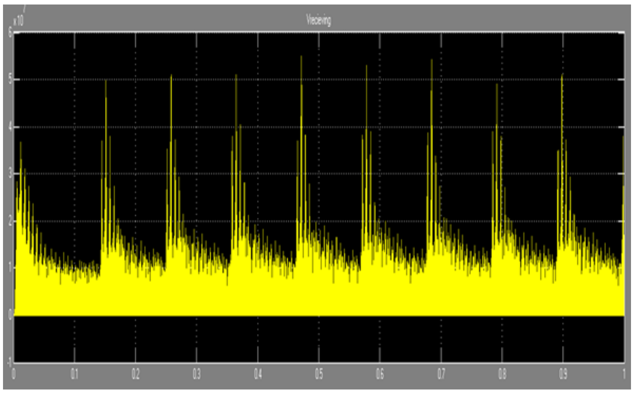

Figure 8 Transmission Output Voltage and Current at receiving end.

3. Inverter Output

The output of the inverter is shown in the given figures at respectively phase a, phase b and phase b. The outputs of inverter are in the form of alternating current. This will transmit on the AC transmission line side.

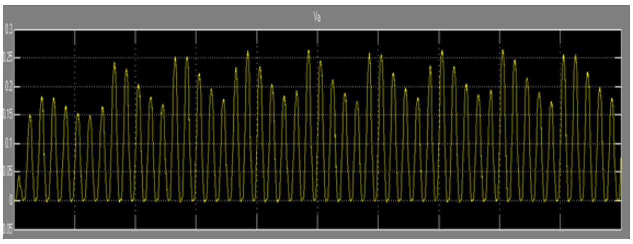

Figure 9 Inverter Output Voltage and Current at phase a.

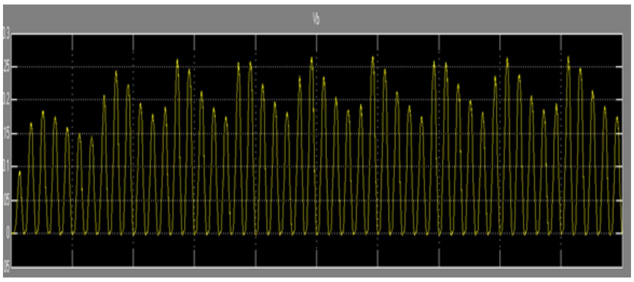

Figure 10 Inverter Output Voltage and Current at phase b.

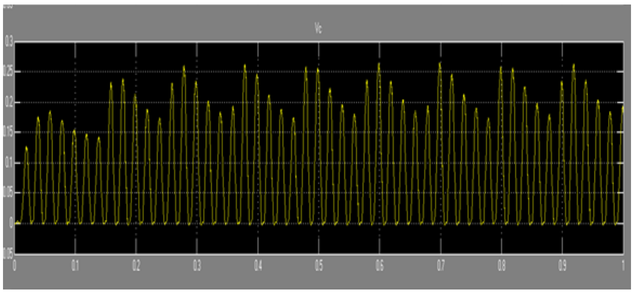

Figure 12 Inverter Output Voltage and Current at phase c.

VII. CONCLUSION

This paper has clearly demonstrated the methodology for modelling steady state operation of HVDC transmission system rectifier using universally available software Matlab/Simulink. A simple scheme of simultaneous EHV ac-dc power transmission through the same transmission line has been presented. Expressions of active and reactive powers associated with ac and dc, conductor voltage level and total power have been obtained for steady state normal operating condition. HVDC is the preferred system for use in a variety of transmission applications, using submarine cables, land cables and overhead lines. The simulation works ensure that simultaneous ac-dc power can be transferred in long distant is possible avoiding thermal limit and transient stability problem. The proposed power system network is very simple and there is no physical alteration in insulator strings, towers and arresters of the original line.

Tools

- The study will be carried out using the MATLAB/SIMULINK.
- MATLAB is a high performance language for a technical computation, computer programming, visualization, C-language and integrates computation differentiate computation is easy to used in the environments and there problems and the solutions are the expressed in familiar mathematical presentation.
- MATLAB is the interactive system whose basic data element is an array that does not required dimensioning.
- MATLAB features a family of application specifics solutions are called toolboxes.

REFERENCE

[1] P. V. K. Babu, P. B. Prasad, and M. P. Lalitha, “Power Upgrading of Transmission Line by Combining AC–DC Transmission,” Int. J. Of Engineering Research and Applications, vol. 2, no. 6, pp.1699-1704, Dec.2012.

[2] P. Zuniga-Haro, J. M. Ramirez, “Multi-pulse Switching Functions Modeling of Flexible AC Transmission Systems Devices", Electric Power Components and Systems, Volume 37,Issue 1 January 2009 , pages 20 –42.

[3] Cleric A, Paris L and Danfors P., "HVDC conversion of HVAC line to provide substantial power upgrading," IEEE Transaction on Power Delivery, 6(1), 1991, pp.324-333.

[4] Clerici A, Valtorta G and Paris L, "AC and/or DC substantial power upgrading of Existing OHTL Corridors," AC DC Conference, London, 1991,pp.220-225.

[5] Brierley R H et al,"Compact Right of Ways with multi-Voltagr Towers" IEEE Transaction on Power Delivery, Vol.6 No.4, October 1991,pp.1682-1689.

[6] H. Rahman and B H Khan "Stability Improvement of Power System by Simultaneous AC-DC Power Transmission" Electric Power System Research Journal, Elsevier, Paper Editorial ID No. EPSRD-06-00732, Press Article No. EPSR-2560— Digital Object Identifier, doi: 10.1016/j.epsr.2007.05.020.

[7] N. Flourentzou, V. G. Agelidis, and G. D. Demetriades, "VSC-based HVDC power transmission systems: An overview," IEEE Trans. Power Electron., vol 24, no. 3, pp. 592– 602, Mar.2009.

[8] H. Rahman and B H Khan "Possibility of Power Tapping from Composite AC-DC Power Transmission Lines" IEEE Transaction on Power Delivery, Vol.23,July 2008 ,pp1464-1471.

[9] P. S. Kundur, "Power system stability and control", NewYork: McGrawhillInc.,1994.

[10] PSCAD/EMTDC, "User's Guide", Manitoba HVDCResearch.