International Journal of Multidisciplinary Research and Modern Education (IJMRME)
ISSN (Online): 2454 - 6119
(www.rdmodernresearch.org) Volume I, Issue II, 2015

MODELING AND SIMULATION OF VOLTAGE SOURCE CONVERTER IN HIGH VOLTAGE DC SYSTEM

Radhey Shyam Meena* & Mukesh Kumar Lodha**
* Member- IET, UACEE, M.Tech (Power System), Rajasthan Technical University, Kota, Rajasthan
** Assistant Professor (SBCET-J), M.Tech (Power System), Indian Institute of Technology, Roorkee, Uttarakhand

Abstract:

High Voltage DC Transmission system is used to transmit bulk power, to control power, to modulate power for improvement in system stability. Converters are main part of dc technology thanks to power electronics engineer who makes a turning point in current war of ac and dc. Several limitations in both ac as well dc but to transmit power at very long distance dc is better option than ac. Mostly voltage source converters used as insulated gate turn of thyristor in dc network. This paper describes basic modeling and simulation of voltage source converter in HVDC. At the end of this paper different output waveform of converter are explained. Modeling and Simulation is done using MATLAB.

Key Words: HVDC, VSC & MTDC

I. Introduction:

HVDC transmission applications can be broken down into different basic categories, although the rationale for selection of HVDC is often economic, there may be other reasons for its selection. HVDC may be the only feasible way to interconnect two asynchronous networks, reduce fault currents, utilize long cable circuits, bypass network congestion, and share utility rights-of-way without degradation of reliability and to mitigate environmental concerns. In all of these applications, HVDC nicely complements the ac transmission system.

II. Converter Technology:

Two basic converter technologies are used in modern HVDC transmission systems. These are conventional line commutated, current source converters (CSC) and self commutated, voltage-sourced converters (VSC). These configurations can be adopted in a Multi Terminal DC (MTDC) systems. In first the parallel connection which allows DC terminals to operate around a common rated voltage V_{DC}. The second configuration is the series connection where one of the converters controls the current around a common rated current and the power is controlled by the rest of converters.

(a) Line-Commutated, Current-Sourced Converter:

Conventional HVDC transmission employs line commutated, current-source converters (CSC) with thyristor valves. Such converters require a synchronous voltage source in order to operate. The basic building block used for HVDC conversion is the three-phase, full-wave bridge referred to as a 6-pulse or Graetz bridge. The term 6-pulse is due to six commutations or switching operations per period resulting in a characteristic harmonic ripple of 6 times the fundamental frequency in the dc output voltage. Each 6-pulse bridge is comprised of 6 controlled switching elements or thyristor valves. Each valve is comprised of a suitable number of series-connected thyristors to achieve the desired dc voltage rating.

(b) Self-Commutated Voltage-Sourced Converter:

HVDC transmission with VSC converters can be beneficial to overall system performance. VSC converter technology can rapidly control both active and reactive power independently of one another. Reactive power can also be controlled at each terminal independent of the dc transmission voltage level. This control capability gives total flexibility to place converters anywhere in the AC network since there is no restriction on minimum network short circuit capacity. Self commutation with VSC even permits black start, i.e., the converter can be used to synthesize a balanced set of three phase voltages like a virtual synchronous generator. The dynamic support of the ac voltage at each converter terminal improves the voltage stability and can increase the transfer capability of the sending and receiving end AC systems thereby leveraging the transfer capability of the DC link. Fig. 7 shows the IGBT converter valve arrangement for a voltage source converter station.

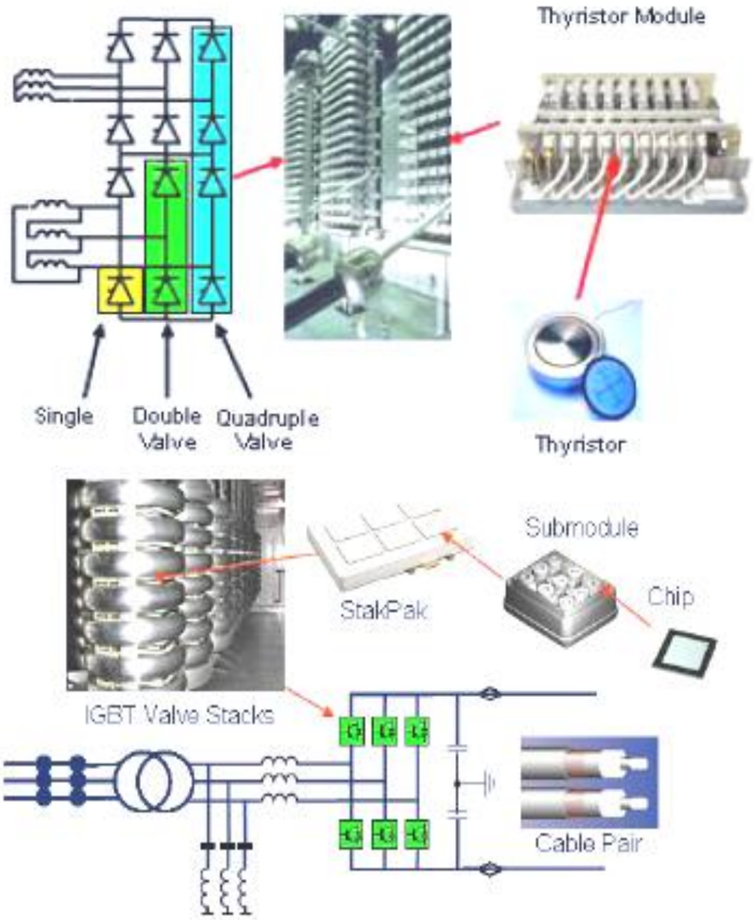


Figure 1: (a) HVDC thyristor valve arrangement (b) HVDC IGBT valve arrangement

Compared to CSCs, VSCs are functioning as an ideal current source in its DC sides allowing the parallel connection of several DC terminals without posing any technical difficulties. As perviously mentioned, in a VSC link the direction of power can be changed through the reversal of current direction and the voltage polarity at the DC side can remain unchanged. These capabilities are perfectly suited for constructing an MTDC system. VSC MTDC systems with parallel connected converters have a great potential to be used in the future bulk power systems. Possibility of such connections has led to the proposition of a DC 'Super Grid' that could connect several renewable energy sources to a common MTDC network. Utilizing VSC-based MTDC systems can give the following possibilities to the power systems- (a) Control of the MTDC system,(b) increasing the flexibility of power flow controllability, (c) enhancing transmission capacity, (d) improving the voltage profile in the network, and integrating large scale of renewable or new energy sources positioning at different locations.

III. VSC-MTDC Modeling:

Since VSC-based MTDC systems consist of several VSC stations, it is firstly necessary to get familiar with structure of VSC station model and its elements required for steady state modeling. In this paper, first the components forming a VSC station are presented and then the operating modes used in AC and DC sides of each satin are explained. Power can be controlled by changing the phase angle of the converter ac voltage with respect to the filter bus voltage, whereas the reactive power can be controlled by changing the magnitude of the fundamental component of the converter ac voltage with respect to the filter bus voltage. By controlling these two aspects of the converter voltage, operation in all four quadrants is possible. This means that the converter can be operated in the middle of its reactive power range near unity power factor to maintain dynamic reactive power reserve for contingency voltage support similar to a static var compensator. It also means that the real power transfer can be changed rapidly without altering the reactive power exchange with the ac network or waiting for switching of shunt compensation. Fig. shows the characteristic ac voltage waveforms before and after the ac filters along with the controlled items Ud, Id, Q and Uac.

Figure shows the VSC station model with its elements. The model at the DC side is depicted as single line representation. The model consists of AC buses, coupling transformer, series reactance, AC filter, converter block on the AC side and on the DC side, DC Bus, DC filter and DC line. As it can be seen each VSC station is connected to the AC grid at the so called point of the common connection (PCC). PCC is connected to AC side of VSC through a converter transformer, shunt filter and finally phase reactor. on the other side i.e. DC side, DC bus, at which a shunt DC capacitor is connected to the ground, is connected to the VSC from one side and to DC line from other side.

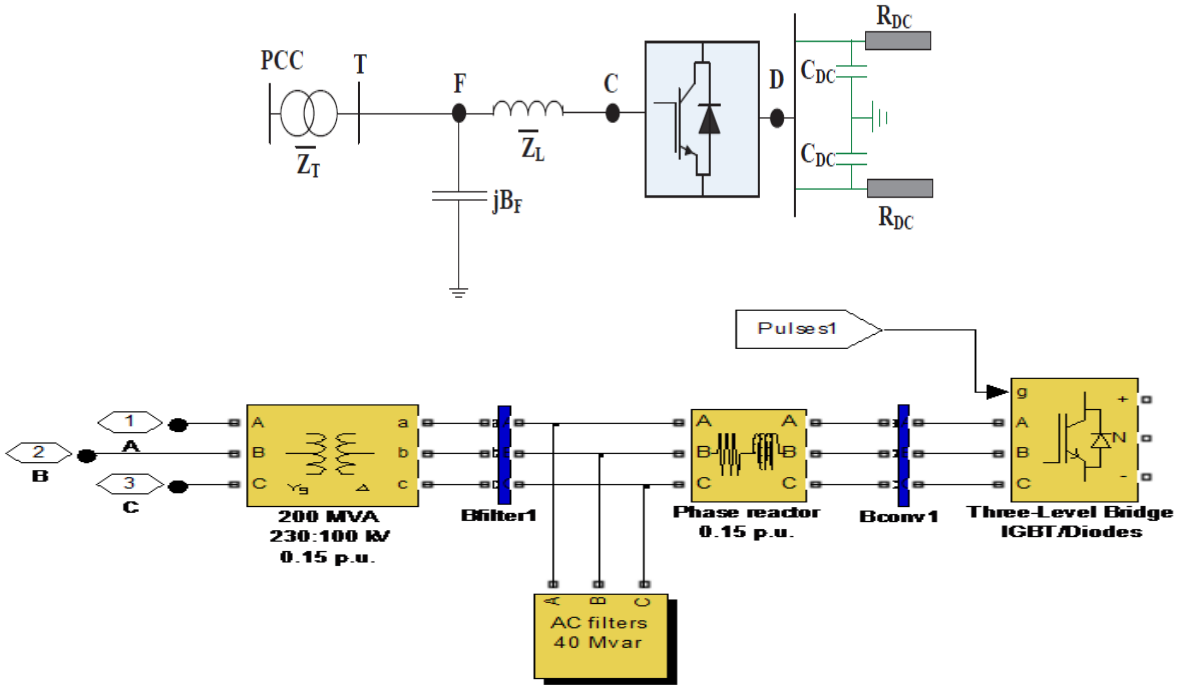


Figure 2: Steady State VSC station model

IV. MTDC Operating Modes:

In this section, the operating modes which can be adopted in AC and DC sides of each station are explained.

(a) AC side Operating Modes:

VSC on its AC side can either control the reactive power or AC voltage at the point of the common connection (PCC). Figure show: PQ bus connected to VSC converter.

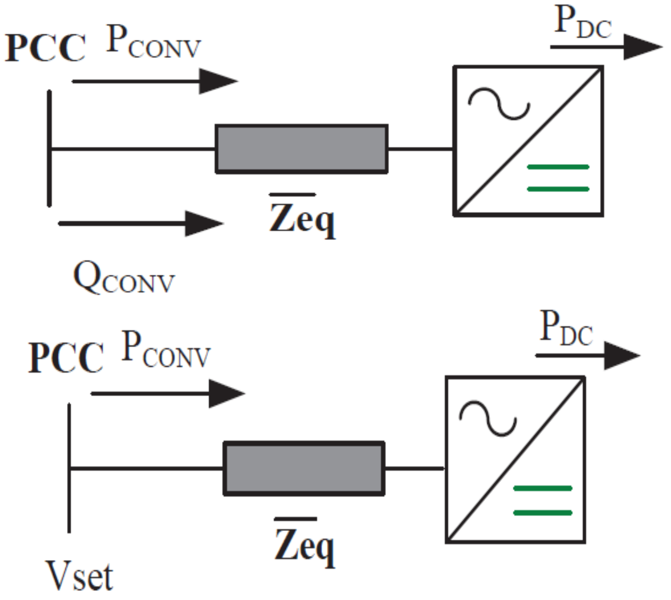


Figure 3: (a) PQ bus connected to VSC (b) PV bus connected to VSC

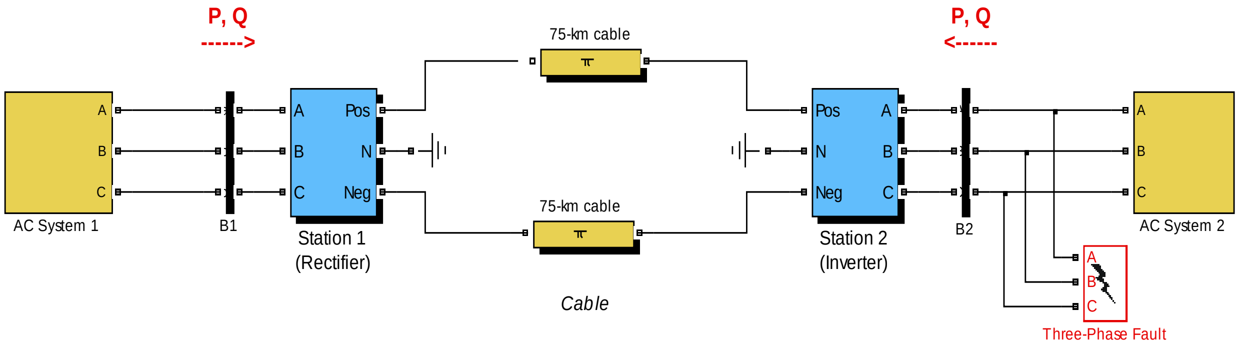


Figure 4: Complete Digram of HVDC

If in an N terminal VSC-MTDC, the reference power of all converters at the PCC is known, every PCC from AC system's point of view can be seen as either a PV or PQ bus depending on the control mode of converter connected to that bus as shown in Figure. Therefore all N converters excluding the slack converter can be separately modeled at each AC bus.

(b) DC side Operating Modes:

A VSC-based MTDC system at its DC terminals can also operate at three different control modes. In a VSC-MTDC system with N converter stations usually one converter controls its DC bus voltage around a constant value. That is why this mode is known as constant DC voltage and the associated bus is called DC slack bus. The voltage-power characteristic of constant voltage mode is shown in Figure.

The slack DC bus is to ensure that the total amount of active power going into the DC grid equals the sum of the amount of power going out plus the losses in the lines according to following equation:

$$P_{DC1}+P_{DC2}+\dots\dots\dots P_{DCN}-P_{L,DC}=0$$

Where P_{DC} is the injected DC power in each DC terminal and $P_{L,DC}$ is losses in the DC lines. In fact, here in a DC grid DC voltage plays the role of frequency in AC systems. The other N −1 VSCs operate at constant power control mode. The voltage-power characteristic of constant power mode is shown in Figure.

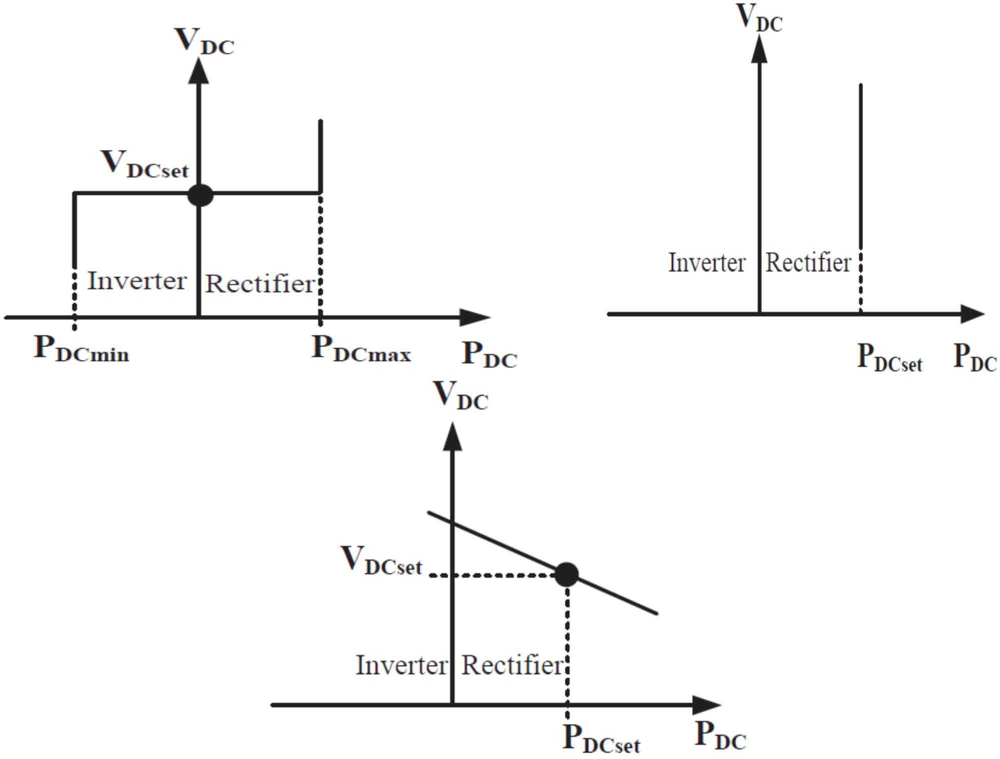
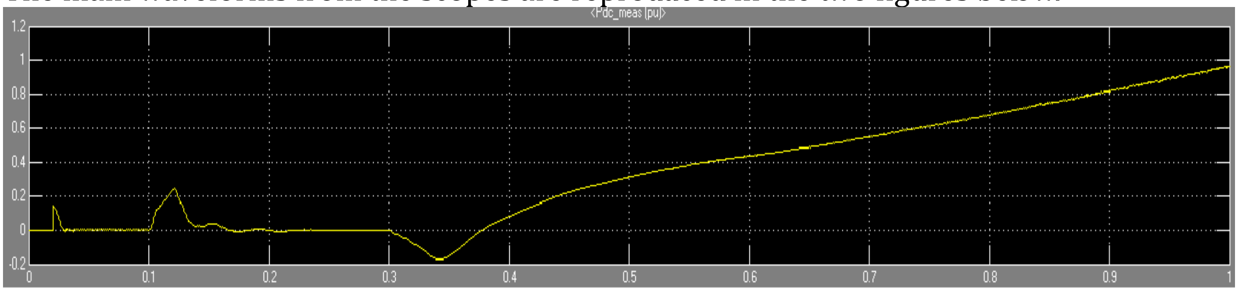


Figure 5: (a) V-P Characteristic of constant voltage mode, (b) V-P Characteristic of constant power mode (c) V-P Characteristic of voltage drop mode

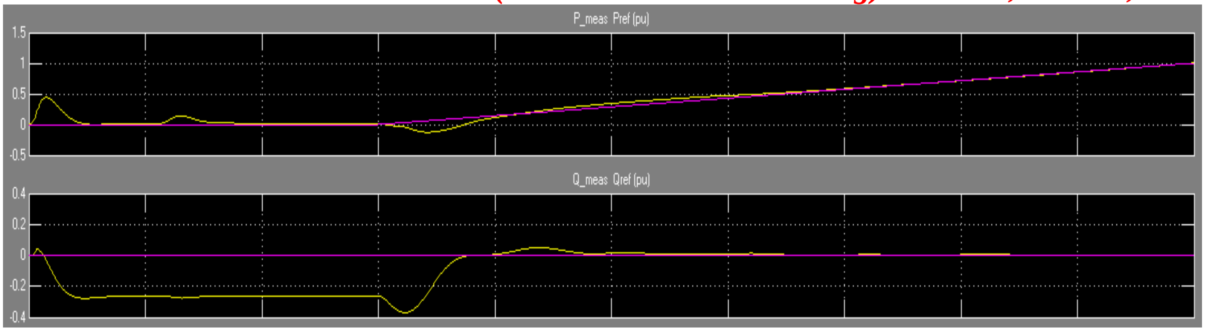
Another DC control mode which is actually a combination of two previous control modes is called voltage droop control mode. As it can be seen from the voltage-power characteristic of this mode in Figure VSC controls the DC voltage around a set value but by balancing the DC power at the same time. The voltage droop control mode gives the possibility of controlling MTDC system without any communication between stations. This control mode is also useful to remove the burden from only on slack bus in balancing power. In this mode the converter can contribute to balance total power together with slack bus.

V. Results:

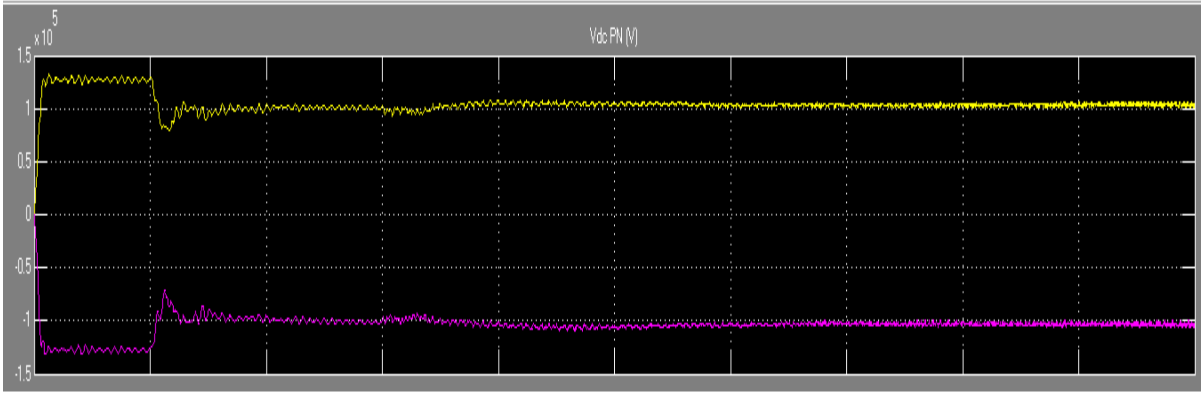
From the steady-state condition, a minor and a severe perturbation are executed at each station systems respectively. A three-phase voltage sag is first applied at station 1 bus. Then, following the system recovery, a three-phase to ground fault is applied at station 2 bus. The system recovery from the perturbations should be prompt and stable. The main waveforms from the scopes are reproduced in the two figures below.



(a)



(b)



(c)

Figure 6: (a) DC Power out Put with time (b) P Q Bus waveform (c) DC Voltage Output with time

VI. Reference:

1. N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics: Converters, Applications, and Design, 2nd Ed. New York: Wiley, 1995.
2. K. Bhattacharya, M. Bollen, and J. Daalder, Operation of Restructured Power System. Norwell, MA: Kluwer, 2001.
3. G. Daelemans, “VSC HVDC in meshed networks,” M.Sc. dissertation, Katholieke University Leuven, Leuven, Belgium, 2008.
4. J. Wood and B. F.Wollenberg, Power Generation Operation and Control, 2nd Ed. New York: Wiley, 1996.
5. Z. Xiao-Ping, “Multiterminal voltage-sourced converter-based HVDC models for power flow analysis,” IEEE Trans. Power Del., vol. 19, no. 4, pp. 1877–1884, Oct. 2004.
6. “Vsc transmission,” Cigre Brochure 269, Working Group B4.37, Tech. Rep., April 2005.