ACTIVE & REACTIVE POWER CONTROL OF VOLTAGE SOURCE CONVERTER BASED HVDC TRANSMISSION

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ABSTRACT**:** *The ever increasing the development of high-voltage, high power fully controlled semiconductor technology continues to have a significant impact to enhance the power quality management of electrical grids. Voltage Source Converter based transmission system technology such as VSC-HVDC is a new power transmission technology preferable in small or medium power transmission. It provides fast and independent control of active and reactive power flow in both directions and low harmonic generation. This paper deals with an overview of the voltage-source converter HVDC technology and its active & reactive power control.*

Index Terms—VSC, PWM, IGBT, LCC-HVDC, HVDC Light

1. INTRODUCTION

In India, with the rapid increase in energy demand, grid integration of renewable energy sources has become very essential. In the different renewable energy sources, wind energy benefits from HVDC technology for power transmission to enhance the system performance and connect AC system which has different frequencies. [1] The HVDC technology is used to transmit electricity over long distances by overhead transmission line or submarine cable. The further development in this technology is VSC-HVDC where VSC converters are used for faster and efficient conversion of power.

Voltage source converter based-HVDC (VSC-HVDC) systems are considered as to be the technology of choice for efficient grid integration. It provides the fast and independent control of active and reactive power flow in both directions and low harmonic generation hence use of large filters are minimized.[2]VSC (Voltage Source Converter) with the semiconductor technology i.e. IGBT (Insulated Gate Bipolar Transistor) makes it economically feasible to connect small scale, renewable power generation plants to the main AC grid.[3] Voltage source converter (VSC) technology provides benefits like controllability, compact modular design, ease of system interface and low environmental impact. With the advance of power electronics technology, the application of VSC-HVDC based on Insulated gate bipolar transistor (IGBT) has increased rapidly in renewable i.e.

Wind energy system and electric power systems. There are two technologies of HVDC transmission: the HVDC Classic and VSC-HVDC transmission. [4]The line commutated current source converters (CSC) based HVDC is also known as classical HVDC, which uses thyristor based converters. This technology is used for the bulk power transmission with the line commutated thyristor valve. In the Voltage source converter (VSC) HVDC uses the self-commutated IGBT. It is used for the medium power transmission.

The general overview of this paper is as follows. In Section 2, overview of VSC-HVDC Technology is discussed. Section 3 presents, active and reactive power control of VSC-HVDC Section 4, presents the control system of the VSC-HVDC system and section 5, concluded the paper.

2. VSC -HVDC

The HVDC transmission technology can be realized by using current source converters(CSCs) commutated thyristor switches, known as traditional HVDC or classic HVDC, or by using voltage source converters (VSC-based HVDC). The first HVDC transmission line using VSC was installed in 1997 in Gotland (Sweden). [5],[6]

The few are the advantages of VSC -HVDC can be mentioned

Independent control of reactive and active power, simpler interface with ac system, compact filters, provides continuous ac voltage regulation, operation in extremely weak systems, no commutation failures, no polarity reversal needed to reverse power *etc.*

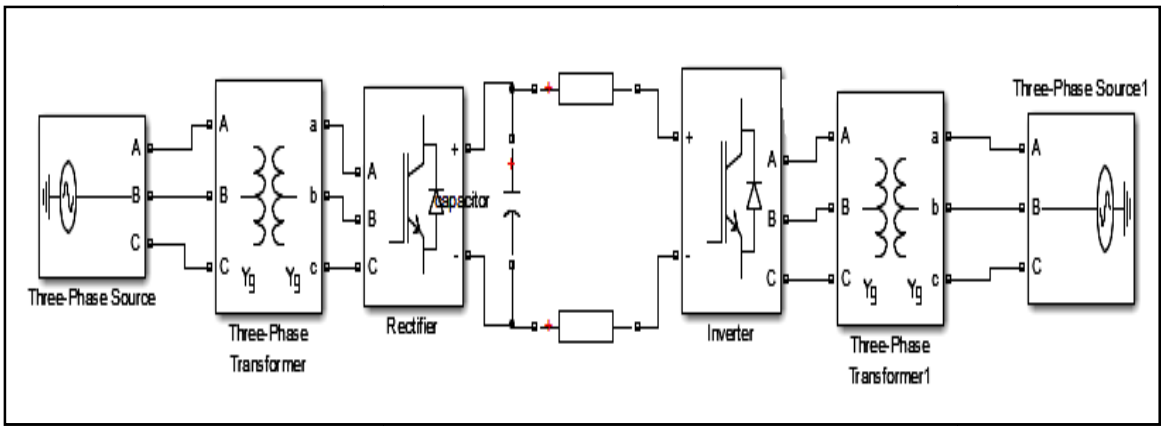

Figure 1: VSC –HVDC System

It consists of the main components such as transformer, smoothing reactor, DC-link capacitor, valves, AC filter & DC filter .Design of these filters is based on speculations of system and loading conditions. [7] The key parts of VSC-HVDC are converters, which can realize the conversion from ac to dc bi-directly. One of the VSCs works as rectifier, while the other one works as an inverter, and both of them are based on IGBT power semiconductors. This technology provides the VSC-HVDC converter with the a switching speed 27 times faster than classical HVDC.The two VSC stations are connected through a DC transmission line or an overhead line.

3. ACTIVE & REACTIVE POWER CONTROL

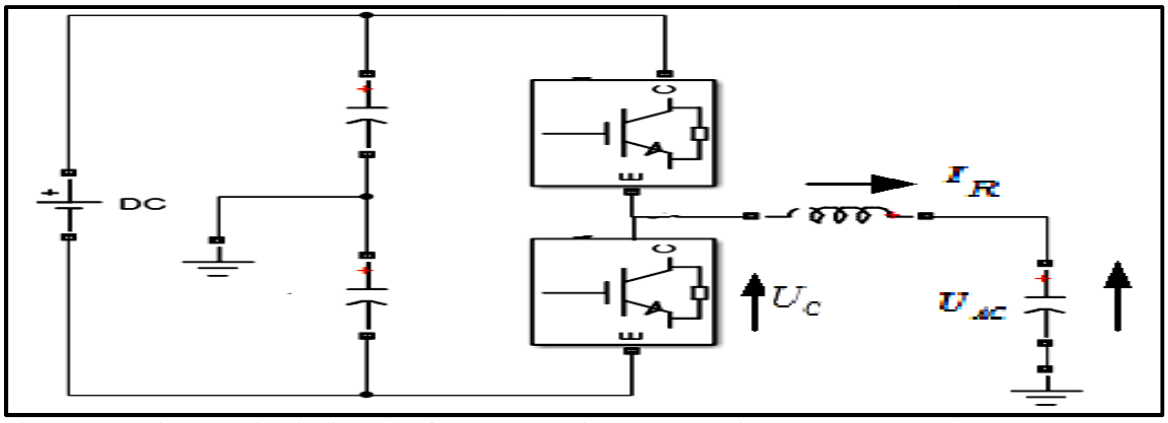

Figure 2: Equivalent Circuit diagram of VSC HVDC inverter operation [8, 9]

The magnitude and the phase angle decide the reactive power & active power exchange between ac & dc system respectively. The power transmitted by VSC–HVDC

$= \sqrt{3}(U_{AC} I_R)^*$

$= \sqrt{3}U_{AC}(U_C - U_{AC})^* / Z_R$

Where S_b is the apparent power

Z_R is the equivalent impedance

U_C is the converter voltage

U_{AC} is the voltage of the ac system

The active and reactive power are given by

$P = U_{AC} U_C Sin\ \partial / X_L$

$Q = U_{AC}(U_{AC} - U_C Cos\,\partial) / X_L$

So by controlling the U_C & ∂ we can control the reactive and active power independently respectively.

Control of active power flow by VSC HVDC is done by changing the phase angle difference δ and control of reactive power flow is realized by changing the voltage amplitude difference between converter bus and filter

bus. The converters PWM control can change the converters voltage angle and amplitude. Thus, active and reactive power can be controlled independently & almost instantaneously. [10, 11]

4. VSC –HVDC Control system:

Depending on the direction of active power flow, one station works as a rectifier while the other operates as an inverter. Each VSC station has two control structures: One is used for reactive power control while the other degree is used for active power or dc voltage control. [12]

In the sender end:
Active power controlled by the phase angle of converter output voltage & reactive power by the magnitude of the converter voltage
In the receiver end:
DC voltage is controlled by the phase angle of the converter output voltage.
AC voltage is controlled by the magnitude of the converter voltage.
Rectifier controller:
a) Power flow control loop: the active power control is calculated by the product of dc voltage and current.

$$P_{dc} = V_{dc} I_{dc}$$

b) Reactive power control loop: Reactive power controller is normally control by PI controller
c) PLL: Phase Locked loop provides the synchronous signal to pulse generator.
d) PWM pulse firing: PWM pulse generator sends the pulse signal to drive the valves in the converter

Inverter controller:
PWM pulse generator & PLL same as the rectifier
AC voltage control loop
DC voltage control loop.

The VSC-HVDC control system, as shown in figure3, allows the fully independent control of active and reactive powers within the operating range of design. Normally, each station controls its reactive power independent of the other station. However, the flow of active power in the dc transmission system must be balanced, which means that the active power entering the HVDC system must be equal to the active power leaving it, if neglecting the losses in the dc system.

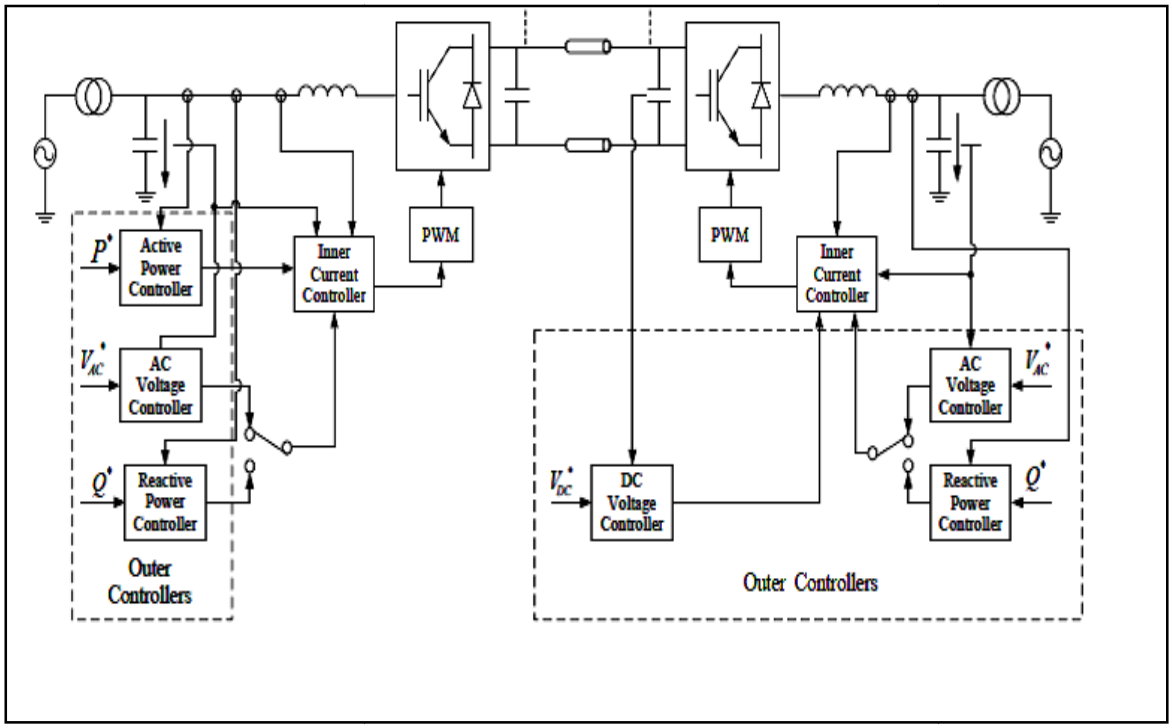

Figure 3:- Control system of VSC –HVDC system [13]

5. Conclusion

VSC- HVDC is a new technology that provides the ability to connect renewable generation to the AC grid. It allows us to supply power to remote locations and islands replacing local diesel generation. Moreover, a key advantage is that it provides accurate control of the transmitted active power and independent control of the reactive power in the connected AC networks. As opposed to an overhead line, an underground cable pair has no visual impact on the landscape. It provides fast and independent control of active and reactive power flow in both directions and low harmonic generation

Application of VSC-HVDC to Indian network just not only provides required reactive power compensation but also improves the power quality of connected network, It will also provide important feature like back start capability to grid .Thus we will get Stable grid with fully controlled transmission line. Research is going on for developing VSC-HVDC Technology for bulk amount of power transmission & to increase its cost effectiveness so as to compete with conventional HVDC system.

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