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Reactive Power Control and harmonic elimination in VSC HVDC system

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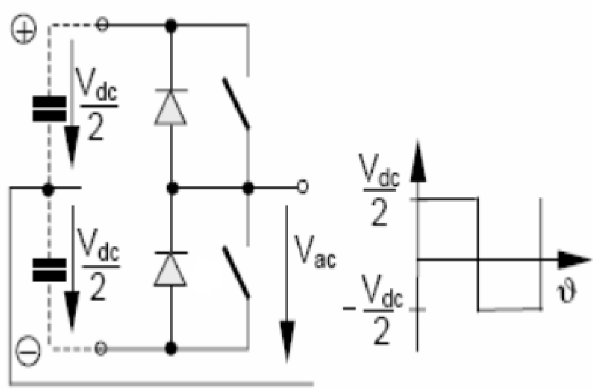
Abstract—
Confronting with an increasing demand of power, there is a need to explore the most efficient and reliable bulk power transmission system. Rapid development in the field of power electronics devices especially Insulated Gate Bipolar Transistors (IGBTs) has led to the High Voltage Direct Current (HVDC) transmission based on Voltage Source Converters (VSCs). This new innovative technology provides substantial technical and economical advantages for direct applications compared to conventional HVDC transmission system. The VSC based HVDC transmission system mainly consists of two converter stations connected by a DC cable. This paper presents the performance analysis of VCS based HVDC transmission system. In this paper a 75kM long VSC HVDC system is simulated for various faults on the AC side of the receiving station using MATLAB®/SIMULINK. The data has been analyzed and a method is proposed to classify the faults by using back propagation algorithm. The simulated results presented in this paper are in good agreement with the published work.

Index Terms— Voltage Source Converters (VSCs); High Voltage Direct Current (HVDC); fault analysis

I. INTRODUCTION :

High voltage direct current (HVDC) transmission is an economic way for long distance bulk power delivery and/or interconnection of asynchronous system with different frequency. HVDC system plays much more important role in power grids due to their huge capacity and capability of long distance transmission [1]. The development of power semiconductors devices, especially IGBT's has led to the transmission of power based on Voltage source converters (VSCs). The VSC based HVDC installation has several advantages compared to conventional HVDC such as, independent control of active and reactive power, dynamic voltage support at the converter bus for enhancing stability possibility to feed to weak AC systems or even passive loads, reversal of power without changing the polarity of dc voltage (advantageous in multi terminal dc system) and no requirements or fast communication between the two converter stations. HVDC light is also called voltage source converter HVDC or VSC HVDC. HVDC light can control both active and reactive power independently without commutation failure in the inverters. Each converter station is composed of a VSC. The amplitude and phase angle of the converter AC output voltage can be controlled simultaneously to achieve rapid, independent control of active and reactive power is bi-directional and continuous across the operating range. For active power balancing, one of the converters operates on dc voltage control and other converter on active power control. When dc line power is zero, the two converters, can function as independent STATCOMs. Each VSC has a minimum of three controllers for regulating active power outputs of individual VSC. It does not require reactive power compensator resulting much smaller equipment size. HVDC light can be applied to the voltage support in the receiver system. It provides inter-connection between two asynchronous power systems, grid connection of large wind farm, undersea power transmission, bidirectional power flow etc., [2]. The basic function of a VSC is to connect the DC voltage of the capacitor into AC voltage. The IGBT can be switched on at any time by appropriate gate voltages. However, one IGBT of a branch can be switched off before to prevent a short circuit of storage capacitor. Reliable storage converter inter lock function will preclude unwanted switching IGBT. Alternating switching the IGBT's of one phase module as shown in Figure 1 successively connects the AC terminals of the VSC to the positive tapping and negative tapping of the DC capacitor [3]. This results in a star stepped AC voltage comprising two voltages levels +Vdc/2 and –Vdc/2.



The VSC based HVDC transmission system mainly consists of two converter stations connected by a dc cable. Usually the magnitude of AC output voltage of converter is controlled by Pulse Width Modulation (PWM) without changing the magnitude of DC voltage. Due to switching frequency, that is considerably higher than the AC system power frequency the wave shape of the converter AC will be controlled to vary sinusoidal. This is achieved by special Pulse Width Modulation (PWM). A three level VSC provides significant better performance regarding the Total Harmonic Distortion (THD).

II. PULSE WIDTH MODULATION (PWM):

A converter is interconnecting two electric networks to transmit electric power from one network to other, each network being coupled to a respective power generator station. The converter, having an AC side and a DC side, includes a bridge of semiconductor switches with gate turn-off capability coupled to a control system to produce a bridge voltage waveform having a fundamental Fourier component at the frequency of the electric network coupled to the AC side of the converter. The control system includes three inputs for receiving reference signals allowing controlling the frequency, the amplitude and the phase angle of the fundamental Fourier component and the alternating voltage of the network coupled to the DC side of the converter [4]. The principle characteristic of VCS-HVDC transmission is its ability to independently control the reactive and real power flow at each of the AC systems to which it is connected, at the Point of Common Coupling (PCC). In constant to line commutated HVDC transmission, the polarity of the DC link voltage remains the same with the DC current being reversed to change the direction of power flow

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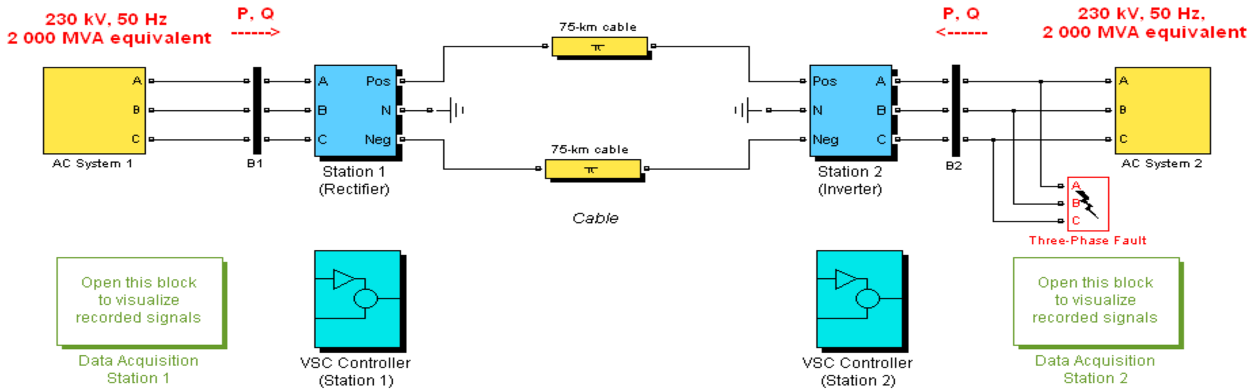

Fig.2. VSC-HVDC Transmission System Model The 230 kV, 2000 MVA AC system (AC system and AC system 2 subsystems) are modeled by damped L-R equivalents, with an angle of 800 at fundamental frequency (50HZ) and at the third harmonic. The simulation model is as shown in Figure 2. The VSC converters are three-level bridge blocks using close to ideal switching device model of IGBT/diodes. The control capability of IGBTs and its suitability for high frequency switching hasmade this device the better choice over GTO and thyristor. Like all power electronic converters, VSC generate harmonic voltages and currents in the AC and DC systems connected. In a simplified manner, from the AC system a VSC can be considered a harmonic current source connected in parallel to the storage capacitor. This behavior is just opposite to those of conventional line commutated converters. Harmonics generated depends on the station topology, switching frequency of IGBTs and pulse pattern applied. Using 12 pulse configurations instead of 6 pulse will improve harmonic condition both on AC and DC side. Characteristic AC side harmonics will have the ordinal numbers Vac=12n+1 ;n = 1, 2 . . . . (1) Characteristic DC harmonic will have the ordinal numbers Vdc =12n;n = 1, 2 . . . . (2) All harmonics will be cancelled out under ideal conditions. Due to its inherent harmonic elimination capability the harmonic interface of VSC converter is rather small in comparison to the conventional line commutated converters. However harmonics filters might be necessary on the AC and DC sides depending on the harmonics performance requirements both for AC and DC sides [5]. AC system harmonic impedance, DC line/cable impedance and loss evaluation.

4. SIMULATION RESULTS :

During no fault the DC line voltage of the bipolar transmission is about 1pu (positive and negative) as shown in Figure 4(a) and the mean DC line voltage of the VCS HVDC transmission system is 1pu as shown in fig Figure 4(b). It is observed that the power transmitted is around -0.8pu. During no fault on the AC side DC line voltage of the bipolar transmission is about 1pu (positive and negative) and the mean DC line voltage of the VCS HVDC transmission system is 1pu. It is observed that the power transmitted is around -0.8pu. During LG fault on AC side of the inverter as shown in Figure 5 active power is about 0.8pu (positive and negative) and the reactive power of the VCS HVDC transmission system is -0.6 pu as. The AC voltage at bus 1 of a phase is zero.

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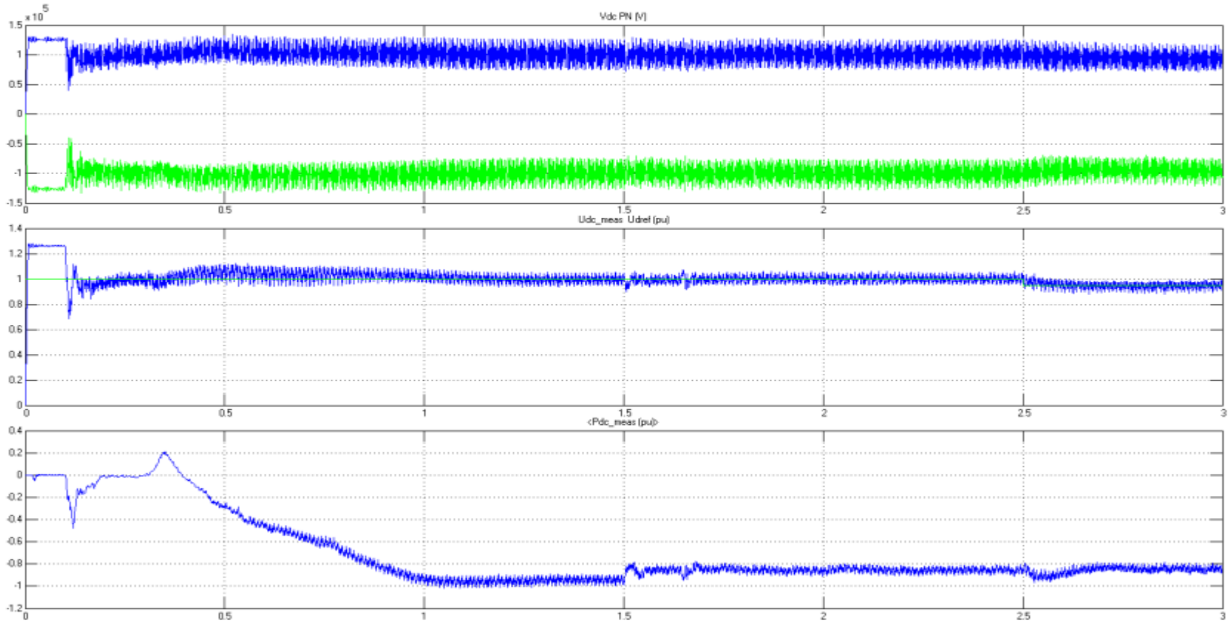
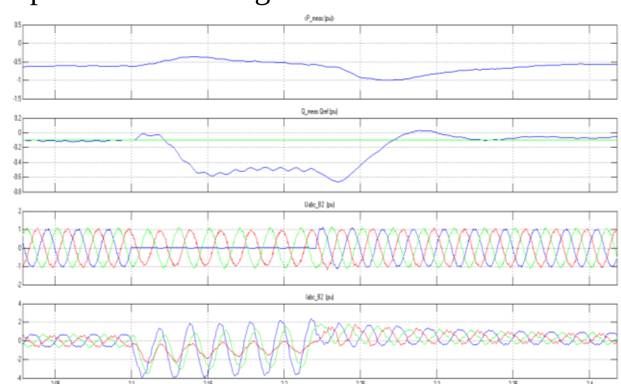


VSC HVDC transmission system without fault condition (a) DC line Voltage; (b) mean DC line voltage; (c) DC power transmitted During LG fault on AC side of the inverter active power is about 0.8 pu and the reactive power of the VCS HVDC transmission system is -0.6 pu as shown in Figure 5. During LG fault on the AC side DC line voltage of the bipolar transmission is about 1pu (positive and negative) as shown in Figure 6(a) and the mean DC line voltage of the VCS HVDC transmission system is 1pu as shown in Figure 6(b). It is observed that the power transmitted is around -0.8pu. During LL fault on AC side of the inverter active power is about 0.8pu (positive and negative) as shown in Figure 7(a) and the reactive power of the VCS HVDC transmission system is -0.6pu as shown in Figure 7(b). The AC voltage at bus 1 of a phase is zero shown in Figure 7(c). The AC current at bus 1 change in phase sequence is shown in Figure 7(d). During LLG on the AC side DC line voltage of the bipolar transmission is about 1pu (positive and negative) as shown in Figure 8(a) and the mean DC line voltage of the VCS HVDC transmission system is 1.2 pu as shown in Figure 8 (b). It is observed that the power transmitted is varies from -0.8 to -0.2pu. During LLG fault on AC side of the inverter active power is about 0.5pu (and the reactive power of the VCS HVDC transmission system is -0.1pu as shown in Figure 8



VSC HVDC transmission system During LG fault on the AC side of the inverter (a) active power (b) reactive power (c) ac voltage at bus 1 and (d) ac current at bus 1

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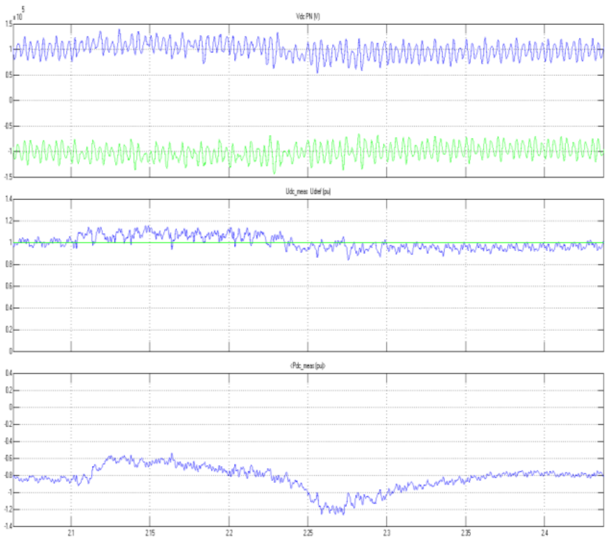

VSC HVDC transmission system During LG fault on the AC side of the inverter (a) DC line Voltage – Positive & Negative; (b) mean DC line voltage; (c) DC power transmitted

CONCLUSION :

Increasing demand of electrical power and need for bulk efficient electrical power transmission system lead to the development of HVDC transmission system. HVDC transmission system today become one of the best alternative for transmitting bulk power over long distance with very less losses. This paper provided a most efficient method to reduce the harmonics contents in the HVDC transmission system by improving the inverter topology through Selective Harmonic Elimination Technique. A sample system has been designed based on the SHE PWM technique and the model is simulated to assess the performance of the system. The fault data has been analyzed using back propagation algorithm

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