Adaptive method for Designing & Analysis of HVDC Transmission Line

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ABSTRACT

Power systems are currently operating under a high amount of stress, which was disregarded when they were created. From the perspectives of controllability, security, and dependability, the operational circumstances of the power system are in danger. HVDC transmission offers a way to secure and enhance the power system's stability margins. The capacity to independently control actual and reactive power enhances the stability of the power system and assures effective power transfer. In order to reduce oscillations in the VSC-HVDC transmission system and increase transient and voltage stability, this method introduces a new modeling and control strategy. The linear and bilinear state space deviation models serve as the foundation for this control technique. The control method's structure is created to reduce the number of control loops (both inner and outer) used in the conventional strategy to only one control loop per output. For the first output, these control loops use active power or DC voltage, and for the second output, reactive power. The effectiveness of the control strategies and the validity of the resulting models are demonstrated by simulations for the VSC-HVDC transmission system model.A grid connected back to back VSC-HVDC modeled in MATLAB/ Simulink environment and a current mode control strategy was implemented. The simulation was done to have an observation of a faster and independent control of real and reactive power.

Keyword: - *High Voltage Direct Current, High Voltage Alternating Current, thyristor, 6-pulse, converter.*

1. Introduction

Increasing trend of energy demand and its mitigation by use of several conventional and nonconventional energy sources and transportation of energy from generating station to remote areas is a great challenge. To serve the above purpose it is needed to have a bulk power transmission over a long distance through overhead transmission line and undersea cable, this becomes hectic in case of AC transmission due to high charging current and losses caused by capacitance. Problem related to interconnect the unsynchronized grids to the existing grid, where the voltage level and frequency is the main constraint which restricts the interconnection through an AC link. For the eradication of above problem, it is having a solution by using DC transmission, where a controlled DC transmission provides the flexibility for a bulk power transmission over a long distance through a DC link [2], [5]. Converter stations are being used at the generating end for AC/DC conversion in a controlled manner which enables a controlled power flow.

A rapid development and research on power electronics switches provides a better, efficient technique for control mechanism, hence control over power flow. HVDC transmission resides a two basic type of converter technology. Those are classical line commutated current source converter (CSCs) and self-commutated voltage sourced converters (VSCs) [3]. Classical HVDC technology employs line commutated current source converters with thyristor valve used as a base technology for DC transmission in 1950s. Where thyristors are not fully controlled switches, hence it put limitation to control mechanism used for controlled power flow. Voltage source converter based transmission technology introduces flexibility in power transmission, as it uses fully controllable switches like IGBT which provides one of the efficient control mechanisms for control of power flow. Both classical and VSC-HVDC are used for the applications like long distance transmission, underground and undersea cable transmission and interconnection of asynchronous networks. But from control point of view VSC-HVDC having more flexibility and efficient power flow mechanism, as it is capable of controlling both active power and reactive power independently of each other, to keep stable voltage and frequency. Particularly self-commutation, dynamic voltage control and black start capability allows VSC transmission technology to serve isolated loads on islands over long distance submarine cables [6]

Thyristor based classical HVDC mostly used for point to point large power transmission long It has certain disadvantage like commutation failure as thyristors can‟t be off immediately, and it requires 40 ~ 60 % reactive power supply of the total active power transmission. To have a solution IGBTs are used that can be switched off and on immediately, no commutation problem, active and reactive power control independently, no reactive power compensation required, filter requirement is less as to filter out high frequency signals from PWM, no requirement of telecommunication between two stations of VSC-HVDC system [7]-[9]. VSC -HVDC link consist of a back to back voltage sourced converters (VSCs), a common DC link, which includes a large DC capacitors and DC cables. The control strategy is being designed to coordinate the active power control between two station which is realized by controlling the DC side voltage of one converter where other converter control the active power.

New converter designs have broadened the potential range of HVDC transmission to include applications for underground, offshore, economic replacement of reliability-must-run generation, and voltage stabilization. Developments include higher transmission voltages up to ± 800 kV, capacitor-commutated converters (CCC) for weak system applications and voltage-sourced converters (VSC) with dynamic reactive power control. This broader technology range has increased the potential HVDC applications and contributed to the recent growth of HVDC transmission. Fig. 1 shows the Danish terminal for Skagerrak pole 3 rated 440 MW. Fig. 2 shows the ± 500 kV HVDC transmission line for the 2000 MW Intermountain Power Project between Utah and California.

Fig. 1. HVDC converter station with AC filters in the foreground and valve hall in the background

Fig. 2. ± 500 kV HVDC transmission line

Objective of this research is to design a VSC- HVDC back to back converter and its control strategy to enhance the dynamic stability of power system. So that a bulk power system can withstand to a wide variety of disturbances. It is desirable to design and operate so that most adverse possible contingencies do not result in uncontrolled and cascaded power interruptions. In this VSC- HVDC back to back converter is used along with the parallel AC transmission line and its various control strategies to ensure a faster active and reactive power flow control, hence stability.

2. Control Strategies of designing of VSC-HVDC

The PWM control strategy in VSC-HVDC system accommodating IGBTs was initially proposed in the early 1990s [17-20]. However, in these studies only the phase shift angle between output fundamental frequency positive-phase sequence voltage and AC bus voltage was set as a control parameter, ignoring the amplitude of fundamental frequency positive-phase sequence voltage. Therefore, independent control of active and reactive power was not realized at that time. In these early schemes separate facilities were required to control reactive power. Therefore these early studies did not fully demonstrate the technological superiority of the VSC-HVDC technology.

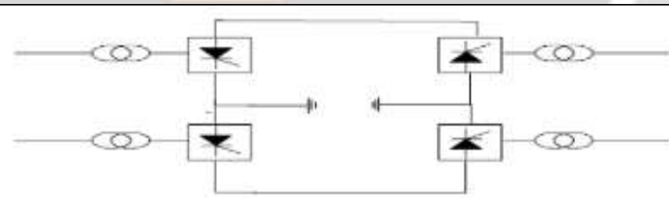
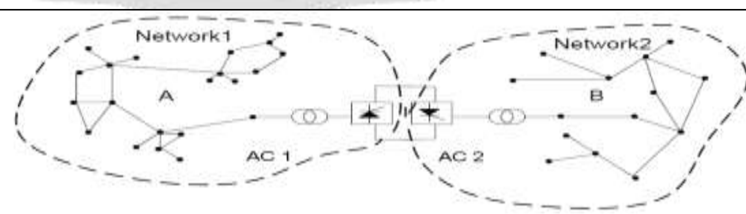
a simpler and straight-forward control strategy based on the power control concept is developed [10]. These control schemes were characterized by relatively low bandwidth and consequently these schemes are unable to damp various resonances that exist in the AC systems. Furthermore, these schemes did not have effective capabilities of limiting over current. Consequently, this control strategy is undesirable.

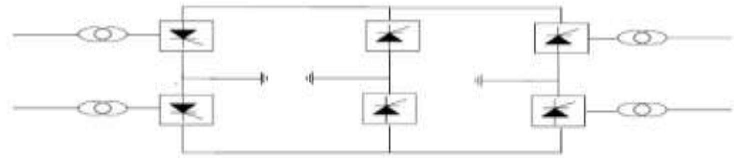
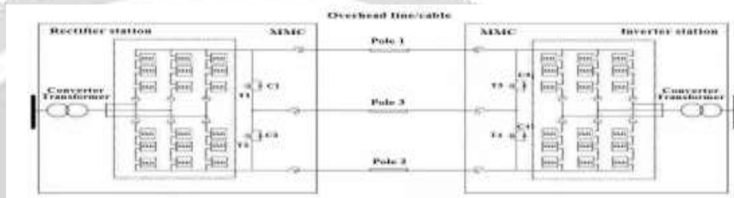
Vector current control is now widely employed worldwide. It has the characteristics power and reactive power control. Conventionally, it is realized through a hierarchical control structure including outer-loop controllers and inner current loop controllers (as shown in Figure 1-1b), within which a dq decoupling technique is applied [11]

the outer-loop controllers produce reference values for the faster acting inner-loop current-controllers, and typically, the sending-end converter controls the real power and the receiving-end converter regulates the DC voltage. However, it is sometimes the case that one end is designated for power flow control and the other end for DC voltage control irrespective of the direction of power flow. The reactive power at either end of the link is controlled separately by the respective converters. The control of reactive power is used to control reactive power directly or indirectly as a means of controlling the power factor or AC voltage at a designated bus. Due to the simplicity and robustness, double closed-loop vector oriented PI controllers have been utilized in compensating the system to achieve the desired performance. The inner-loop controllers employ feed-forward decoupled control to make the active- and reactive-current track the reference values produced by the outer-loop controllers.

3. HVDC Configuration system

In terms of connectivity HVDC transmission system, depending on the location, type and purpose of use, as well as the choice of cable, there are several configurations and types of HVDC transmission system. The main types of connections HVDC electricity transmission system are

Sr no	Configuration system	Parameter
1	Monopolar	 In this HVDC configuration the return line must be earthed, and can be connected to the return line of another converter station
2	Bipolar	 represents a parallel connection of two monopolar HVDC system for the transmission of electricity. The main advantages of bipolar HVDC transmission system configurations are continued operation in the event of failure, and the ability to change the flow of energy
3	Back-to-Back	 It Consists of two converter stations located in the same location. The main characteristics (specificity) of this configuration are the fact that it does not use the DC transmission line of electricity. More specifically, within a configuration Back-to Back HVDC transmission system, the rectifier and the inverter are in the same transferring cell [1]. Back-to-back configuration of the HVDC transmission system is used and ensures the connection of two systems with different AC frequencies (asynchronous interconnections) and/or a second

		AC system and the same frequency
4	Multiterminal	 Consists of a transmission line/cable, and more than two of the converter which can be connected sequentially or in parallel The main advantage of the is to link different AC transmission systems.
5	Tripolar HVDC configuration.	Based on the use of the latest technologies MMC (Modular Multilevel Converter) converters. Specifically, within the structure of this configuration, the rectifier and inverter consist of a three phase six-bridge arms modular multilevel converter (MMC), and two converter valves are arranged on the DC side of the rectifier and inverter 

IV Proposed Methodology

Figure 4.1: MATLAB simulation model for hvdc line power system includes rectifier station subsystem, inverter station subsystem and dc transmission line

From the various literature review of designing & Analysis of HVDC transmission line it observed that there are so limitation in efficiency and performance observed to overcome that we proposed the complete HVDC transmission line Simulink model in which red colour subsystem block is rectifier station and green colour subsystem block is inverter substation. Rectifier subsystem block connected with inverter station using DC link transmission line having distance 300KM

4.1 Simulation of Rectifier Subsystem

Table 4.1: MATLAB simulation model parameter specification for three phase rectifier circuit

Sr No	Name of simulation block	Parameter specification
1	Single phase AC source	Peak voltage = 110V, Frequency =50Hz
2	Gain	1/110*1.2
3	Source impedance	Resistance R =0.5Ohm, Inductance H =1 mH
4	MOSFET	FET Resistance Ron = 0.1Ohm, Internal diode resistance Rd =0.01Ohms Snubber Resistance Rs = 10000 Ohm

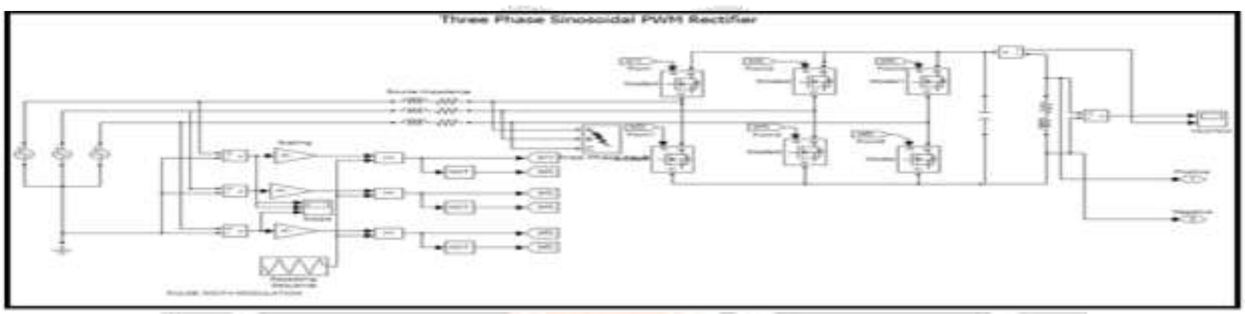


Figure 4.2: MATLAB simulation subsystem model for rectifier station

4.2 Simulation of inverter Subsystem

Table 4.2: MATLAB simulation model parameter specification for three phase inverter station

Sr No	Name of simulation block	Parameter specification
1	MOSFET	FET Resistance Ron =0.1Ohm, Internal diode resistance Rd =0.01 Ohm, Snubber resistance = 100000 Ohm.
2	Three phase series RLC load	Nominal Phase to phase RMS voltage = 80 V, Normal frequency =60Hz; Active power = 10 KW.
3	DC Line 300km	Resistance per unit length = 0.015 Ohm/km, Inductance per unit length =0.792mH/km; Capacitance per unit length = 14.4nF/km, Line length = 300km.
4	Input inverter DC voltage	60 KV
5	Inverter output AC voltage	240 KV

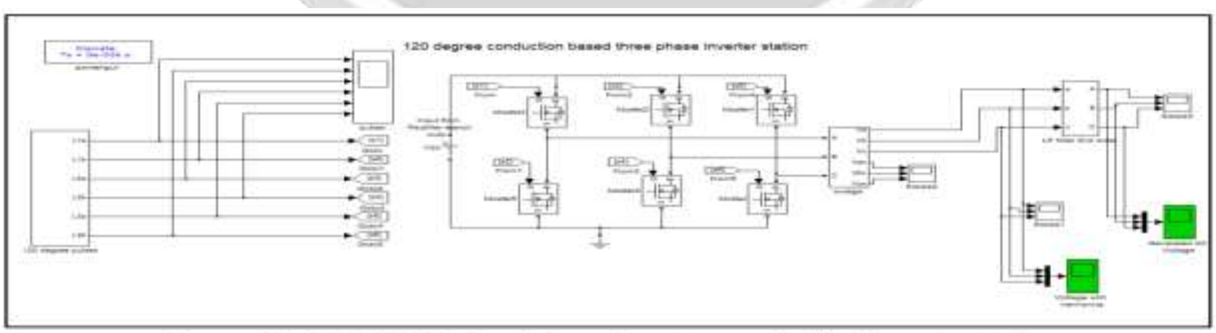


Figure 4.3: MATLAB simulation subsystem model for inverter station

V Result & Discussion

Figure 4.4 shows the three phases rectifier output generated DC voltageand DC current. Figure Figure 4.5 shows the three phase generated voltage without harmonics content after using filter bank on each phase of three phase inverter output..

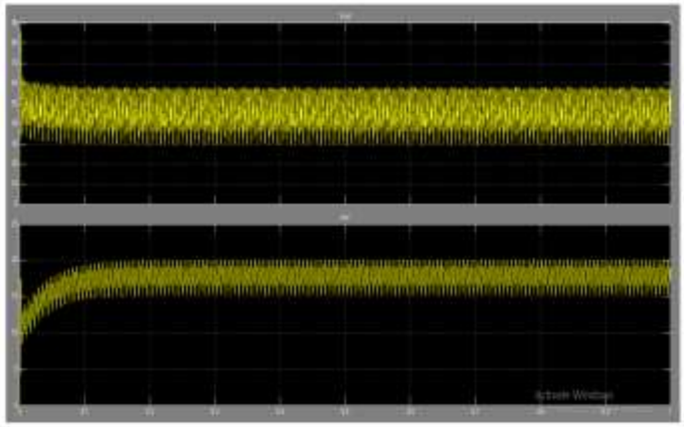


Figure 4.5: Rectifier generated DC voltage and DC current during normal condition

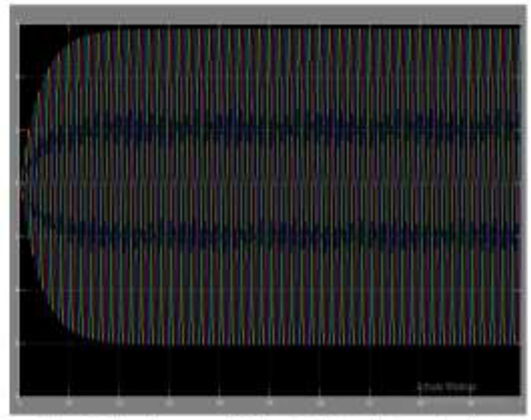


Figure 4.8: Three phase generated AC voltage after filtering during normal condition

VI Conclusion

We can control the HVDC active and reactive power Controlling the harmonics and give protection of HVDC system. And simulation of HVDC transmission line located any type of fault. Also controlling frequency and other dynamics characteristics HVDC simulation software are MATLAB. In this novel signal processing technique has been proposed and applied for the analysis of various operating conditions. AC & DC line faults at various distances (50, 100, 150, 200, 250kM) from the inverter & rectifier end were analyzed and presented using MM. The technique for the classification of fault is proposed. Fault location technique based on closing operation is presented. It is observed that 98.56% accuracy is identified in the location of fault. DC fault behavior of modular multilevel converter based HVDC system was also studied and found to be comparable to a conventional VSC system after the blocking of the converters in both cases. Despite the advantages offered, modular multilevel converters are still susceptible to faults in a similar manner to conventional systems.

VI. REFERENCES

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