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VSC BASED HVDC TRANSMISSION SYSTEM

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Abstract

The chief advantage of VSC based HVDC links over conventional HVDC is the controllability it offers on both the rectifier and inverter ends. The DC voltage, AC voltage, frequency, active and reactive power can be controlled on either side, which has been studied.

Thereafter, stability analysis for the two- terminal VSC based HVDC transmission system is performed. For the integration of VSC based HVDC links into the networks consisting of large wind farms and other industrial systems, the VSC based link has been checked for transient stability, voltage stability and frequency stability. All simulations are performed using MATLAB. Further, small signal stability of the link is studied to ensure that it is stable under small disturbances. For this analysis, both cases of lossless converter and converter with losses are considered.

I. INTRODUCTION

The Voltage Source Converter (VSC) acts like a synchronous machine and can generate AC voltage at required frequency. Therefore, it can be used in applications such as supplying to large industrial installations or wind farms. Compared to current source converters, VSC-HVDC is more controllable since both their active and reactive powers can be controlled. Due to these features, VSC-HVDC control systems and their effect on system stability have been studied in this work. The control system has been developed based on the references listed. Two of the control strategies have been implemented. Transient stability has been studied as shown in [9]. Further, the voltage stability, frequency stability and small signal analysis of the system has also been performed. The model for small- signal analysis is developed using [5].

In addition, the converter switching and conduction losses have also been included in the system to study the effect of losses on the small signal stability.

II. CONTROL OF VSC BASED HVDC TRANSMISSION

A. Description of the system

The system under study is as shown in Figure 1. There are two 230 kV, 200 MVA AC systems on either side operating at 50 Hz. The AC system is modeled as a three-phase programmable source in Simulink. There are 230 kV/100 kV, 200 MVA transformers connecting the AC system and the converter station on either side. They operate at 50 Hz and the windings are connected in Yg/D. The winding resistance is 0.0025 pu and the winding inductance is 0.075 pu. The turns ratio of the transformer on the side of AC system 1 is 0.9 while for the transformer on the side of AC system 2 is 1.02. The reactor values on either side are 0.15 pu. AC filters are 27th and 54th order high pass filters, with quality factor of 15 and a total rating of 40 MVar. Sinusoidal PWM (SPWM) is used to pulse width modulated IGBT switches. DC system is composed two pi- section cables of length 75km.

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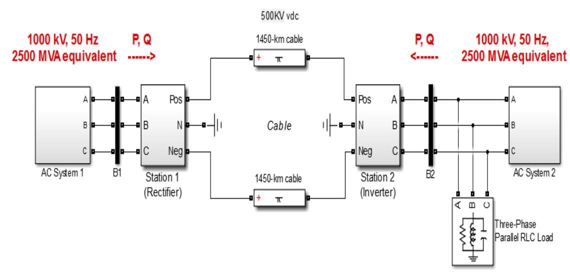

Figure 1. VSC based HVDC transmission system

VSC-HVDC is a new dc transmission system technology. It is based on the voltage source converter where the values are built by IGBT's and PWM is used to create the desired voltage waveform. The main function of the VSC-HVDC transmit constant DC power from rectifier to inverter. The fundamental operation of VSC-HVDC is explained by considering each terminal as a voltage source connected to the AC transmission network. The two terminals are interconnected by a DC link.

B. Controller Design

The control system is composed of a fast inner current controller and outer controllers. The type of outer controller to be used depends on the application. The outer controller can be DC voltage controller, AC voltage controller, active power controller or reactive power controller. These outer controllers generate the reference d-component and q- component currents. These reference values are fed into the inner controllers which give the d-component and q- component voltage values that are inputs to the PWM generator. All outer controllers are implemented by a PI controller where the difference between the reference value and actual value is fed into the controller the reference d- axis and q- axis currents. Two control strategies are employed.

• Strategy 1: Control of active and reactive power on VSC-1 side, and control of DC voltage and reactive power on VSC-2 side.

• Strategy 2: Control of active and reactive power on VSC-1 side, and control of DC voltage and AC voltage on VSC-2 side.

TYPES OF DC LINKS

There are three different types of HVDC transmission links, which are used to transmit bulk power over a longer distance. They are,

- Mono-polar DC link
- Bi-polar DC link
- Homo-polar DC link

MONO-POLAR DC LINK

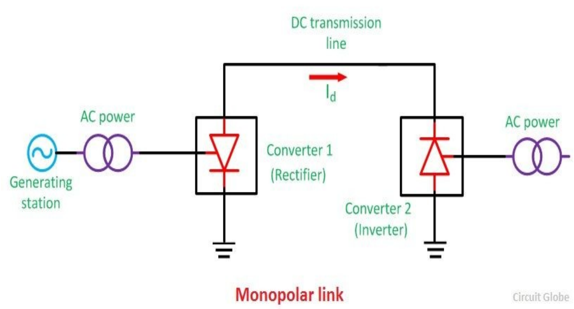

Figure :Mono-Polar DC Link

It has a single conductor of negative polarity and uses earth or sea for the return path of current. Sometimes the metallic return is also used. In the Mono-polar link, two converters are placed at the end of each pole. Earthing

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of poles is done by earth electrodes placed about 15 to 55km away from the respective terminal stations. But this link has several disadvantage because it uses earth as a return path. The mono-polar link is not much in use nowadays.

HOMO-POLAR DC LINK

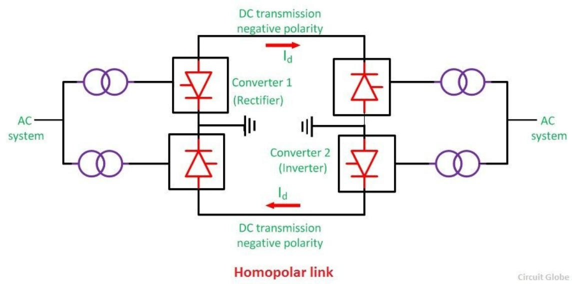

Figure : Homo-Polar DC Link

It has two conductors of the same polarity usually negative polarity, and always operates with earth or metallic return. In the homo-polar link, poles are operated in parallel, which reduces the insulation cost. Since the corona effect in DC transmission line is less for negative polarity, homo-polar link is usually operated with negative polarity. The disadvantage is the earth return. So it is not used presently.

BI-POLAR DC LINK

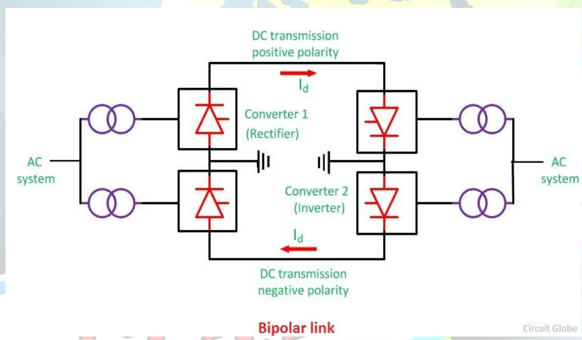

Figure : Bipolar DC Link

The Bipolar link has two conductors one is positive and other one is negative to the earth. The link has converter station at each end. The midpoints of the converter stations are earthed through electrodes. The current in the two poles are equal and there is no ground return. The voltage of the earthed electrodes is just half the voltage of the conductor used for transmission the HVDC.

Here, the plots of active and reactive power on rectifier side and DC voltage on inverter side are shown.

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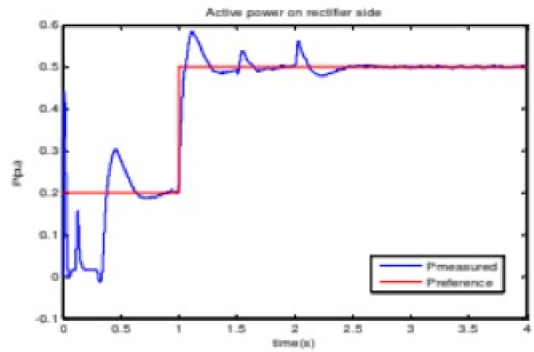

Figure 2. Active power on rectifier side (Strategy 1)

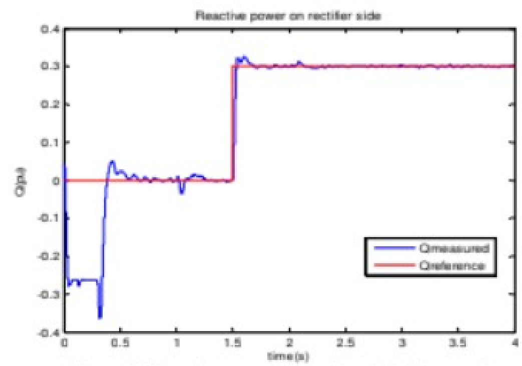

Figure 3. Reactive power on rectifier side (Strategy1)

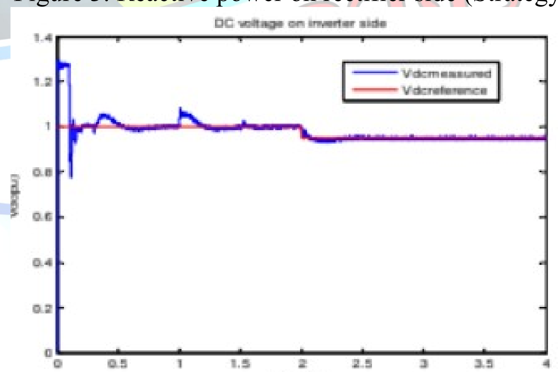

Figure 4. DC voltage on inverter side (Strategy 1)

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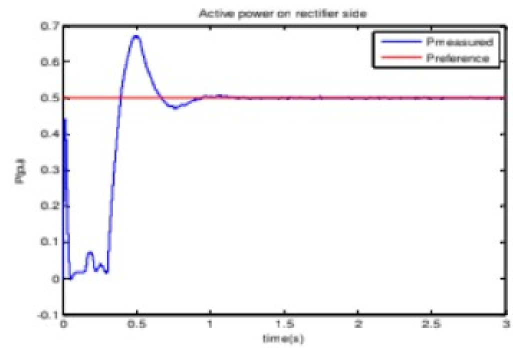

Figure 5. Active power on rectifier side (Strategy 2)

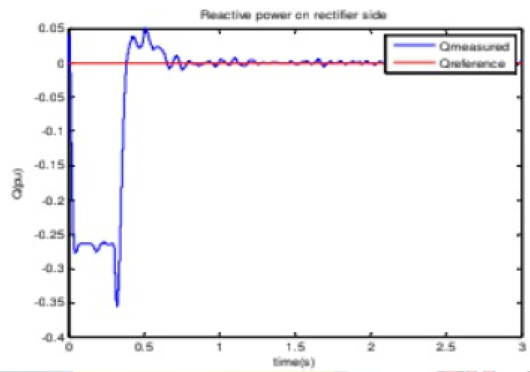

Figure 6. Reactive power on rectifier side (Strategy2)

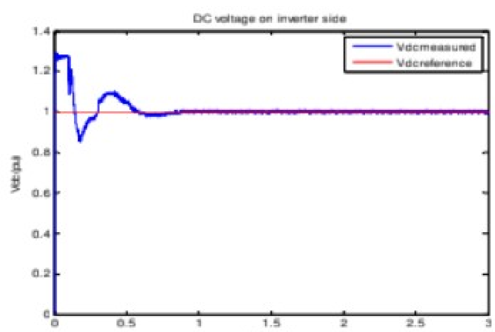

Figure 7. DC voltage on inverter side (Strategy 1)

III. STABILITY ANALYSIS

A. Transient Stability

To study the transient stability of the VSC based HVDC system, a three phase fault is simulated on the system described in Figure 1. It can be seen from Figure 9 that the VSC link is able to maintain the AC voltage undisturbed on the rectifier side. The voltages and currents on VSC-2 side follow their initial operating conditions after the fault is removed. Therefore, the DC link is capable of recovering from disturbances, and the system is transient stable.

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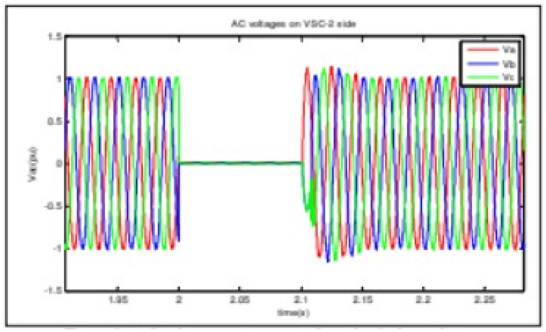

Figure 8. AC voltages on inverter side under fault conditions

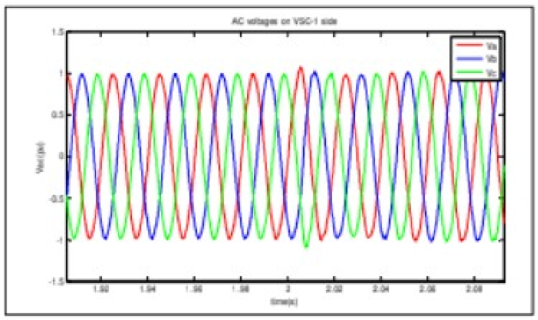

Figure 9. AC voltages on rectifier side under fault conditions

B. Voltage Stability

Voltage stability refers to the ability of a power system to maintain steady voltages at all buses in the system after being subjected to a disturbance from a given initial operating condition. To study the voltage stability of the VSC bases HVDC system, P-V curve is used. The AC system on inverter side is replaced with a load. The remaining system remains the same. To plot the P-V curve, load is increased in steps of 10 MW at a constant power factor, and the corresponding voltage at the load bus is noted. The P-V curve has been plotted for power factors 0.5 and 0.9. For pf = 0.5, this point is at 110 MW for a voltage of 0.7 pu. Similarly, for pf = 0.7, this point is at 200 MW for a voltage of 0.8 pu. The system can be loaded up to this point for it to remain voltage stable.

C. Frequency Stability

To test the system for frequency stability, a small loss on generation side is considered for 1.4-1.5 s. The frequency is measured at any of the bus and the values are recorded as shown in Figure 11.

As it can be seen from the results, the frequency of the system falls to up to 49.6 Hz, and after the disturbance is over it again settles at almost 50 Hz after a few oscillations. For the first case the frequency settles at about 49.9 Hz. This suggests that a frequency controller is needed along with other controllers, so that the frequency settles at exactly 50 Hz after the effect of the disturbance is over. Since the frequency settles at 50Hz after the disturbance, the system is stable.

D. Small signal stability

If a system is able to maintain synchronism under small disturbances, it is referred to as small signal stable. On the other hand, if the oscillations caused by the disturbance sustain or continue to increase, the system is small signal unstable.

Here, systems being operated with VSC- HVDC links can be broken down into subsystems such as the AC grid, the VSC models and the HVDC link. The VSC model has reference values r, as inputs to the controllers, and the outputs are the DC currents i , injected into the DC side. For the DC sub-system, the input is the DC currents i , and the outputs are the node voltages.

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The main aim of this project is to transmit power through VSC based HVDC transmission line with more stability and controllability of active and reactive power on both sides of the power system. The bidirectional action of the voltage source converter is studied. The 3 types of HVDC transmission links such as mono-polar, homo-polar, bipolar DC links are constructed. VSC based HVDC system under normal working conditions and also various fault conditions with load is performed. A practical HVDC system from Talchar to Kolar is adopted. The load sharing between the sources in the interconnected power system is performed. Hence results are compared for the three types of DC links and it is justified that the VSC-HVDC system using bipolar DC link is more advantageous during normal condition and also during faulted conditions.

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