Power Flow Control In VSC Based HVDC System

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***Abstract*—Due to the increasing demand for electric power, various technologies are coming up to transfer the bulk amount of power. The most prominent technologies used in electric power transmission are extra high voltage alternating current (EHVAC) transmission and the high voltage direct current (HVDC) transmission. The evolution of power transformer made extra high voltage alternating current transmission to use in bulk power transmission. In contrast, the high voltage direct current transmission technology is evolved due to the development of power electronics technology. Compared to EHVAC transmission, high voltage direct current transmission is playing a significant role in power transmission due to the many advantages at high voltages and also for long distances.In this report, the modeling and the analysis of the VSC-HVDC system is carried out to evaluate the performance in electric power transmission. The waveforms for sending end AC and the receiving end DC are shown. The entire analysis is carried out in MATLAB / SIMULINK. The results obtained in this paper are useful in understanding the performance of the VSC HVDC system and can apply to all the systems.**

***Index Terms*— EHVAC, HVDC, VSC-HVDC, analysis**

I. INTRODUCTION

All the developing and developed countries in the world are moving towards electricity, i.e., generated by the non-conventional energy sources. Various sources of energy are photovoltaic, wind, gas-based, and tidal energy. As on today, India is in the third position in the electrical energy consumption. India has a total installed capacity of 371.054 GW, out of which 36% is from the non-conventional energy sources.

A. HVDC Systems

The HVDC systems are initiated the first time in the year of 1897 by inventing the low voltage DC supply for a very short distance. The development of mercury arc rectifier technology in power electronics made the natural conversion of power from AC to DC. The advancements in power conversion are made more straightforward due to the advanced technologies.

The HVDC consists of two ends, the sending end, and the receiving end. The sending end converter requires AC to DC conversion, and the receiving end requires DC to AC conversion. The power conversion process at each end requires a converter to be installed. After the conversion of power from AC to DC, the transmission will take place. The transmission requires only two conductors using HVDC transmission.

It is vital to monitor the voltages of both the sending end and receiving voltages and to control the real and reactive powers. This study involves all the aspects related to the control of power flow in HVDC transmission systems. The multi-terminal systems require multiple numbers of DC links at several ends. The incorporation of many converts requires appropriate synchronism and control among all the systems.

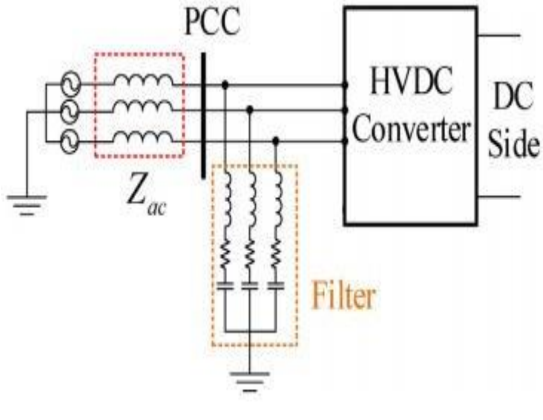


Figure 1 HVDC systems

II.VSC- HVDC SYSTEM

The following figure s shows the single line diagram of the VSC HVDC system and its integration with flywheel energy systems. Following are the steps in the design of VSC HVDC systems

- Switch selection for voltage source converter
- Selection of the inductor, which is used in interface with other systems
- Choosing an appropriate DC link capacitor

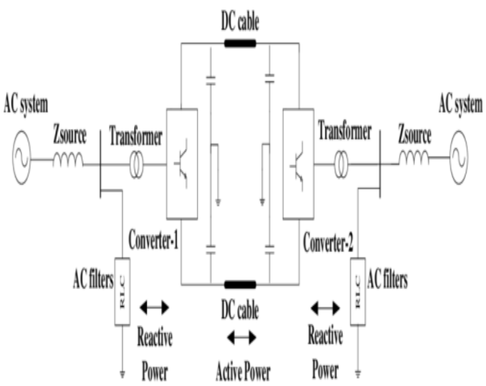


Figure 2 Single Line Diagram of VSC HVDC systems

All the parameters that are chosen for the VSC HVDC system need to cope up with the synchronization with other subsystems. These systems can be operated in connection with energy storage systems also, which results in efficiency improvement. Once the values of the components are chosen, the system can be modeled in any environment. The most prominent tools used for the modeling of VSC HVDC systems are MATLAB/SIMULINK, PSCAD, PSIM, SPICE, and POWER Simulator. All the tools available tools, the preference will be decided by the type of analysis that needs to be performed.

In this report, modeling is carried out to investigate power flows in the system along with the system voltages. So the SIMULINK is the best tool that can solve the purpose. If the other analysis like stability study or the fault analysis needs to be done, then one can choose either PSCAD or PSIM.

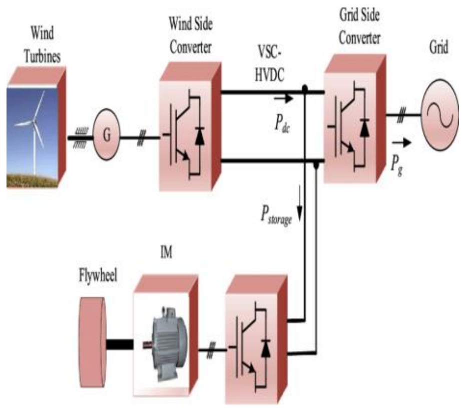


Figure 3 VSC HVDC with Energy Storage Systems

A. Performance of VSC HVDC

The system that is designed needs to be tested by imposing various conditions on it. It requires several tests to be performed on it to evaluate the performance. The following are the various parameters that need to be observed while designing and analyzing the VSC based HVDC systems.

- The condition of the loads
- Voltage sag or swell
- Presence of non-linearity
- Occurrence of fault
- If the fault occurred, if it is symmetrical or unsymmetrical
- Stability range.

The studies that are required will be modeled, and then simulations are carried out on the MATLAB /SIMULINK tool. In the present study, the sending end voltage, the receiving end voltage, active power flow, and the reactive power flow in the lines are analyzed.

III.SIMULATION RESULTS OF VSC HVDC

A. Description of VSC HVDC

In this work, two identical systems are used to transmit the power from one to another using VSC HVDC technology. Following are the system specifications

- 230 KV, 2000 MVA, and 50 Hz identical systems are used

- Systems are interconnected using 200 MVA, 100 KV DC
- A three-level Diode Clamped MLI is employed in the system modeling
- Sinusoidal pulse width modulation is used for producing the firing pulses
- The switching frequency used is 1.3 kHz.
- A 75 Km cable is used in the interconnection process
- A smoothing reactor is employed in the circuit
- Three-phase to ground fault is applied on AC side

The simulations are carried out with fault and without fault, conditions using the specifications as mentioned above of the VSC HVDC system.

B. Schematic of VSC HVDC

The schematic of the system under study consists of the following things, which is clear from the simulation diagram shown in the figure below

- Two identical AC systems
- Two Converter stations
- Fault block at the AC side in one of the two systems
- Filter for the Converters
- Pulse generation blocks for the VSCs
- Data analyzing block for observing the output waveforms

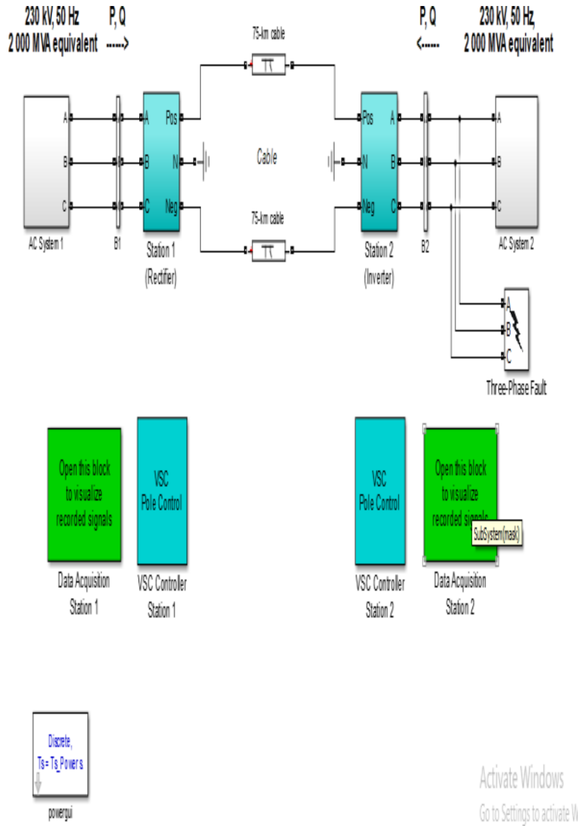


Figure 4 Schematic of the system

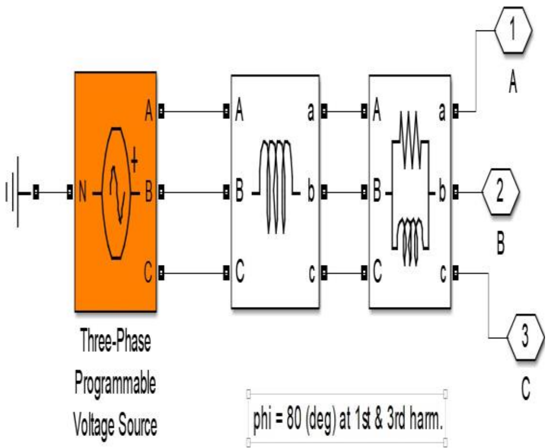


Figure 5 AC Source in System 1

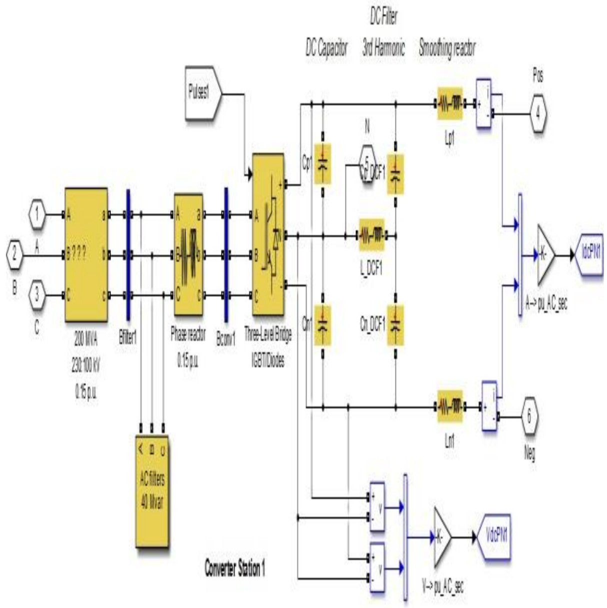


Figure 6 AC Rectifier Stations 1

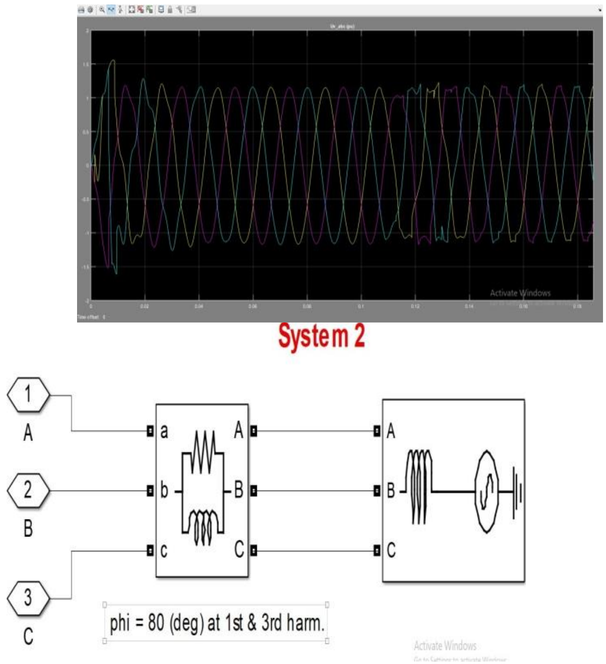


Figure 8 AC Source 2

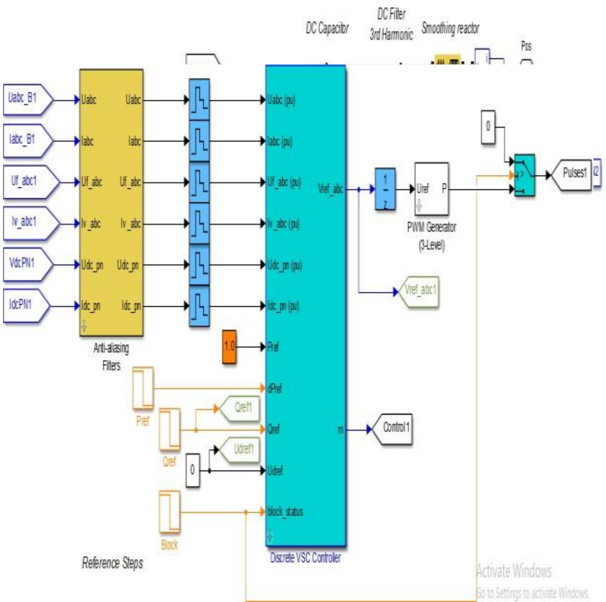


Figure 7 PWM pulses for VSC 1

Figure 9 Converter stations 2

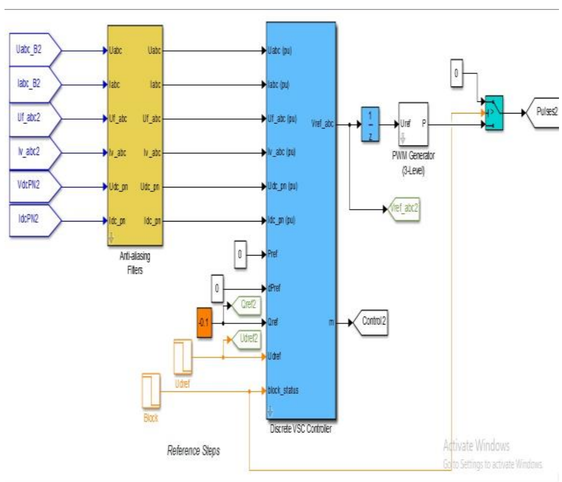
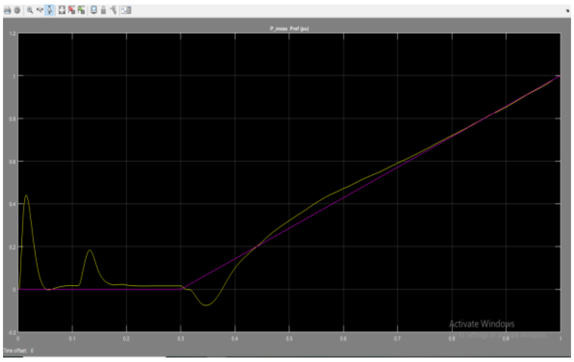


Figure 10 PWM pulses for VSC 2

C. Output waveforms of system 1



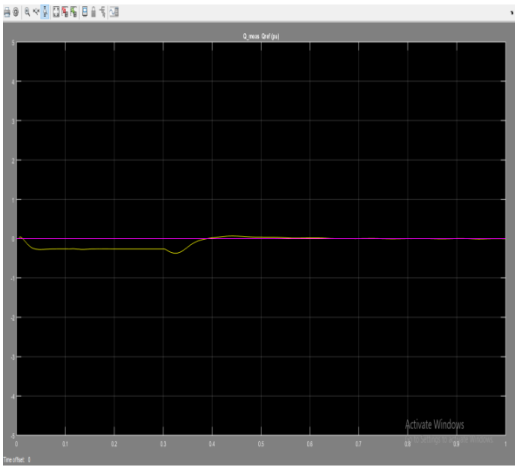


Figure 12 Reactive power and Real power balance

D. Output waveforms of system 2

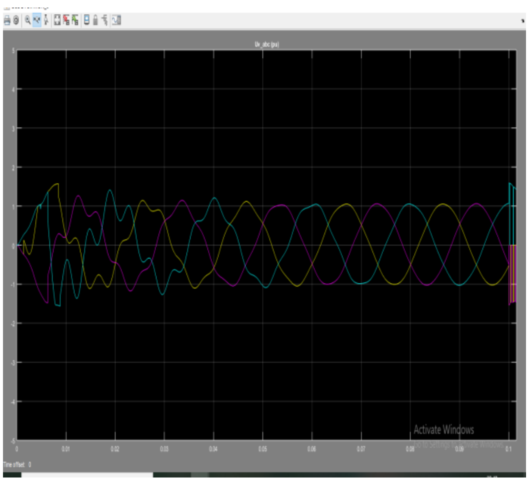


Figure 13 Reactive power and Real power balance

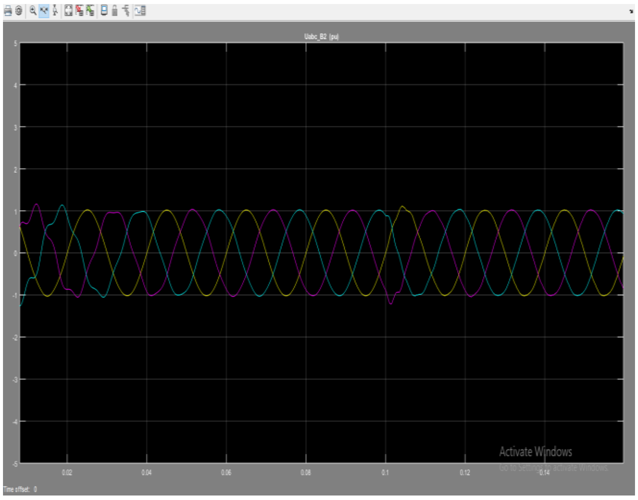


Figure 14 Three-phase balanced voltage after filtering

From all the above waveforms shown for the two converter stations, it can be observed that the usage of voltage source converter results in sinusoidal three-phase voltage at the AC side. The following observations are made from the output waveforms.

- VSC in HVDC results in balanced three-phase voltages
- Right real power balance is achieved
- Reactive power balance is also satisfactory
- Only simple filters will serve the purpose, no need to use the active power filters to achieve power quality
- Stability of the system is not affected
- Time response is fast
- The system is efficient with the inclusion of VSC
- VSC based HVDC systems are simple and effective in interconnecting the systems.

IV. CONCLUSIONS

Following conclusions are made from the work carried out in this project

- Bulk power can be easily transmitted using HVDC
- If the HVDC is operated using VSC, then the quality of the output voltages

improves.

- Usage of active power filter can be avoided by employing the VSC in HVDC systems.
- The real power and the reactive power balances are good with VSC HVDC systems

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