Design and simulation of Voltage Source Converter based HVDC Transmission

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Abstract

Voltage source converter-based high voltage direct current systems (VSC-HVDC), particularly for offshore wind farms and distant power sources, are becoming a more practical option for long-distance transmission. Because they don't need a rectified voltage from the associated AC mains, VSCs are good at powering isolated remote loads. VSC-HVDC may in the future rank among the most crucial elements of power systems as a result of these benefits. The possibilities of employing VSC-based HVDC transmission to transmit power will be discussed in this article.

***Keywords:* VSC, PI, MLI and Harmonics.**

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1. INTRODUCTION

In order to meet the nation's high power demand, private engagement in power generation is encouraged. Consequently, a large number of independent power producers (IPP) are constructing pit head thermal power plants. The state electricity board, whose jurisdiction the location of the generating plant comes under, frequently requires IPPs to sign contracts stipulating that a specific proportion of the plant's installed capacity must be supplied to the state grid and the remaining power may be distributed to third parties. In these situations, a transmission line between the IPP's generating station and the state grid substation in which the contracted power is to be delivered must be carefully managed and there is need for a plan in place for evacuating the remaining power to a nearby state grid substation. If the installed capacity of the IPP is 500 MW, then whenever the generation is greater than 300 MW, 300 MW of power must be sent to the state grid and if the generation is less than 300 MW, the full generated power must be supplied. Eventhough, only AC transmission lines are required for power evacuation, accurate power controllability is difficult to establish. To manage power precisely, an HVDC transmission system based on VSC can be employed.

II. VSC HVDC System:

A VSC-HVDC system is configured using the components illustrated in Figure 1 [8]: ac filters, transformers, converters, phase reactors, dc capacitors, and dc cables.

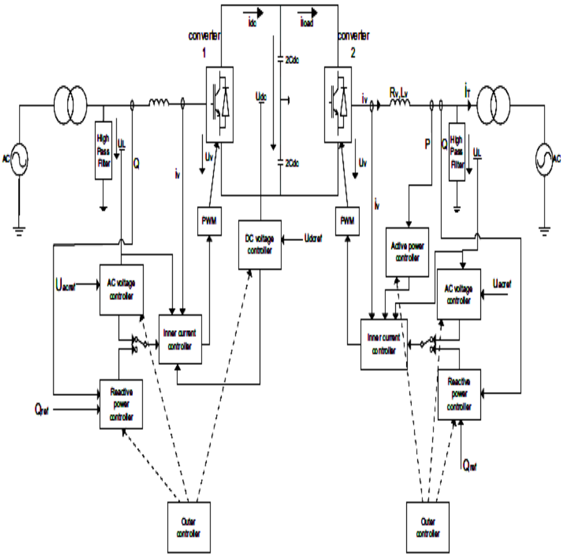


Figure. 1 Configuration of a VSC-HVDC system.

Traditional HVDC and VSC-HVDC operate differently with the latter being easier to handle. In the recent technology yet there aren't many installations, with PWM, VSC HVDC[3],[7] provides the option of controlling active and reactive power separately. Where the active power is being transmitted stays constant, the reactive power controller will automatically alter the voltage of the AC grid. The active power flow between the converter and the network can be controlled by changing the phase angle (∂) between the fundamental frequency voltage generated by the converter (Vr) and the voltage (Vs) on the bus. The power is calculated according to Equation (1) assuming a lossless reactor (Xr)

$$P = \frac{Vs\ sin\partial}{Xr}\ Vr \tag{1}$$

The reactive power flow is determined by the amplitude of Vr which is controlled by the width of the pulses from the converter bridge. The reactive power is calculated according to Equation (2)[12]. The maximum fundamental voltage out from the converter depends on the dc voltage.

$$Q = \frac{Vs\ cos\partial - Vr}{Xr}\ Vr \tag{2}$$

The instantaneous active power $P_{(abc)}$ and reactive powe[15]r $Q_{(abc)}$ transmitted in the three-phase system on the ac side and the power P_{dc} transmitted on the dc side of the VSC expressed as

$P_{(abc)} = u_{La}\, i_{va} + u_{Lb}\, i_{vb} + u_{Lc}\, i_{vc}$ 3

$Q_{(abc)} = (u_{La} - u_{Lb})\, i_{vc} + (u_{Lb} - u_{Lc})\, iva + (u_{Lc} - u_{La})\, i_{vb}$ 4

$P_{dc} = u_{dc}\ i_{dc}$ 5

the three-phase voltages are balanced in normal operation condition, the u_{Lan}, u_{Lbn}, u_{Lcn}, are equal to zero, so the uLαn ,uLβn in the αβ-frame and uLdn, u_{Lqn} in the dq-frame are equal to zero. So the u_{Ldp}, u_{Lqp} can be described as:

$u_{Ldp} = 0 \qquad u_{Lqp} = U$ 6

The instantaneous active and reactive power Pac(dq) and Qac(dq) in dq-frame

$Pac(dq) = u_{Lqp}\, i_{vqp}$ 7

$Qac(dq) = u_{Lqp} i_{vdp}$ 8

The active power controller

The simple method to control the active power is an open-loop controller. The reference of the active current is:

$$i^*{}_{vdp} = \frac{P^*}{u_{Lqp}} \tag{9}$$

Where P* is reference active power and u_{Lqp} positive sequence voltage on secondary side of the transformer.

If more accurate control of the active power is needed, a combination of a feedback loop and an open loop can be used. The structure of the resulting active power controller is illustrated in [8]Figure 2.

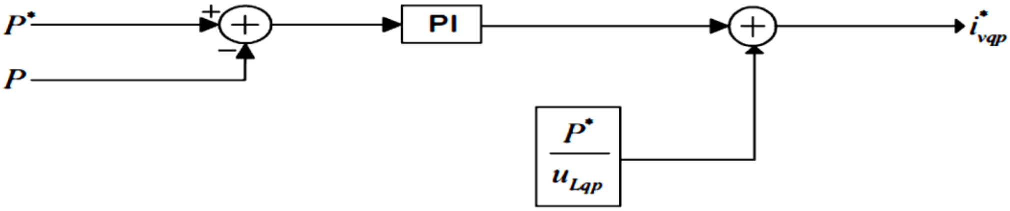


Figure. 2 Active power controller.

The reactive power controller

The reactive power controller is similar to the active power controller. An open-loop controller is obtained by using Equation 4.2, where Q* is reference reactive power and u_{Lqp} positive sequence voltage on secondary side of the transformer.

$$i^*{}_{vdp} = \frac{Q^*}{u_{Lqp}} \tag{10}$$

Another method is to combine a feedback loop with an open loop[17]. The block diagram of the reactive power controller is in Figure 3.

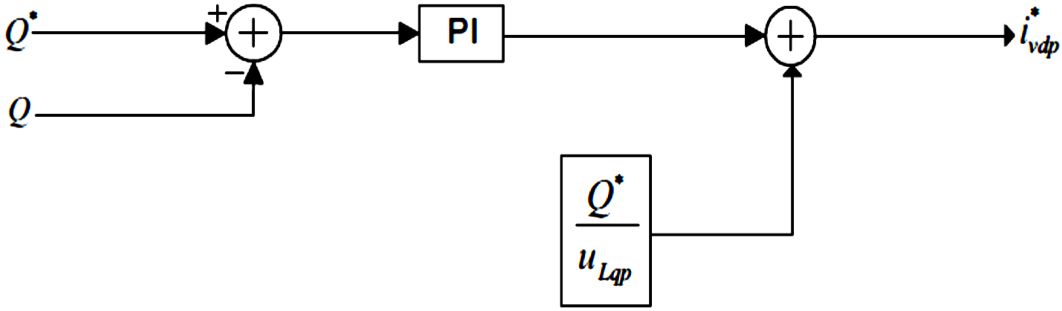
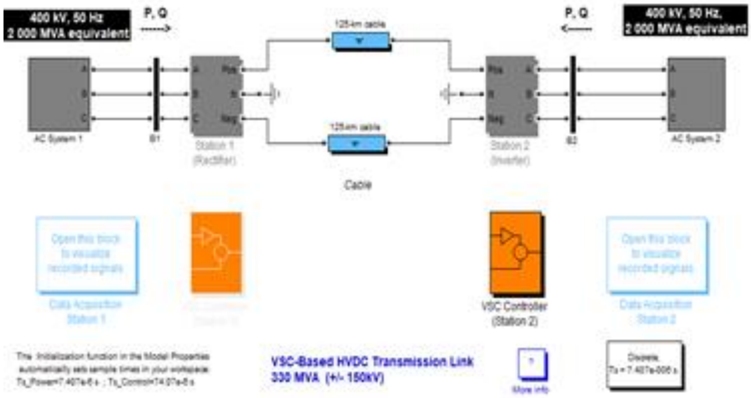


Figure. 3 Reactive power controller.

III. SIMULATION RESULTS:



The Initialization function in the Model Properties automatically sets sample times in your workspace: Ts_Power=7.407e-6 s ; Ts_Control=74.07e-6 s

Figure. 4 VSC-Based HVDC Transmission Link 315 MVA (+/- 150kV)

To test the response of the designed control system, the system shown in the Figure 4 is simulated by using MATLAB/SIMULINK software. All the simulation has been performed with three level MLI. The converter bridge values are represented as ideal switches. On state losses and switching losses are neglected [16]. The phase reactors and transformers are linear. System parameters are shown in the table.

[Type here]

Table. 1 VSC HVDC system parameters

Constant	**Actual Value**	**Value in P.U**
Rated AC Voltage (Sending End)	400kV	1 P.U
Rated AC Voltage (Recieving End)	400kV	1 P.U
Rated DC Voltage	150 kV	1 P.U
Rated DC Power	300MW	1 P.U
Line length	125km	
Reactor Inductance	0.2546H	0.15 P.U
Reactor Resistance	8Ω	0.015 P.U
DC capacitors	70µF	
AC System Frequency	50 Hz	
Switching frequency	1350 Hz	

For the best voltage conversion grounded/delta converter transformers are employed. The inverter's third harmonics are suppressed by the way the current windings are configured. The chosen magnification results in a modulation factor of around 0.85. (transformer ratio is 0.915 on the rectifier side and 1.015 on the inverter side), AC filters are a crucial component of the plan since they help AC systems satisfy their harmonic requirements. These will be attached to the converter side or the AC side of the converter transformer as shunt components. The Shunt filtering is relatively insignificant in comparison to the converter's performance because there are only high frequency harmonics. The 27th and 54th high pass matched 78.5 Mvar shunt AC filter revolves around two significant harmonics. According to the aforementioned simulation results, switching from an AC transmission line to a VSC HVDC transmission line reduces reactive power on the receiving side and maintains the receiving voltage at 1pu without the need for correction.

The load is an established ac system then the VSC-HVDC can control the ac voltage or reactive power flow and active power flow. There are two different control strategies

Stratagy1:

Converter1: controls the active power and reactive power

Converter2: controls the dc voltage and reactive power

Stratagy2:

Converter1: controls the dc voltage and ac voltage

Converter2: controls the ac voltage and reactive power

Here we are using the control strategy 1.

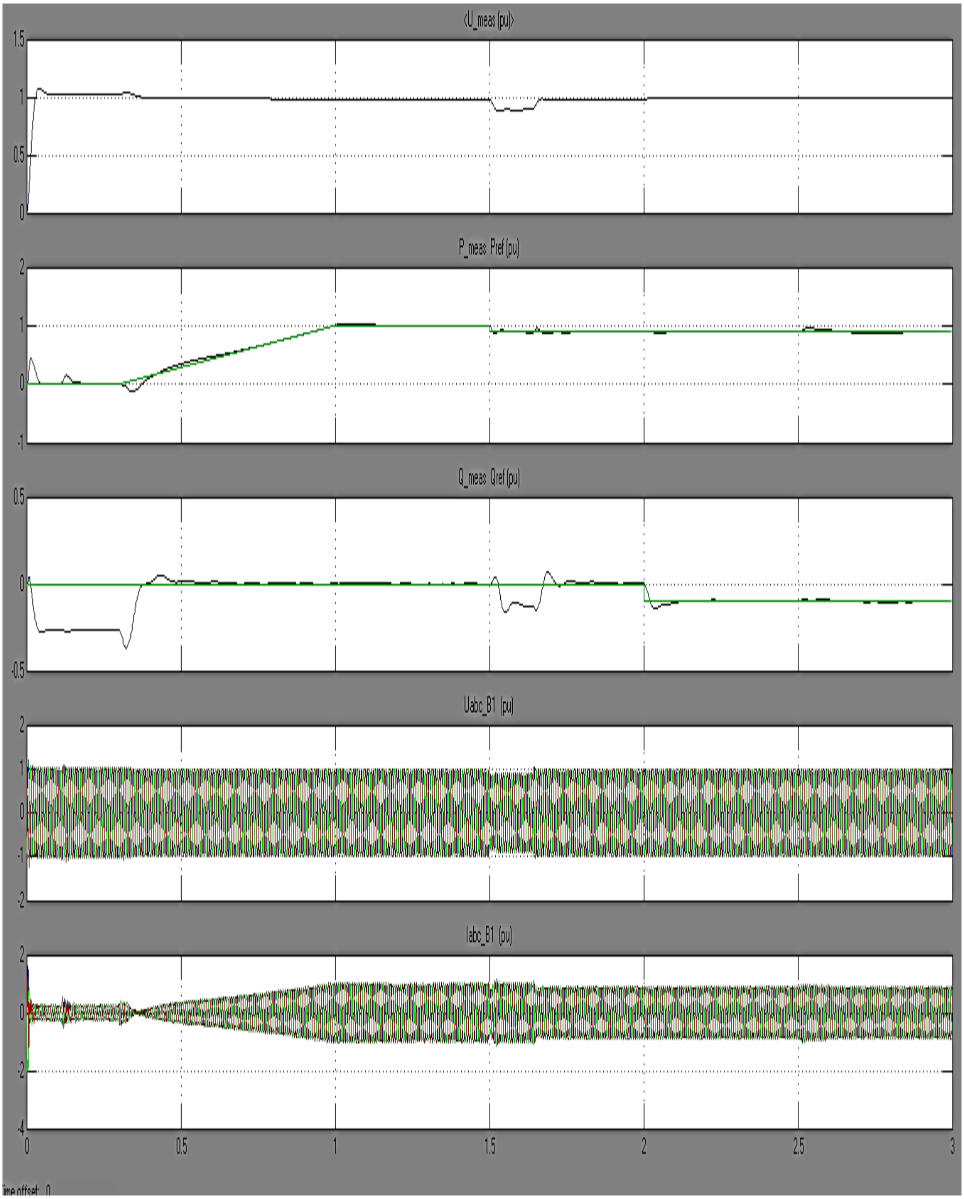


Figure. 5 Sending end AC parameters

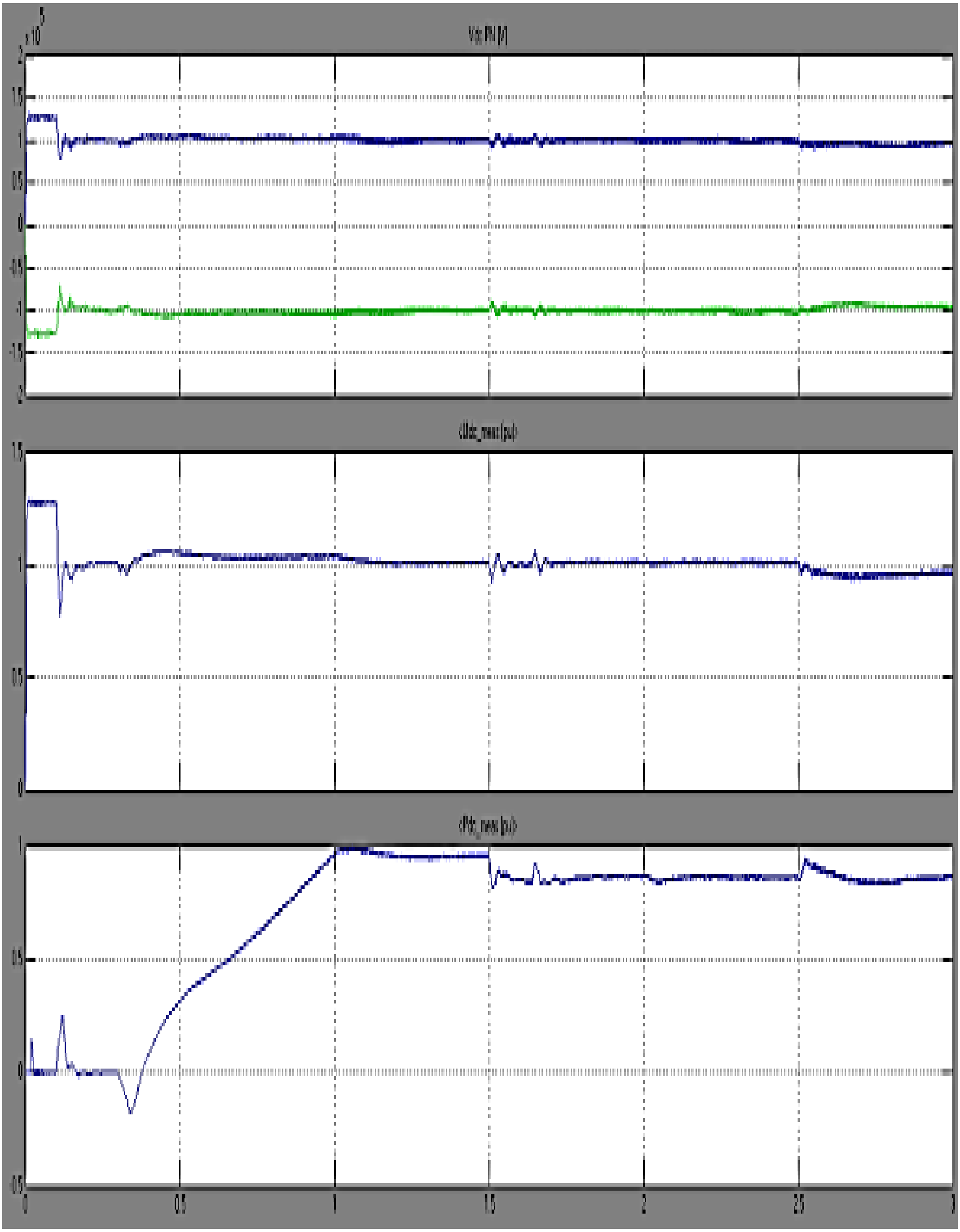


Figure. 6. Sending end DC parameters

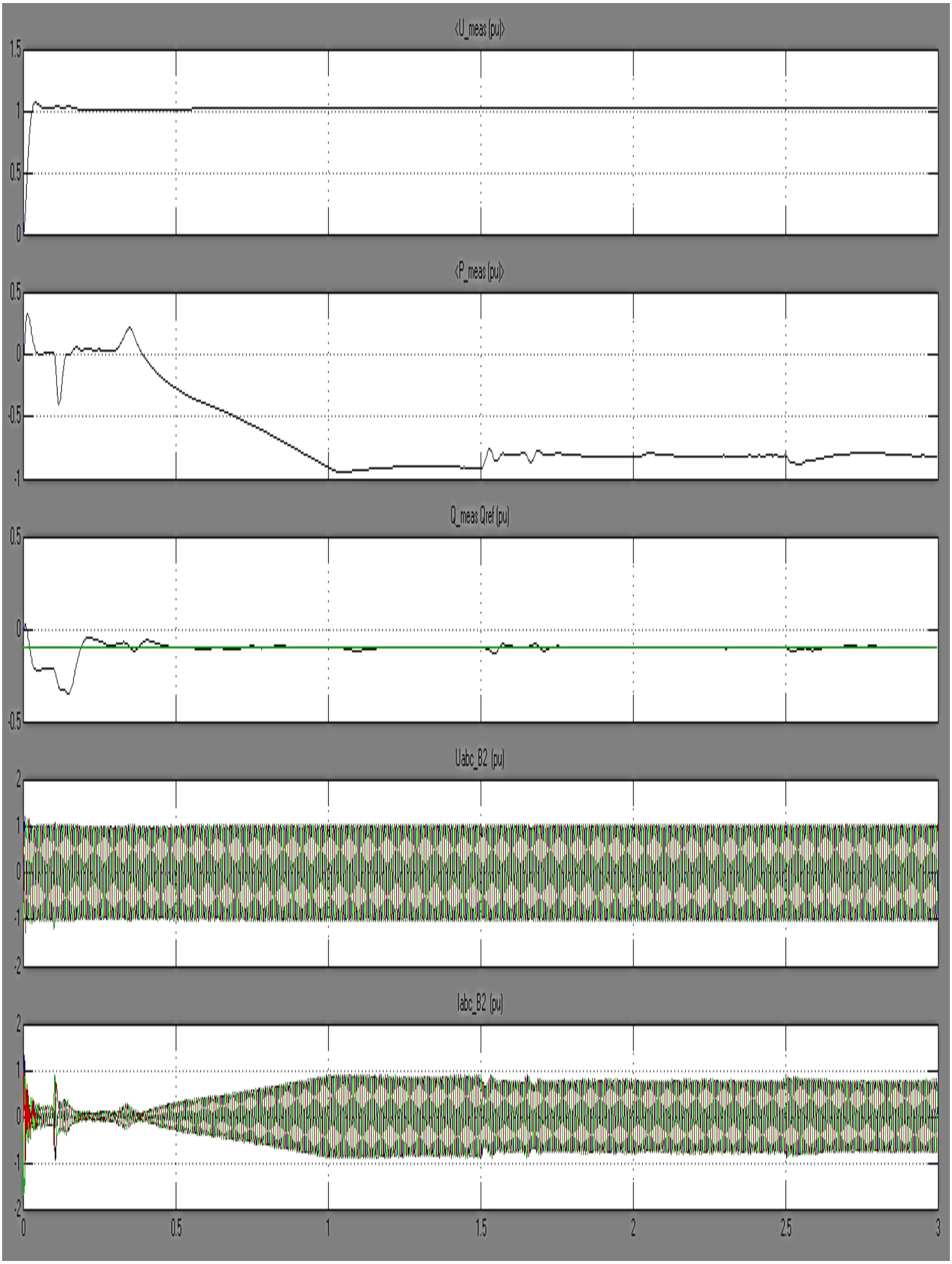


Figure. 7. Recieving end AC parameters

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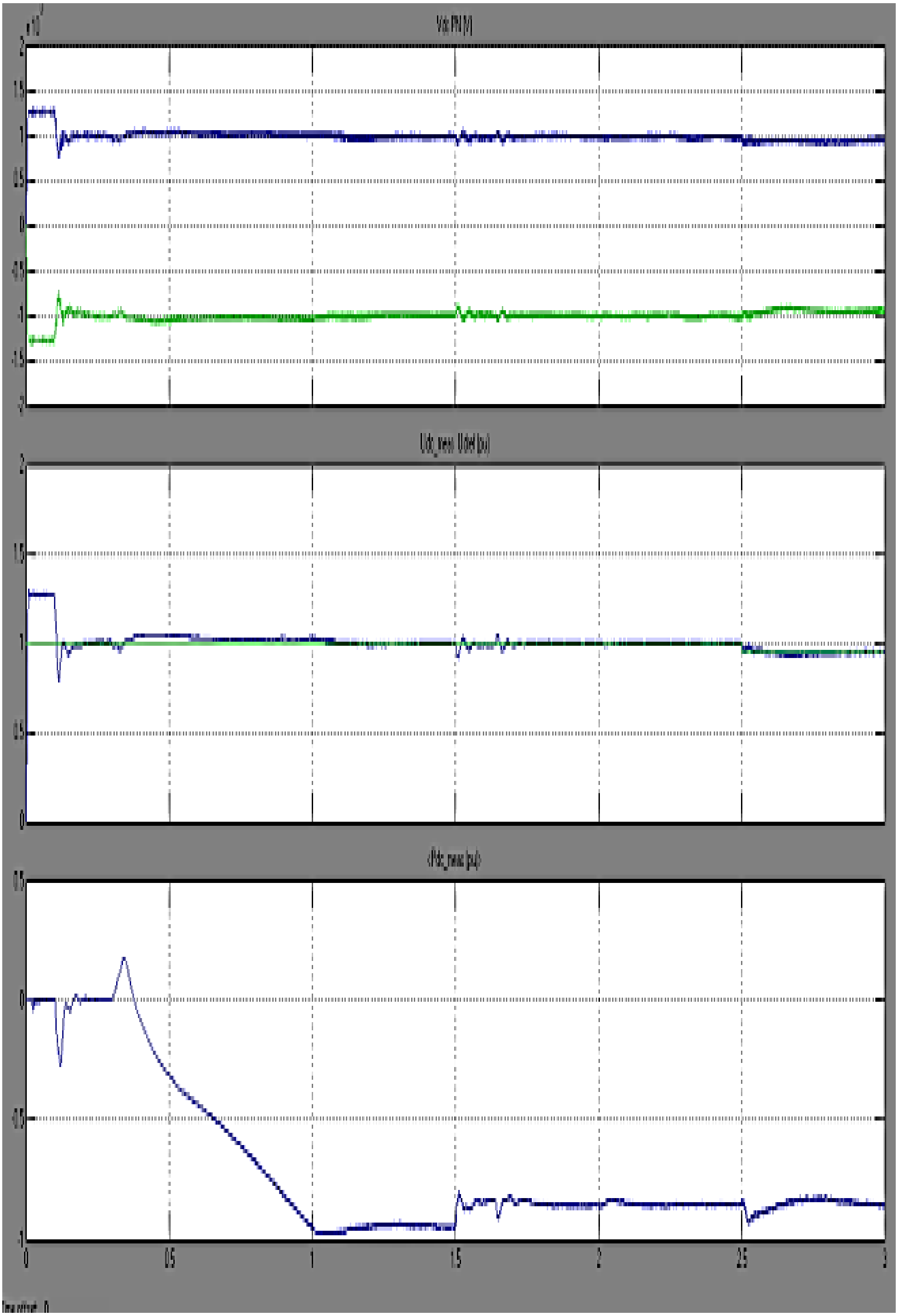

Figure. 8. Recieving end DC parameters

Table.2 Simulation results.

Vs	Vr	Active power at Sending End	Active power at Receiving End	Reactive power at Receiving End
(PU)	(PU)	(PU)	(PU)	(PU)
1.00	1.00	0.94	0.9	1.00

A single phase fault is made in phase A at the receiving end side at 2.1sec and is cleared at 2.5sec. The voltage at the faulted phase a in receiving end side decreases from1 p.u. to ground and recovers to normal value after clearing fault. The voltages in the sending end side are not affected by the unbalanced voltage at the receiving end side. The phase currents at fault side increases and at the other side there is small decrease in value [5]. The active power and reactive power at the faulted side decreases and recovers to normal value after clearing the fault. As the corresponding active power and reactive power at the sending end is constant about small oscillations at the beginning and ending of the fault. Due to ac side fault the power that can inject into the ac system is decreased. This will cause the dc capacitors will charge then the dc voltage at the receiving end side and sending end side increases during the fault and recovers to normal value after clearing the fault.

IV. CONCLUSION:

The steady-state performance of an HVDC transmission system based on VSC is presented in this work. The specifics of the HVDC system's three-level VSC modelling are presented. According to the simulation's findings, the system responds quickly, high-quality ac voltages and currents may be produced, and active and reactive power can be independently controlled in both directions. The suggested system also makes sure that the voltage at the receiving end is kept at 1 pu without any kind of adjustment. In this paper, the steady-state performance of an HVDC transmission system based on VSC is reported. The three-level VSC modelling specifics for the HVDC system are described. The simulation results show that the system responds quickly, high-quality ac voltages and currents can be generated, and active and reactive power can be independently controlled in both directions. The suggested approach also ensures that the voltage at the receiving end is maintained at 1 pu without any form of change.

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