TRANSMISSION SYSTEM TRANSIENT STABILITY ENHANCEMENT BASED ON VSC-HVDC

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Abstract *— Voltage Source Converter (VSC) based High Voltage Direct Current (HVDC) technology (VSC-HVDC or HVDC Light) is an attractive transmission technology. With switch device having turn off and turn on capability, such as IGBT, VSC-HVDC has special characteristics comparing to classical HVDC. Some of these characteristics are: the possibility of realizing independent controlling of active and reactive power; no requirement for fast communication between VSC stations. Based on the method of current injection at the ac bus of voltage source converter, the dynamic model for VSC-HVCD is described .*

From the simulation results, the VSC-HVDC is proven to be able to improve the rotor angle and speed stability and dynamic performance of AC/DC interconnected transmission system.

Key words: *VSC-HVDC, HVDC Light, AC/DC transmission system, transient stability*.

1. Introduction

High-Voltage direct current (HVDC) transmission system plays an important role in modern large-scale interconnected power systems,it's an economic way for long distance power delivery and/or interconnection of asynchronous systems with different frequency. Conventional HVDC transmission system is based on line-commutated thyristor rectifier [[1-3]]. Voltage source converter high voltage direct current (VSC HVDC) based on insulated gate bipolar transistor (IGBT) switch technology has received much attention in recent years [3-6].

A VSC-HVDC transmission system connects ac networks and includes converters at each ac side. In VSC-HVDC transmission schemes, the controls of dc voltage and power flows are of primary necessity and importance. Unlike conventional HVDC with the VSC HVDC we have active and reactive power can be controlled independently and flexibly without the problem of commutation failures in the inverter side. It doesn’t require communication between tow stations or reactive power compensators resulting much smaller equipment size [13].

HVDC light can be applied in defferent field such us the voltage support in the receiver systems , interconnection between asynchronous power systems ,grid connection of large wind farm or offshore wind farm and subsea power transmission.

For AC/DC interconnected transmission systems, the introduction of HVDC Light can enhance the voltage support and improve the system stability. The following sectors will discuss the effect of HVDC Light for improvement of the AC/DC interconnected systems [1].

The four-machine two-area test system is used to validate the results of transient dynamic simulations. The performance of HVDC Light in enhancing both power angle stability and Rotor speed stability in these systems is taken into considerations.

2.Fundamental Principle of VSC-HVDC

Generally the VSC-HVDC system is composed of converters, DC capacitors, transformer and filters, as shown in figure 1. The role of the transformer is to step down the AC voltage to satisfy the demand of self commutated solid-state devices, such as series and parallel of GTOs, IGBTs or IGCTs. High frequency components caused by the switches of valves are isolated from power system by filters. The key parts of the VSC-HVDC are converters, which can realize the conversion from AC to DC bi-directly. DC capacitors are used as the DC voltage source in VSC-HVDC , which need being charged and recharged.[2,7,8]

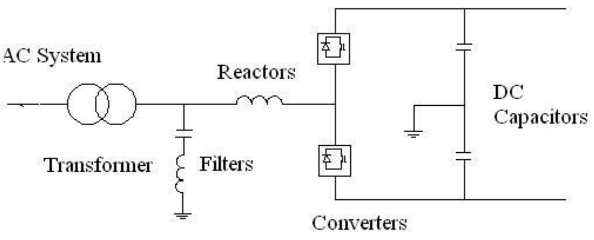


Fig.1 Schematic diagram of VSC-HVDC converter

The converter is composed of a three-phase, two-level and six-pulse bridges as shown in Fig. 1. is the fundamental component of ac bus voltage. is the fundamental component of converter's output voltage. δ is the angle that U_c lags U_s .

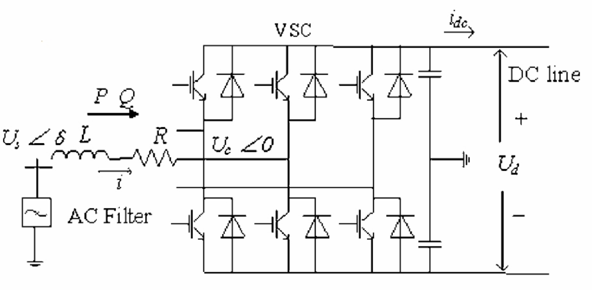


Fig.2 Equivalent circuit diagram of the VSC-HVDC converter

Ignoring the harmonic components and resistance *R*, The power transmitted by HVDC Light is given as:

$$S = P_S + jQ_S = \sqrt{3}U_S I^*$$

the active and reactive power absorbed by VSC can be expressed as:

$$P_S = \frac{U_S U_C}{X}\sin\delta \tag{1}$$

$$Q_S = \frac{U_S(U_S - U_C\cos\delta)}{X} \tag{2}$$

Where $X = \omega L$

For ac voltage control station, assume the dc voltage utilization ratio of the adopted PWM equals 1 and the modulation index of PWM is *M*. Then we have

$$U_C = \frac{M}{\sqrt{2}}u_d \tag{3}$$

From (1)-(3), the active power flowing over the VSC is primarily determined by the angle δand *M* can change the amplitude of the reactive power. Therefore, δ and *M* can be used for regulating both active and reactive power. [7,13]

If the converter's output voltage is controlled as desired, the exchange power between AC and DC system is also controlled.

When δ>0, which means the *US* is leading *UC*, the active power will be transferred from AC to DC and the converter is worked as rectifier. By contrast, the converter can also be worked as inverter. The converter will generate reactive power, if *UÇ* > *UC* cos δ, and will absorb reactive power on the contrary.[11]

3. Control System of VSC-HVDC

The VSC-HVDC control system is based on PWM control technology, the amplitude and phase angle of VSC output voltage can be regulated independently and rapidly by the modulation ratio *M* and the shift angle *δ*. So with the two controllable varies *M* and *δ*, VSC can control the power Ps and Qs in all four quadrants as shown in Fig.3.

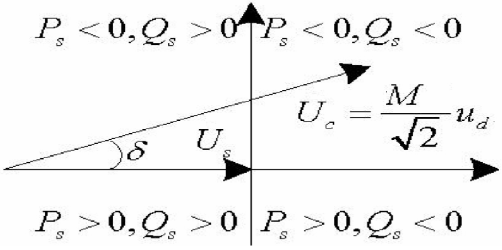
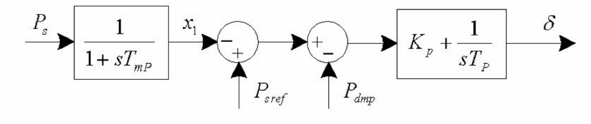


Fig.3 VSC power control schematic diagram

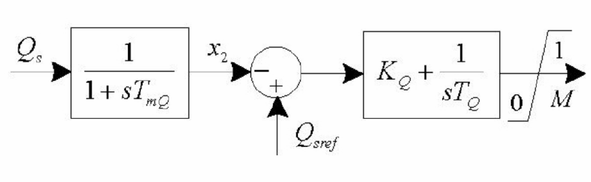
Under normal operation conditions, each VSC can control its reactive power independent of the other VSC. However, the active power inject into the VSC-HVDC inner dc system must be balanced which means that active power out from the dc network must equal the active power into the dc network minus the losses in the network. Any difference will cause dc voltage increase or decrease.

In order to achieve the active power balance automatically, one of the VSCs should select its dc voltage as control object. The other VSC can control its active power at any value within its capacity limits.

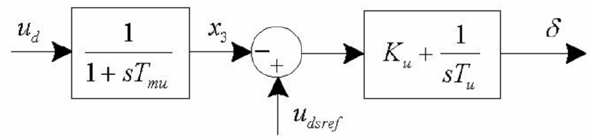
In this paper, the transfer-function block diagram of controllers for controlling VSC active power, dc voltage, reactive power and ac bus voltage are all based on proportional integral (PI) regulator as shown in Fig.4 , Where P_{sref} . Q_{sref} , u_{dref} and U_{sref} are the reference values for corresponding control objects. T_p, T_{mQ}, T_{mu} and T_{mU} are time constants for measuring. K_p, K_Q, K_u , K_U and T_p, T_Q, T_u, T_U are proportional factors and integral time constants of PI regulators. P_{dmp} is the output of VSC-HVDC additional controller. [2,9]



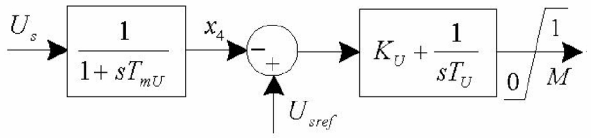
(a) Active Power Controller



(b) Reactive Power Controller



(c) Dc Voltage Power Controller



(d) VSC ac bus voltage Controller

Fig. 4. Control system block diagram for VSC-HVDC

4. Systems description

A two-area, four-machine tested system is adopted in this paper Fig. 5, consisting of two coupled areas [10,12].

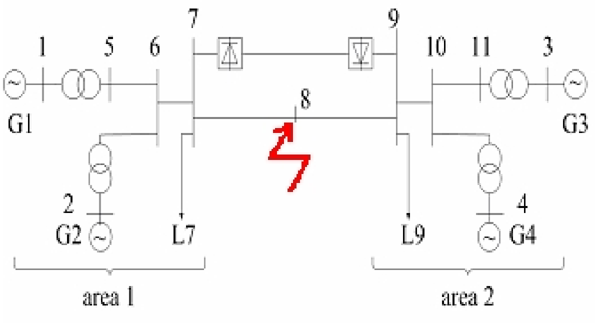


Fig. 5.two-area, four-machine system

Each area has two similar units. The generator parameters in per unit on rated 900MVA and 20kV base are as follows:

$x_d = 0.8$ $x_q = 1.7$ $x_1 = 0.2$
$x'_d = 0.3$ $x'_q = 0.55$ $x''_d = 0.25$
$x''_q = 0.25s$ $R_a = 0.0025$ $T'_{do} = 8.0s$
$T'_{qo} = 0.4s$ $T''_{do} = 0.03s$ $T''_{qo} = 0.05s$
$A_{sat} = 0.015$ $B_{sat} = 9.6$ $\psi_{T1} = 0.9$
D=6.5 (for G1 and G2)
D=6.175 (for G3 and G4)
KD=0

Step-up transformer has an impedance of 0+*j*0.15 per unit on 900MVA and 20/230kV base, and has an off-nominal ratio of 1.0.

The parameters of the lines in per unit on rated 900MVA and 20kV base are
r =0.0001pu/km, x_L = 0.001pu/km; b_C = 0.00175pu/km, and the lines distances are
$x_{5,6}=x_{10,11}$=25km, $x_{6,7}=x_{9,10}$=10km, $x_{7,8}=x_{8,9}$=110km.
In Fig. 5, L7 and L9 are power load. G1, G2, G3 and G4 are generators.

5. Simulation results

To demonstrate the performances of the VSC-HVDC, a Matlab –simulink model is elaborated, a three-phase fault is applied on the ac link at locations 8 individually as shown in Fig. 5. The sequence of events is specified as follows:

Time t=0.2 s, fault applied;
Time t=0.4 s, fault cleared;
Figs. 6-9 show the machines speed response with classical regulator, (HVDC and classical regulator) and without regulation.

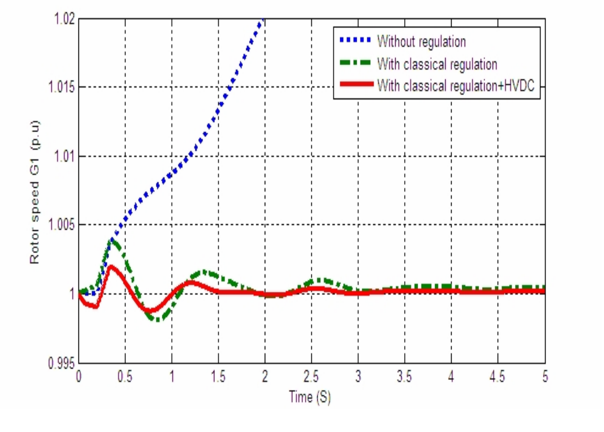


Fig. 6 Rotor speed swing (gen 1)

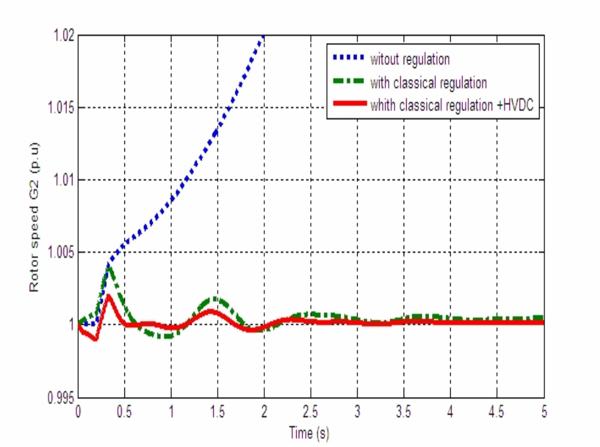


Fig. 7 Rotor speed swing (gen 2)

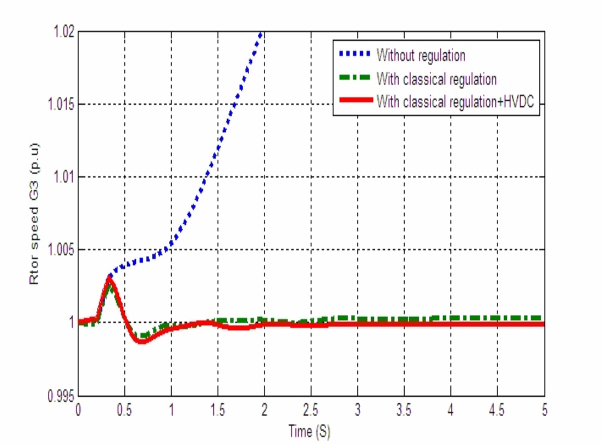


Fig. 8 Rotor speed swing (gen 3)

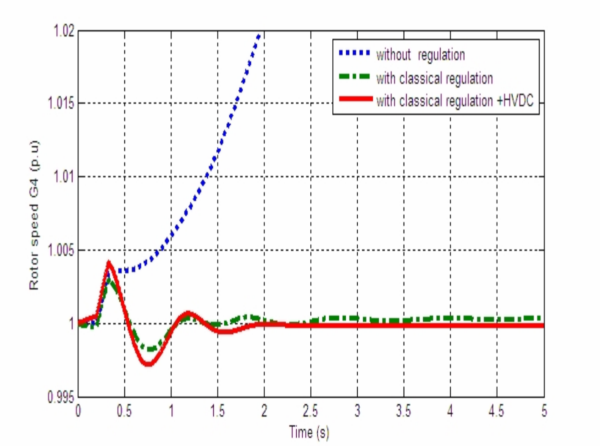


Fig. 9 Rotor speed swing (gen 4)

Figs. 10-13 show the machines angle response with classical regulator, (HVDC and classical regulator) and without regulation.

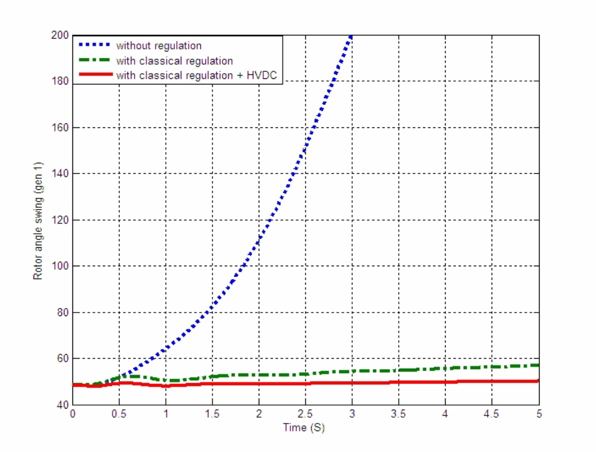


Fig. 10 Rotor angle swing (gen 1)

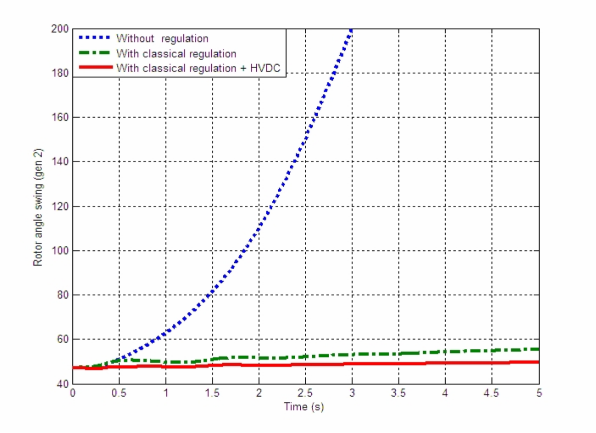


Fig. 11 Rotor angle swing (gen 2)

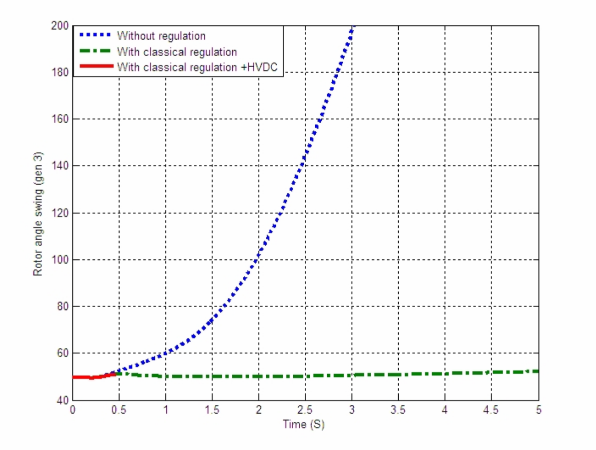


Fig. 12 Rotor angle swing (gen 3)

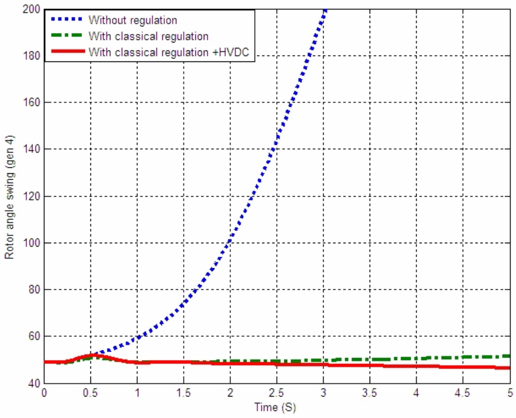


Fig. 13 Rotor angle swing (gen 4)

Simulation results for the rotor speeds and the rotor angles of the different generators;are shown that the introduction of the VSC-HVDC can enhance significantly the transient stability of the power system

Figs. 14-17 shows active and reactive power flows of transmission lines injected from the two converters compared to their references

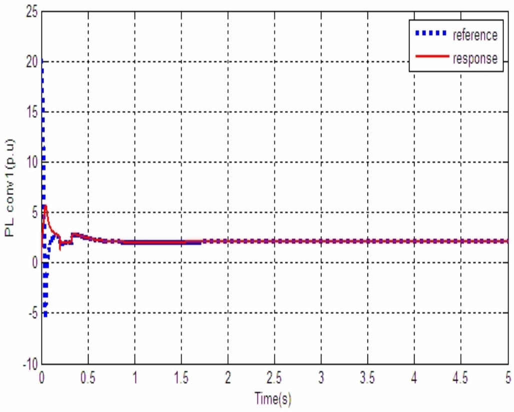


Fig. 14 Real power through transmission line and its reference conv1

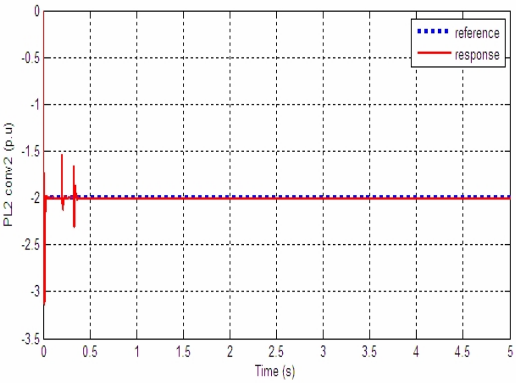


Fig. 15 Real power through transmission line and its reference conv**2**

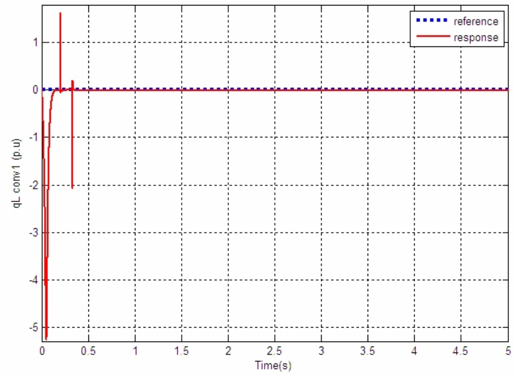


Fig. 16 Reactive power through transmission line and its reference conv1

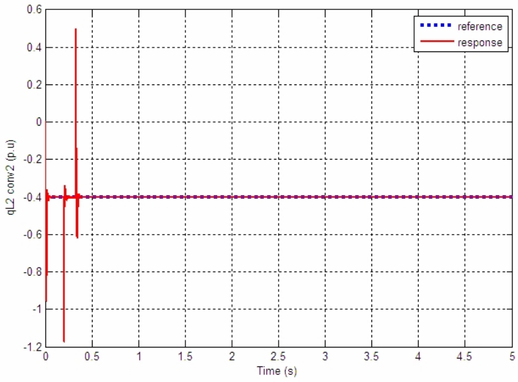


Fig. 17 Reactive power through transmission line and its reference conv**2**

Fig. 18 illustrates the dc-link voltage of the HVDC system. The dc-link voltage remains virtually constant, apart from some transients that last for about 0.5sec when the tree fault is applied.

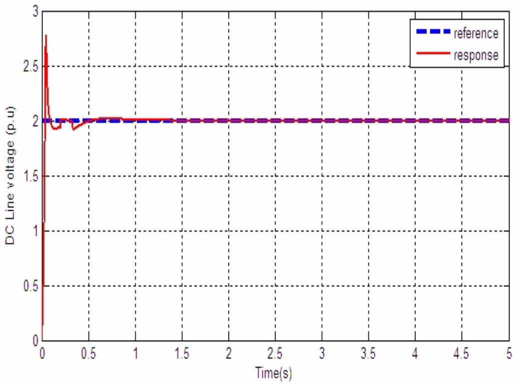


Fig. 18 DC-line voltage.

6. Conclusion

This paper presents a study on use of the VSC-HVDC for the enhancement of power system trensient stability . A detailed dynamic model of

VSC-HVDC has been developed and a brief description of the control system is shown

The results of simulation demonstrate that the use of the VSC-HVDC can impove significantly the power system transient stability

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