ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

Performance of DC Voltage Control of Multi-Terminal VSC- HVDC Systems

B.Siva Krishna[1], B.Veeresh [2]

M.Tech Student (EPS), Department of EEE, Bheema Institute of Technology and Science, Adoni, AP, India[1]

Associate Professor, Department of EEE, Bheema Institute of Technology and Science, Adoni, AP, India[2]

ABSTRACT: This paper discusses a multi-terminal VSC HVDC system proposed for integration of deep sea wind farms and offshore thermal and nuclear platforms in to the grid onshore. An equivalent circuit of the VSC in synchronous d-q reference frame has been established and decoupled control of active and reactive power was developed. A three terminal VSC-HVDC was modeled and simulated in MATLAB/SIMULINK software. Voltage margin method has been used for reliable operation of the HVDC system without the need of communication. Simulation results show that the proposed multi-terminal VSC-HVDC was able to maintain constant DC voltage operation during load switching, step changes in power demand and was able to secure power to passive loads during loss of a DC voltage regulating VSC-HVDC terminal without the use of communication between terminals.
Index Terms --VSC-HVDC Multi-Terminal HVDC (MHVDC), Transmission system for offshore wind power, voltage control, and wind power generation

KEYWORDS: High voltage directs current (HVDC) transmission control, power system modeling, power system stability.

I. INTRODUCTION

Growth of electric power transmission facilities is restricted despite the fact that bulk power transfers and use of transmission systems by third parties are increasing. Transmission bottlenecks, non uniform utilization of facilities and unwanted parallel path or loop flows are not uncommon. Transmission system expansion is needed, but not easily accomplished. Factors that contribute to this situation include a variety of environmental, land-use and regulatory requirements. As a result, the utility industry is facing the challenge of the efficient utilization of the existing AC transmission lines. Offshore wind farms present a number of benefits compared to traditional onshore wind farms. Namely, the availability of higher wind speed, the ease of transport of very large structures (allowing larger wind turbines), and the limited available inland locations to install new wind farms in some countries (mainly in Europe) render them a promising alternative [1].

Thus, the number of offshore wind farms has grown in the recent years. Eight hundred sixty-six megawatt of can be connected to the main ac grid using transmission systems based on ac or dc technology [3]. The choice between these technologies depends on the cost of the installation which depends, in turn, on the transmission distance and power. The need to compensate for the impedance of the lines in ac transmission [4] makes its price grow with the distance at a higher rate than dc transmission, whereas dc transmission implies a high fixed cost due to the need of large power converters. Thus, there is a break-even distance from which the dc options become lower priced than ac [5], [6]. An interconnection between the offshore wind farms, the oil and gas platforms and onshore grid can result in reduced operational costs, increased reliability and reduce CO2emissions. The connection of different wind farms and different onshore ac grids can be performed with a common dc grid based in a multiterminal HVDC (MHVDC) grid arrangement, where the terminals are wind farms or grid connections. A multi-terminal HVDC (MTDC) network will then be the core of such an interconnection system. MTDC can also open new power market opportunities and result in better utilization of transmission lines [7].

Classical HVDC based upon line commutated converters has a main challenge in that it needs reversal of voltage polarity during reversal of power flow. This means that classical HVDC is unable to operate at fixed DC voltage level for both rectifier mode and inverter mode of operation. Since maintaining a constant dc voltage during all conditions is one expected and important feature of the MTDC, the thyristor based classical HVDC may not be a good candidate in developing MTDC. New converter topologies and lower priced fast switching semiconductors have recently made it possible to build voltage source converter (VSC)-based HVDC transmission systems. The benefits of using VSC and fast switching are the ability to independently control the active and reactive power while reducing the size of the output filters needed to have a low harmonic distortion [8]–[11].

Voltage source converters (VSC) on the other hand do not need reversal of polarity for changing the direction of power flow and also are capable of independent control of active and reactive power. This makes VSC and ideal component in making MTDC. This paper presents a proposed three terminal VSCHVDC model linking an onshore grid, offshore wind farm and offshore oil and gas platform and discusses the control strategy for the terminals.

II. TWO-TERMINAL VSC HVDC CONTROL

a) CONVERTER AND DC GRID MODELING

The converter can be modeled as a controllable voltage source behind a complex impedance connected to the point of common coupling (PCC), as shown in figure.1.The converter can be modeled as a controllable voltage source $\underline{u}_c$behind a complex impedance $\underline{Z}_c = R_c + jX_c$ connected to the point of common coupling (PCC), as shown in figure.1.

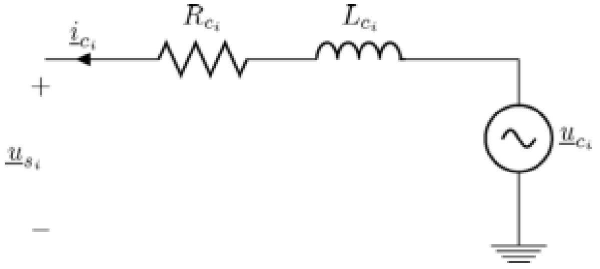


Fig. 1. Single phase diagram converter station AC side.

This complex impedance comprises both the converter reactance and the transformer. This section recapitulates the control of a two-terminal scheme, a full detailed description can be found in [20]. The first part briefly summarizes the decoupled current control Principles, with emphasis on the converter voltage limits. The second part discusses different outer control loops. The third part proposes an alternative implementation using a cascaded structure of an active power controller and DC voltage controllers at the two converters in order to increase overall redundancy.

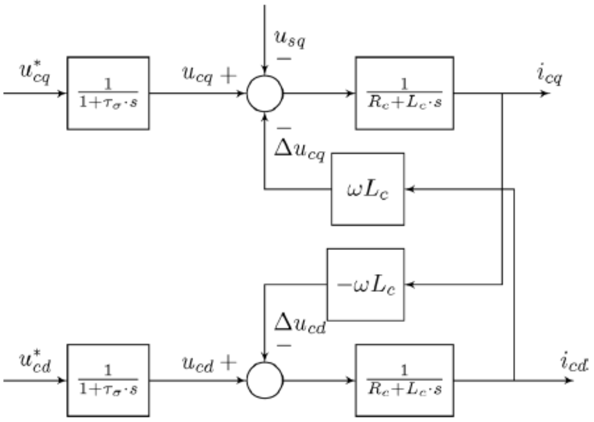


Fig. 2. Converter model block diagram.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

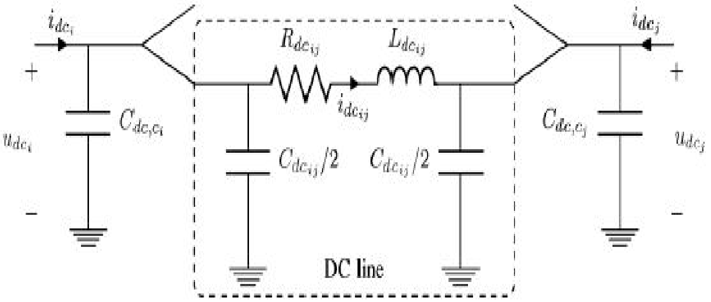
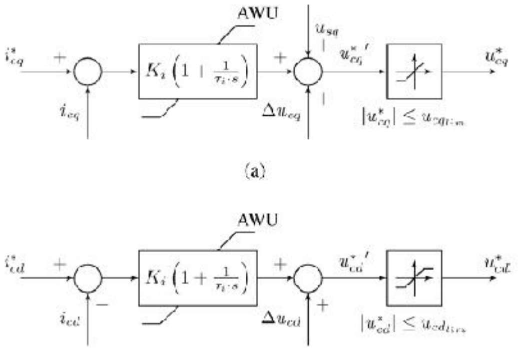


Fig. 3. DC side lumped parameter model.

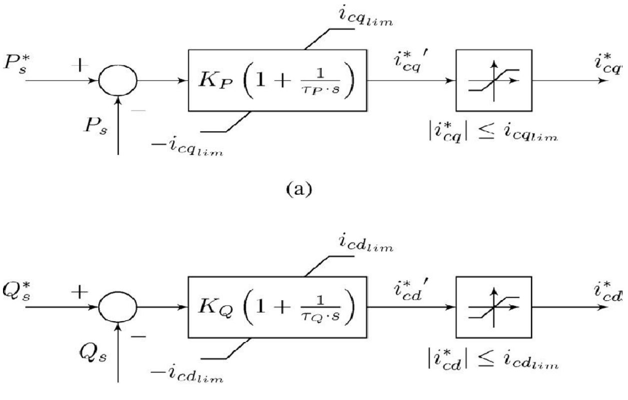


(a)

(b)

Fig. 4. Decoupled inner current controllers. (a) i_{cq}current controller. (b) i_{cq} current controller.

Alternatively, equal priority can be given to the active and reactive power control, by having with the current reference before limiting, as shown in Figs. 5 and 6. Instead of giving equal priority to both control components, this formulation can be generalized to prioritize one current component over the other, without completely compromising the other.



(a)

(b)

Fig. 5. Outer active and reactive power controllers. (a) Constant P_s controller. (b) Constant $Q_s$controller

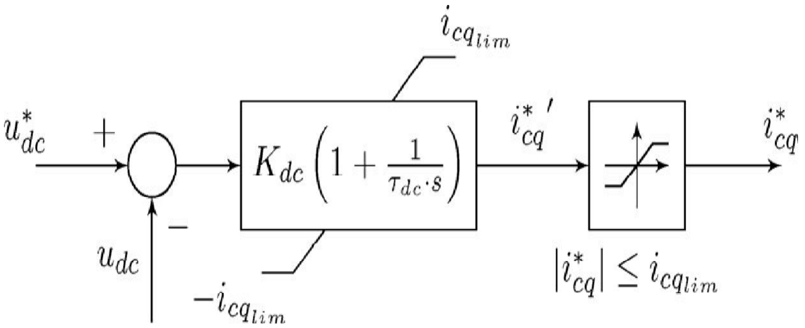


Fig. 6. Outer DC voltage controller

This implementation guarantees operation at constant power factor and can be of interest when the reactive power support provided to the AC network has to be guaranteed when a converter limit is hit.

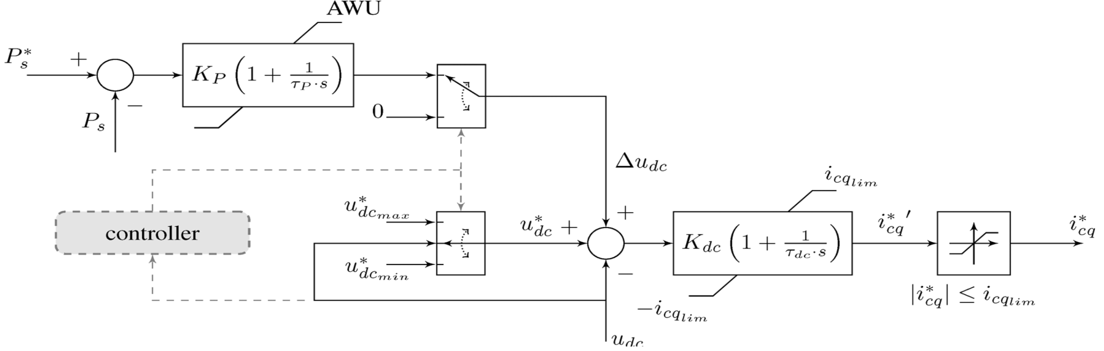


Figure.7 over all Controller

B. REDUNDANT OUTER CONTROL

One of the disadvantages of the control implementation from the previous part, is that the control structure as such cannot cope with an outage or blocking of the DC voltage controlling converter. Whereas an outage or blocking of the power controlling converter only causes the power to drop, it does not cause a system outage since the DC voltage controlling converter can still control the DC voltage. As the control of the DC voltage is crucial to the operation of the power system, one can therefore duplicate the DC voltage control, as proposed in [21] and elaborated in [23] for the power synchronization control, and mentioned in [24] for the operation of a two-terminal scheme. Fig. 7 shows the control structure for such a cascaded power control that has been developed in the framework of this paper. By implementing a correct control structure depending on the DC voltage at the converter's DC terminal, it is guaranteed that only one converter at a time controls the DC voltage. In the power controlling converter, the DC voltage is used both as a reference signal and feedback signal as shown in Fig. 7, hence only is retained as an input to the DC voltage controller. By using the actual DC voltage instead of a reference value , one avoids counteracting actions of the DC voltage controller when the DC voltage varies as a result of an active power or DC voltage set-point change at another converter in the system.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

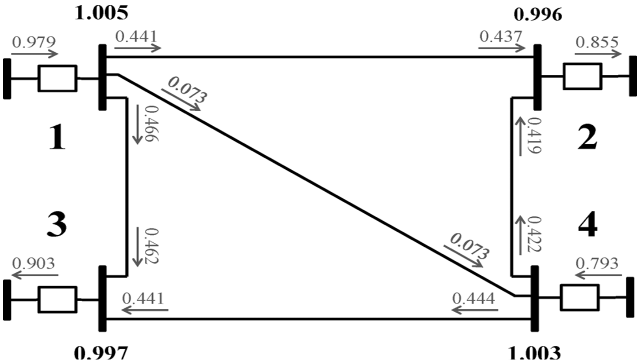
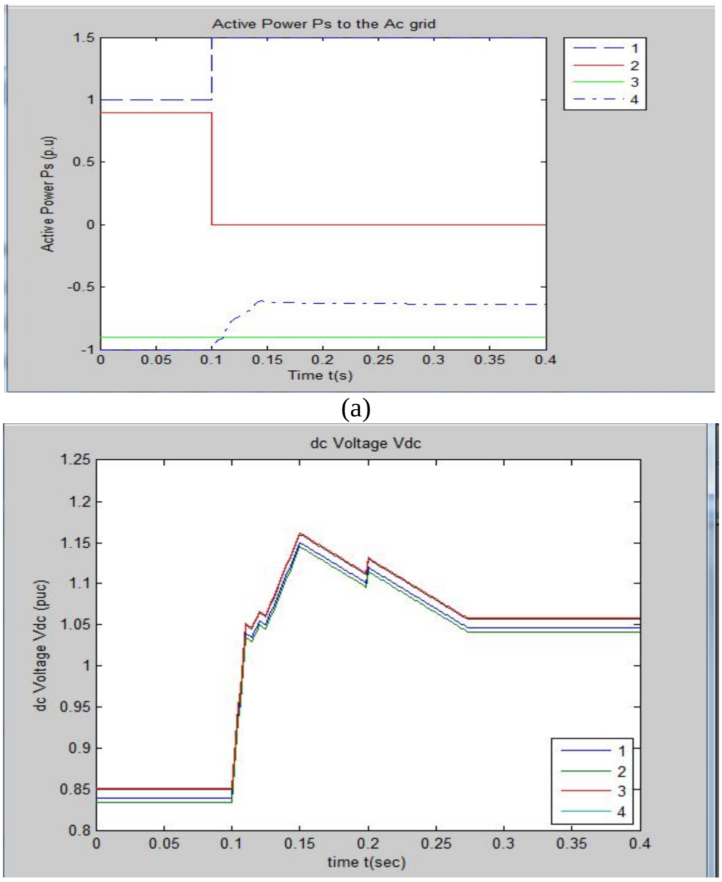


Fig. 8. Initial conditions of the test system.

III. SIMULATION RESULTS

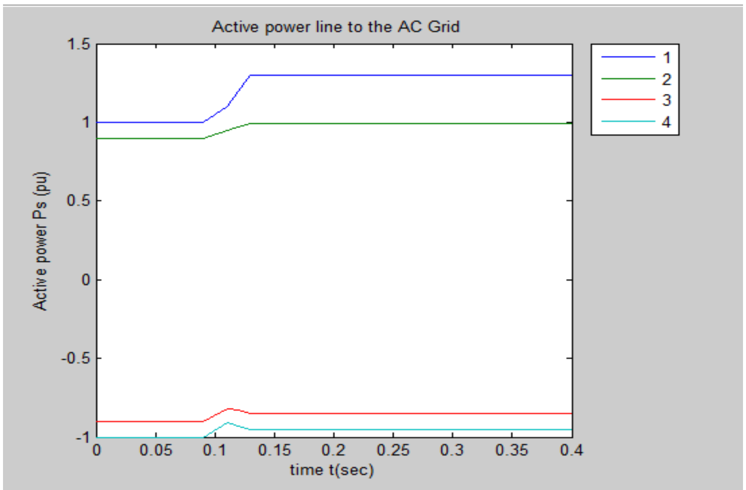
Contrary to the two-terminal system, it is still possible to transfer power in case the DC slack converter fails or blocks. Fig. 9 shows simulation results for the voltage margin control implemented in the 4-terminal VSC HVDC system from Fig. 8 using *MatDyn*, an open-source MATLAB-based transient stability program [18].



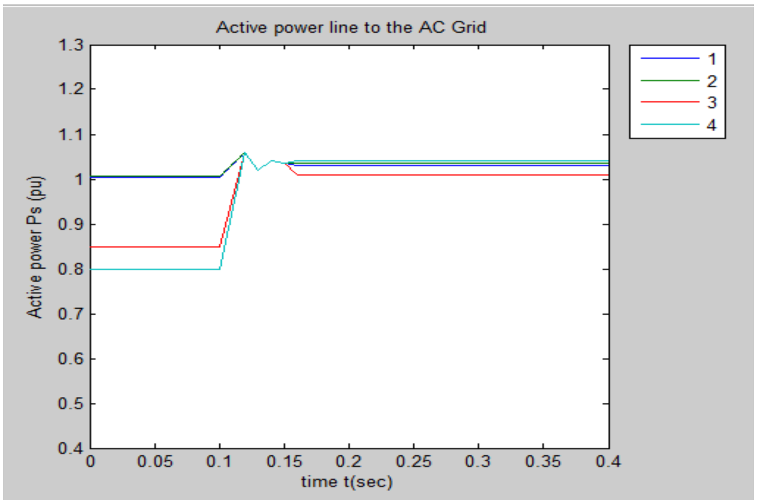
(a)

(b)

Fig. 9. Interactions of converters in the DC grid after outage of converter 2: (a) Active power to the AC grid and (b) DC voltage (*MatDyn* simulation,including).



(a)



(b)

Fig. 10. Interactions of converters in the DC grid after outage of converter 2 (Voltage droop control): (a) Active power to the AC grid and (b) DC voltage

The results were respectively obtained advanced symmetrically A-stable algorithm with variable step size that guarantees constant accuracy as well as high speed simulation [26]. In these simulations, the control scheme continues operating as a voltage droop scheme, since no voltage limits were hit at any of the converters. Similarly to the results in case of the voltage margin control in Fig. 9, converter 1 hits a current limit, which is accounted for by the other converter's droop action. The advantage of this voltage droop over the voltage margin control, is that the power after the converter outage is shared amongst the different droop controlled converters in the DC system, which makes the voltage droop control a suitable candidate for an operation in large DC grids. The joint control action of the different converters in the system also results in smaller voltage deviations.

VI. CONCLUSION

In this paper, a general electromechanical multi-terminal VSC HVDC model has been presented. The salient features of the model are that it has a generalized cascaded control scheme for MTDC systems that allows for voltage margin and voltage droop control and that current and voltage limits are represented in detail. A strategy to cope with a loss of the voltage controlling converter in a two-terminal system is generalized to voltage margin control for multi-terminal system and the model has been extended to include distributed DC voltage control. It is shown by simulations how the limits influence the dynamics and what the effects are of neglecting converter limits. The results indicate that reduced order models approximate the detailed model well. The model has been implemented in the open-source.

REFERENCES

[1] D. Van Hertem andM. Ghandhari, “Multi-terminal VSC HVDC for the European supergrid: Obstacles,” *Renew. Sustain. Energy Rev.*, vol. 14, no. 9, pp. 3156–3163, Dec. 2010.

[2] S. Cole, J. Beerten, and R. Belmans, “Generalized dynamic VSC MTDC model for power system stability studies,” *IEEE Trans. Power Syst.*, vol. 25, no. 3, pp. 1655–1662, Aug. 2010.

[3] L. Zhang, L. Harnefors, and H.-P. Nee, “Power-synchronization control of grid-connected voltage-source converters,” *IEEE Trans. Power Syst.*, vol. 25, no. 2, pp. 809–820, May 2010.

[4] L. Zhang, H.-P. Nee, and L. Harnefors, “Analysis of stability limitations of a VSC-HVDC link using power-synchronization control,” *IEEE Trans. Power Syst.*, vol. 26, no. 3, pp. 1326–1337, Aug. 2011.

[5] T. M. Haileselassie, M. Molinas, and T. Undeland, “Multi-terminal VSC-HVDC system for integration of offshore wind farms and green electrification of platforms in the North Sea,” in *Proc. NORPIE 2008*, Espoo, Finland, Jun. 19–21, 2008, p. 8.

[6] N. R. Chaudhuri and B. Chaudhuri, “Adaptive droop control for effective power sharing in multi-terminal DC (MTDC) grids,” *IEEE Trans. ower Syst.*, vol. 28, no. 1, pp. 21–29, Feb. 2013.

[7] M. Aragüés-Peñalba, A. Egea-Àlvarez, O. Gomis-Bellmunt, and A. Sumper, “Optimum voltage control for loss minimization in HVDC multi-terminal transmission systems for large offshore wind farms,” *Elect. Power Syst. Res.*, vol. 89, pp. 54–63, 2012.

[8] E. Prieto-Araujo, F. D. Bianchi, A. Junyent-Ferre, and O. Gomis-Bellmunt,“Methodology for droop control dynamic analysis of multiterminal VSC-HVD C grids for offshore wind farms,” *IEEE Trans. Power Del.*, vol. 26, no. 4, pp. 2476–2485, Oct. 2011.

[9] N. Chaudhuri, R. Majumder, B. Chaudhuri, and J. Pan, “Stability analysis of VSC MTDC grids connected to multimachine AC systems,” *IEEE Trans. Power Del.*, vol. 26, no. 4, pp. 2774–2784, Oct. 2011.

[10] C. Dierckxsens, K. Srivastava, M. Reza, S. Cole, J. Beerten, and R. Belmans, “A distributed DC voltage control method for VSC MTDC systems,” *Elect. Power Syst. Res.*, vol. 82, no. 1, pp. 54–58, Oct. 2012.

[11] T. Haileselassie and K. Uhlen, “Primary frequency control of remote grids connected bymulti-terminalHVDC,” in *Proc. IEEE PES General Meeting 2010*, Minneapolis, MN, USA, Jul. 25–29, 2010, p. 6.

[12] N. R. Chaudhuri, R. Majumder, and B. Chaudhuri, “System frequency support through multi-terminal DC (MTDC) grids,” *IEEE Trans. Power Syst.*, vol. 28, no. 1, pp. 347–356, Feb. 2013.

BIOGRAPHY

B.Veeresh, M.Tech working as a Assistant professor in EEE dept in BITS Adoni KNL dist A.P.His area of interest is Power electronics and industrial drives, Special machines.

M.Tech student(EPS), Department of Electrical and Electronics Engineering Bheema institute of technology and science, Adoni. His area of interest is Power electronics.