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DC Voltage Droop Control Design for Muliterminal HVDC System Considering AC and DC Dynamics

V.Deepaprincy[1], J.Nivethitha M.E.[2]

M.E. Power Systems Engineering, Department of Electrical and Electronics Engineering, Mother Terasa College of Engineering and Technology, Mettusalai, Illuppur, Pudukkottai (dt), Tamil Nadu, India.

Assistant Professor, Department of Electrical and Electronics Engineering, Mother Terasa College of Engineering and Technology, Mettusalai, Illuppur, Pudukkottai (dt), Tamil Nadu, India.

ABSTRACT: This article is focused on the droop-based DC voltage control design for multi-terminal VSC-HVDC grid systems, considering the AC and the DC system dynamics. The droop control design relies on detailed linearized models of the complete multi-terminal grid, including the different system dynamics, such as the DC grid, the AC grid, the AC connection filters and the converter inner controllers. The PI controller used in PHASE 1 to process the error signal generated at the required angle to drive the error near to zero. In this paper FKBC (fuzzy knowledge based controller) is employed in place of conventional PI- controller.

KEYWORDS: DC microgrid, droop control, voltage source converters, control design.

I. INTRODUCTION

Voltage droop is the loss in output voltage from a device as it drives a load. It is typically unintentional, as voltage sources are meant to stay stable with load. The multi-terminal VSC-HVDC grid concept poses several challenges as the technology of the different elements connected to the system is still evolving in terms of power and voltage levels. Among other problems, the control of the DC voltage of multi-terminal VSC-HVDC grids has become a priority, in order to ensure the overall grid system stability.

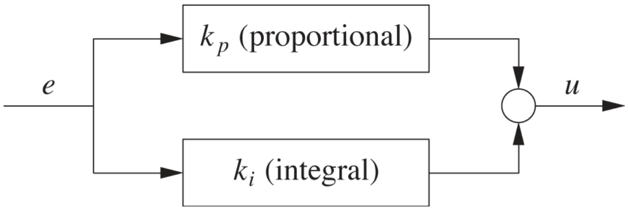

Fig.1. PI Controller

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PI Controller – A Summary

PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller. PI controllers are very often used in industry, especially when speed of the response is not an issue. There are many drawbacks associated with PI Controller, some of them are described below: (a) Fast response of the system is not required, (b) Large disturbances and noise are present during operation of the process, (c) There is only one energy storage in process (capacitive or inductive) and (d) There are large transport delays in the system.

Fuzzy Logic Controller

A fuzzy logic based controller will use fuzzy membership functions and inference rules to determine the appropriate process input. Designing a fuzzy controller is a more intuitive approach to controller design since it uses a comprehendible linguistic rule base. A fuzzy controller can be broken down into three main processes. The first of these is the fuzzification; this uses defined membership functions to process the inputs and to fuzzily them. These fuzzified inputs are then used in the second part, the rule-based inference system. This system uses previously defined linguistic rules to generate a fuzzy response. The fuzzy response is then defuzzified in the final process: Defuzzification. This process will provide a real number as an output. Designing a fuzzy controller can be done with several different computer based tools; the tool we will be using is the Fuzzy Logic Toolbox in MATLAB with Simulink.

There are several disadvantages associated with Fuzzy Logic Controller; some of them are listed below: (a) Fuzzy logic provides a certain level of artificial intelligence to the conventional controllers, leading to the effective fuzzy controllers. Process loops that can benefit from a non-linear control response are excellent candidates for fuzzy control, (b) since fuzzy logic provides fast response times with virtually no overshoot. Loops with noisy process signals have better stability and tighter control when fuzzy logic control is applied and (c) Fuzzy controller has faster transient as compared to PI controller, while, transient for Fuzzy controller is almost periodic. There are several advantages associated with Fuzzy Logic Controller; some of them are listed below: (a) Improve the system performance and (b) High stability.

A. Existing System - Research Summary

The multi-terminal VSC-HVDC grid concept poses several challenges as the technology of the different elements connected to the system is still evolving in terms of power and voltage levels. Among other problems, the control of the DC voltage of multi-terminal VSC-HVDC grids has become a priority, in order to ensure the overall grid system stability. Electro Magnetic Transient Programs (EMTP) accurately represents the switching dynamics and electromagnetic transients. Two important extensions are added to the model. Firstly, current and voltage limits are represented in detail in the current control loop and in the outer controller. Secondly, a cascaded control structure is introduced in the outer controller which allows power controlling converters to take over the voltage control when the DC voltage controlling converter fails.

B. Proposed System Summary

In combination with the droop control, a DC oscillation damping scheme is proposed, in order to improve the system performance. The control design is validated through simulations of a one terminal system.

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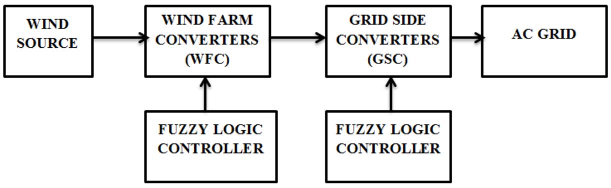

Fig.2 Block Diagram

Finally, the paper discusses two possible model reductions, in line with the assumptions made in transient stability modeling. The control algorithms and VSC HVDC systems have been implemented using MATLAB SIMULINK. The PI controller used in this paper to process the error signal generated at the required angle to drive the error near to zero. In this paper FKBC (fuzzy knowledge based controller) is employed in place of conventional PI-controller. A generic VSC-HVDC multi-terminal grid layout is shown in Fig. 1. The HVDC grid is built to interconnect the offshore wind power plants and the main land AC grid or grids by means of VSC power converters.

Wind Farm Converters (WFC) injects the generated power from the wind power plants to the DC grid, whereas the Grid Side Converters (GSC) regulate the DC grid voltage employing droop control. This type of controller allows regulating the DC grid voltage without communications among converters, being implemented at each of the GSCs locally. Also, droop control allows establishing the power sharing between converters acting over the power loop of the converter. Possible deviations of the power can be compensated through an upper secondary control that could be implemented with communications between the grid converters acting in a slower time frame. In this work, this upper controller is not included in the analysis, as the study is mainly focused on the grid voltage control based on droop, considering the overall grid dynamics.

II. LITERATURE SURVEY

In the year of 2010, the authors "Ludois, D.; Venkataramanan, G.", proposed a paper titled "An examination of AC/HVDC power circuits for interconnecting bulk wind generation with the electric grid", in that they described such as: the application of high voltage dc (HVDC) transmission for integrating large scale and/or off-shore wind generation systems with the electric grid is attractive in comparison to extra high voltage (EHV) ac transmission due to a variety of reasons. While the technology of classical current sourced converters (CSC) using thyristors is well established for realization of large HVDC systems, the technology of voltage sourced converters (VSC) is emerging to be an alternative approach, particularly suitable for multi-terminal interconnections.

More recently, a more modular scheme that may be termed ‘bridge of bridge’ converters (BoBC) has been introduced to realize HVDC systems. While all these three approaches are functionally capable of realizing HVDC systems, the converter power circuit design trade-offs between these alternatives are not readily apparent. This paper presents an examination of these topologies from the point of view of power semiconductor requirements, reactive component requirements, operating losses, fault tolerance, multi-terminal operation, modularity, complexity, etc. Detailed analytical models will be used along with a benchmark application to develop a comparative evaluation of the alternatives that maybe used by wind energy/bulk transmission developers for performing engineering trade-off studies.

In the year of 2013, the authors "Pinto, R.T.; Rodrigues, S.F.; Wiggelinkhuizen, E.; Scherrer, R.; Bauer, P.; Pierik, J.", proposed a paper titled "Operation and power flow control of multi-terminal DC networks for grid integration of offshore wind farms using genetic algorithms", in that they described such as: for achieving the European renewable electricity targets, a significant contribution is foreseen to come from offshore wind energy. Considering the large scale of the future planned offshore wind farms and the increasing distances to shore, grid integration through a transnational DC network is desirable for several reasons.

This article investigates a nine-node DC grid connecting three northern European countries-namely UK, The Netherlands and Germany. The power-flow control inside the multi-terminal DC grid based on voltage-source converters is achieved through a novel method, called distributed voltage control (DVC). In this method, an optimal power flow (OPF) is solved in order to minimize the transmission losses in the network. The main contribution of the paper is the utilization of a genetic algorithm (GA) to solve the OPF problem while maintaining an N-1 security constraint. After describing main DC network component models, several case studies illustrate the dynamic behavior of the proposed control method.

In the year of 2011, the authors "Chen, X.; Sun, H.S.; Wen, J.Y.; Lee, W.; Yuan, X.; Li, N.; Yao, L.", proposed a paper titled "Integrating wind farm to the grid using hybrid multi-terminal HVDC technology", in that they described such as: since wind generation is one of the most mature renewable energy technologies, it will have the greatest share of future renewable energy portfolio. Due to the special characteristics of the wind generation, it requires extensive research to explore the best choice for wind power integration.

In light of the practical project experience, this paper explores the feasibility of using HVdc transmission technology, particularly multi-terminal HVdc (MTDC), as one of the preferable solutions to solve the grid interconnection issue of wind generation. This paper mainly focuses on the application of the hybrid MTDC to integrate wind farms into the electric power grid. A five-terminal hybrid MTDC model system including a large capacity wind farm is set up in PSCAD/EMTDC, in which the corresponding control strategy is designed. The operation characteristic of the hybrid system is studied, and the proposed control strategy is verified through simulation under various conditions, including wind speed variation and faults on ac side and dc side.

III. EXPERIMENTAL RESULTS

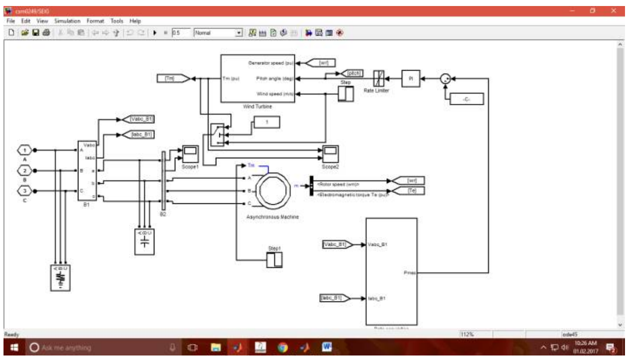

Fig.3 Wind-Source Design

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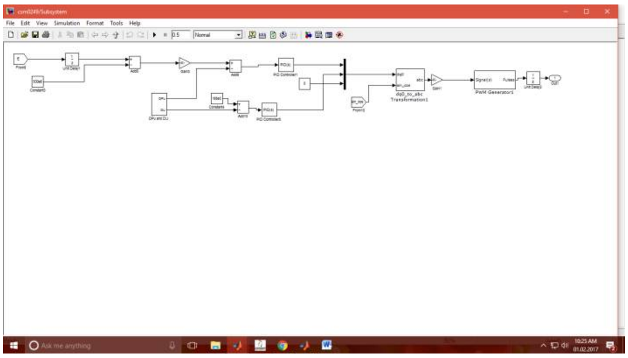

Fig.4 WFC Controller

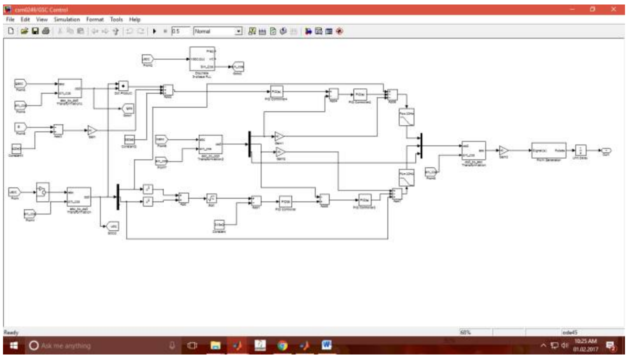

Fig. 5 GSC Controller

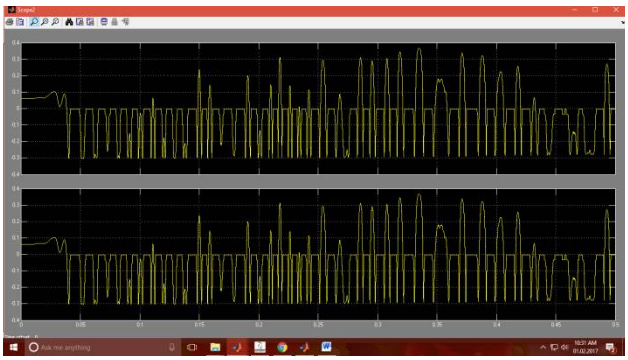

Fig.6 Wind Torque

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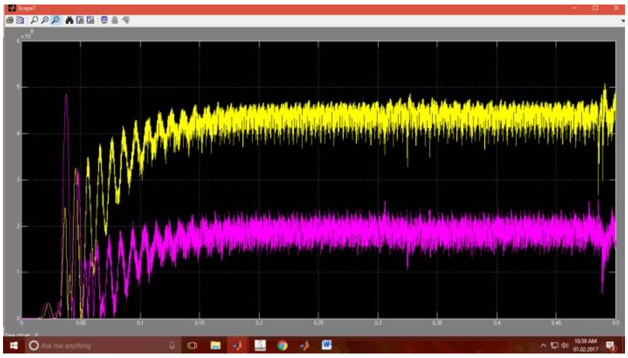

Fig.7 Load Side Real And Reactive Power

IV. CONCLUSION AND FUTURE SCOPE

A typical four-terminal VSC-HVDC system was built for integrating large offshore wind farms. The operation principles and control strategies of the system were described. The two WFVSCs were controlled to establish a constant AC voltage and frequency for the PCCs with wind farms. DC voltage control based on the V-I characteristics of GSVSCs was designed to regulate DC voltage and coordinate power sharing between the two AC girds. The relationship between the power sharing ratio and proportional gain was described. The proposed control method allows multiple converters to control the DC voltage and dispatch the power at a set ratio in real time without fast communications. Simulations results under variable wind power and power sharing ratio have been presented to validate the performance of the proposed control strategies. The results show satisfactory dynamic response. The system can maintain stability and show good performance in a certain degree during large disturbance caused by three phase to ground fault on the AC gird.

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