A Suitable Power Transfer Control System for Interconnection Converter of DC Microgrids

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1. Brief Introduction

Local aggregation of Distributed Generation (DG) systems and electrical loads results in a Microgrid (µG). In order to meet energy, reliability, power quality, power back-up and peak shaving needs and to allow sharing of resources within a common infrastructure, multiple µGs could be interconnected resulting in a power park [1]. Modern DG systems and modern electrical loads have DC link stages for interconnection to the AC distribution network. As a result, DCµGs provide the best solution for aggregation of these devices by integrating their DC power link stages. Previous researches have shown that DCµGs are preferable to both power frequency and high frequency AC µGs from various technical, economical and reliability viewpoints [2]-[7]. Thus, the DC Microgrid (DCµG) concept and consequently, DC power parks have provided a new paradigm for future distribution power systems. The interconnection of DCµGs in a DC power park has not been studied in previous researches. In this paper, a DC/DC converter named Interconnection Converter (ICC) has been used for interconnection of two DCµGs. The main goal of this research is to develop a suitable control system for the DC/DC ICC.

Keywords

DC Microgrid, Distributed Generation, Droop Control, Hysteresis Current Control.

2. DCµG Modeling

The typical structure of a DCµG is shown in Fig. 1. All DCµG converters are Voltage Source Converter (VSC) systems. The DC bus provides a common capacitive terminal for the VSCs.

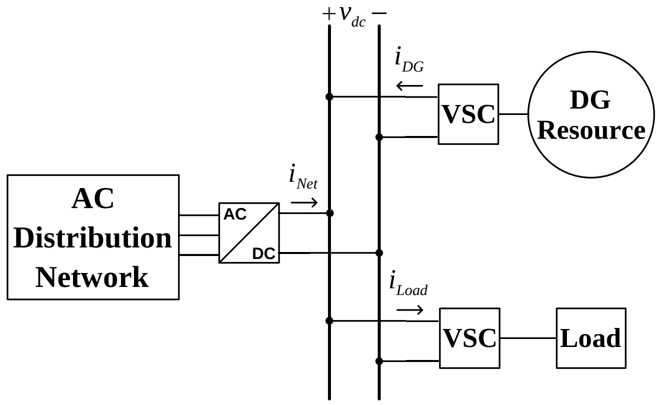

Fig. 1. Typical structure of DCµG

The original and large signal values of the DCµG bus voltage are the same, since the capacitive terminals of VSCs do not include high frequency switching waveforms [3]. As DCµG bus voltages are the only signals from the DCµGs which interact with the DC/DC ICC, detailed and large signal modeling of the DCµGs would provide the same results for studying the DC/DC ICC. As a result, the large signal model of the DCµG studied in [2] and [3] has been developed in this paper as illustrated in Fig. 2.

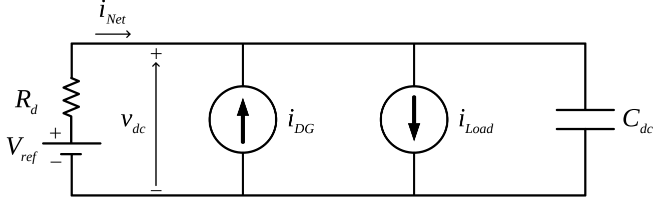

Fig. 2. DCµG model

As shown in Fig. 2, the network converter is modeled as a DC voltage source in series with a droop resistor. The DG and load systems are modeled as independent current sources. The DC bus is modeled by the total required capacitor for its VSCs. The design of the DCμG parameters has been presented in details.

3. DC Power Park

Fig. 3 illustrates the DC power park which has been studied in this paper.

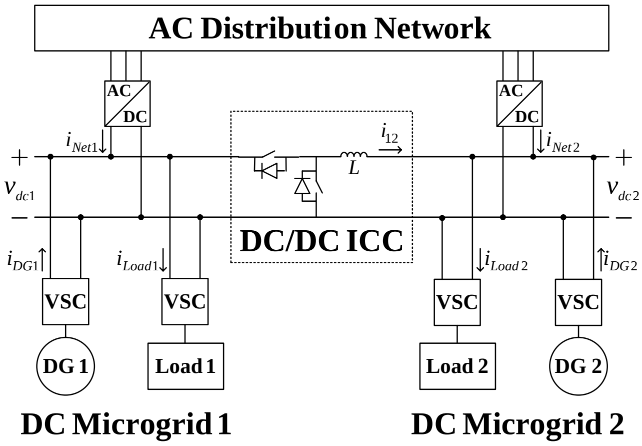

Fig. 3. DC power park

The DC/DC ICC has a DC/DC VSC topology with IGBT switches. The proposed control system for the DC/DC ICC should provide proper regulation of power flow and cancellation of interactions between the DCμGs. As a result, the DC/DC ICC control system should have fast dynamic response and insensitivity to system parameters variations. Hysteresis Current Control (HCC) is the simplest PWM system which has the above characteristics [9]. Thus, a two level HCC is used for the DC/DC ICC and its reference current is calculated as follows:

$$i_{12,ref} = \frac{P_{12,ref}}{v_{dc2}} \quad (1)$$

where $i_{12,ref}$ is the HCC reference current and $P_{12,ref}$ is the scheduled transfer power reference. As it can be seen, (1) is based on an instantaneous power regulation resulting in faster dynamic response than average power regulation methods. The maximum HCC switching frequency of the DC/DC ICC should be limited to an acceptable value. This issue has been considered in the design of the inductor L shown in Fig. 3.

4. Simulation Results

The system shown in Fig. 3 has been modeled and simulated by PSCAD/EMTDC. Large signal models of the DCμGs and detailed model of the DC/DC ICC has been used for modeling of the DC power park in this paper. As explained before, the large signal modeling of the DCμGs in this paper is just for simplification and it is not an approximation. In the first section, the system performance under changes of the scheduled transfer power reference is studied. In the second section, the system performance under changes in active powers of the DG resource and the load in both DCμGs is studied. The steady state results have been verified by mathematical expressions. Simulation results indicate the good performance of the DC voltage droop controllers in adjusting the DC bus voltages within specified limits and the effectiveness of the proposed control system for the DC/DC ICC in the proper regulation of power transfer between the DCμGs. Furthermore, the DC bus voltage of either DCμG is not changed due to changes in the DG or load power of the other DCμG. As a result, disturbances in one DCμG have no effect on the other DCμG. This indicates the good performance of the proposed control system for the DC/DC ICC in cancellation of interactions between the DCμGs.

5. Conclusion

The operation and control strategies for the interconnection of DCμGs have not been studied in previous researches. In this paper, a suitable control strategy has been developed for a DC/DC voltage source converter which interconnects two DCμGs. A large signal model of DCμGs has also been developed which can effectively be used to study the interactions of DCμGs in a DC power park. Simulation results indicate that the proposed control strategy can properly regulate the instantaneous power transfer and can eliminate the interactions between interconnected DCμGs.

References

[1] J. Eto, V. Budhraja, C. Martinez, J. Dyer, M. Kondragunta, "Research, Development, and Demonstration needs for Large-Scale, Reliability-Enhancing, Integration of Distributed Energy Resources", Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, Jan. 2000.

[2] M. Mahmoodi, G. B. Gharehpetian, M. Abedi, R. Noroozian, "Control Systems for Independent Operation of Parallel Connected DG Units in Distribution DC Systems", IEEE International Power and Energy Conference (PECon'06), Nov. 2006.

[3] M. Mahmoodi, G. B. Gharehpetian, M. Abedi, R. Noroozian, "A Powerful Control Strategy for Source Converters and a Novel Load-Generation Voltage Control Scheme for DC Voltage Determination in DC Distribution System", IEEE International Power and Energy Conference (PECon'06), Nov. 2006.

[4] Y. Ito, Y. Zhongqing, H. Akagi, "DC Micro-grid Based Distribution Power Generation System", The 4-th International Conference on Power Electronics and Motion Control, IPEMC, Aug. 2004.

[5] M. Brenna, E. Tironi, G. Ubezio, "Proposal of a Local DC Dstribution Network with Distributed Energy Resources", 11th IEEE International Conference on Harmonics and Quality of Power, Sep. 2004.

[6] P. Karlsson, J. Svensson, "DC Bus Voltage Control for a Distributed Power System", IEEE Transactions on Power Electronics, Vol. 18, No. 6, Nov. 2003.

[7] B. K. Johnson, R. Lasseter, "An Industrial Power Distribution System Featuring UPS Properties", IEEE Power Electronics Specialists Conference, PESC 1993.

[8] A. L. Dimeas, N. D. Hatziargyriou, "Operation of a Multiagent System for Microgrid Control", IEEE Transactions on Power Systems, Vol. 20, No. 3, Aug. 2005.

[9] M. P. Kazmierkowski, L. Malesani, "Current Control Techniques for Three-Phase Voltage-Source PWM Converters: A Survey", IEEE Transactions on Industrial Electronics, Vol. 45, No. 5, Oct. 1998, pp 691- 703.