

Simple Electrical Circuit for Large Signal Modeling of DC Microgrids

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Abstract. In previous researches, the large signal models of DC microgrids have been developed without using any time averaging technique. Thus, the results obtained from available DC microgrid large signal models have not been verified by results from their detailed models. This paper presents a suitable large signal model for DC microgrids which has the same response as control area and detailed models.

Keywords

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

1. Introduction

The interest in Distributed Resources (DR), including both Distributed Generation (DG) and energy storage resources, is increasing due to their technical, economical, reliability and environmental merits. Local aggregation of DR systems and electrical loads results in a Microgrid (μ G) [1]-[4]. The DC Microgrid (DC μ G) concept provides the best solution for the μ G infrastructure because it is formed simply by integrating the available DC link stages in power electronic systems which interface with modern DR systems and loads [5]-[12]. As shown in Fig. 1, the DC μ G has a lossless DC bus infrastructure as the common capacitive link of its Voltage Source Converter (VSC) systems. Generally, detailed and large signal modeling approaches are used to study power electronic systems [13]. Large signal modeling of DC μ Gs has been studied in several researches [5], [9], [10]. However, the large signal models of previous researches have not been verified by detailed models. The main goal of this paper is to develop a simple DC μ G large signal model which can represent the same behavior of detailed model.

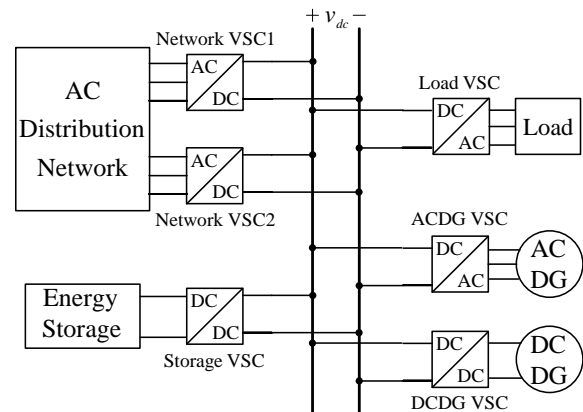


Fig. 1. General structure of DC μ G

2. Proposed Large Signal Model of the DC μ G

As a typical DC μ G operation and control strategy, it is assumed that the network VSCs and the storage VSC have DC μ G Voltage Regulator (DCVR) systems to control the DC bus voltage and the ACDG and DCDG VSCs have Power Regulator (PR) systems to apply their optimal or maximum power requirements. Each DCVR incorporates a current-voltage droop characteristic with a low-pass filter for DC voltage measurement [5]-[14]. Each PR incorporates instantaneous power-based reference current calculation for a hysteresis current controller [5]-[8], [15].

A novel electrical circuit is developed which represents the DCVR large signal model as a current source in parallel with a resistive-inductive branch. The large signal model of the PR can be presented as a constant power source, because it operates in active mode control condition obtained from sliding mode analysis. The large signal

model of the load VSC can be presented as a constant power load, because it controls the load supply voltage independent of the DC μ G voltage changes. Consequently, the large signal model of the DC μ G shown in Fig. 1 is developed as illustrated in Fig. 2.

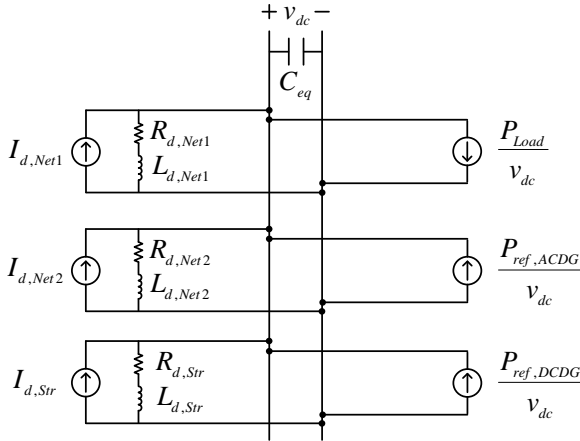


Fig. 2. Proposed large signal model of DC μ G

3. Modeling Verification

Based on the concepts of the conventional Load Frequency Control (LFC) of AC power systems, an effective DC μ G model named control area model has been developed in [8] which can provide the same results as compared to its detailed model. Unlike the LFC model, the DC μ G control area model includes a wide range of changes [8]. It is shown that control area equation of the DC μ G shown in Fig. 1 is the same as the electrical circuit equation of the large signal model in Fig. 10. Thus, the proposed DC μ G large signal model can be verified by its control area model, and consequently, its detailed model.

4. Conclusion

This paper has presented a novel and simple large signal model for the DC μ G system including several DRs and loads. The proposed model has been verified by the DC μ G control area and detailed models. As a result, the proposed DC μ G model provides an efficient modeling approach for studying the DC μ G stability and control issues as well as DC μ G subsystems interacting with each other within the DC μ G or within a DC power park including multiple DC μ Gs.

References

[1] M. Stadler, H. Aki, R. Firestone, J. Lai, C. Marnay, A. Siddiqui, "Distributed Energy Resources On-Site Optimization for Commercial Buildings with Electric and Thermal Storage Technologies", ACEEE Summer Study on Energy Efficiency in Buildings, California, Aug 2008.

[2] C. Marnay, M. Stadler, H. Aki, B. Coffey, R. Firestone, J. Lai, A. Siddiqui, "Microgrid Selection and Operation for Commercial Buildings in California and New York States", 4th European PV-Hybrid and Mini-Grid Conference, Greece, May 2008.

[3] C. Marnay, "Microgrids: An Emerging Paradigm for Meeting Building Electricity and Heat Requirements Efficiently and with Appropriate Energy Quality", European Council for an Energy Efficient Economy Summer Study, France, June 2007.

[4] C. Marnay, "Microgrids and Heterogeneous Security, Quality, Reliability and Availability", Power Conversion Conference, Japan, Apr. 2007.

[5] M. Mahmoodi, R. Noroozian, G. B. Gharehpetian, M. Abedi, "A Suitable Power Transfer Control System for Interconnection Converter of DC Microgrids", International Conference on Renewable Energies and Power Quality (ICREPQ), 12-14 March 2008, Santander, Spain.

[6] N. Moadabi, M. Mahmoodi, G. B. Gharehpetian, "Control Systems for Grid Interconnection of Multiple Distributed Generation Modules Aggregated by Cascaded Boost Converters", International Conference on Renewable Energy and Power Quality (ICREPQ'07), March 2007, Sevilla, Spain.

[7] 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.

[8] 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.

[9] 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.

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

[11] M. Baran, N. R. Mahjan, "DC Distribution for Industrial Systems: Opportunities and Challenges", IEEE Industrial and Commercial Power Systems Technical Conference, 2002.

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

[13] J. G. Kassakian, M. F. Schlecht, G. C. Verghese, "Principles of Power Electronics" Addison-Wesley, 1991.

[14] J. Liao, S. Yeh, "A Novel Instantaneous Power Control Strategy and Analytic Model for Integrated Rectifier/Inverter Systems", IEEE Transactions on Power Electronics, Vol. 15, No. 6, Nov. 2000, pp 996- 1006.

[15] C. H. Rivetta, A. Emadi, G. A. Williamson, R. Jayabalan, B. Fahimi, "Analysis and Control of a Buck DC-DC Converter Operating With Constant Power Load in Sea and Undersea Vehicles", IEEE Transactions on Industry Applications, Vol. 42, No. 2, March/April 2006.