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Energy management of DC microgrid based on photovoltaic combined with diesel generator and supercapacitor

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ABSTRACT

Microgrid is promoted as an economical and efficient energy system in which different renewable sources and storage are interconnected to meet the load power demand at any time. It can operate in on-grid and off-grid mode. Since the electrical contribution of each renewable energy source is dependent on the variation of its resource and the load power demand changes time to time, it is possible that the microgrid cannot generate enough electricity at some time. Thus, especially in off-grid mode, a diesel generator is needed as another backup power. However, due to the slow dynamic behavior of the diesel generator start-up stage, the power quality is lowered down because of the shortage of power. Therefore, during the period of the diesel generator starting up, a supercapacitor is suggested to compensate the power balance because of its fast response and high power density. In addition, the supercapacitor can be also used to overcome the electrochemical storage limits like its state of charge and maximum current. This paper proposes a method for power balance control of a hybrid multisource DC microgrid system aiming to meet the load power demand with reliability and stabilizing the DC bus voltage. In order to realize this function, an experimental platform has been set up and the energy management strategy has been implemented into the control process. The experimental results show that the designed control strategy improves the DC microgrid dynamic and static performances under such operating conditions.

1. Introduction

Growing consideration of environmental friendly energy and decreasing conventional fossil energy day-by-day are the two key issues to make researchers and governments to change the form of electricity generation and transmission. With the technical development of distributed sources based on renewable energy, the distributed generation system [1] emerges. As the lower layer of smart grid [2], microgrid is a self-supply distributed system that aggregates loads, storage, renewable and traditional sources, to generate and distribute power across a limited area. Microgrid can operate in grid-connected configuration, where the system is able to exchange power with the utility grid, off-grid configuration, during islanding or power outage of the utility grid, and isolated configuration such as in remote areas far from the utility grid. In this paper, the off-grid and isolated microgrid configurations are named standalone microgrid.

Depending on the usage of AC or DC bus for coupling different elements within microgrid, AC microgrid, DC microgrid, and hybrid AC/DC microgrid structures exist [3]. Compared with DC system, the power of AC system can be easily and economically transformed to another level (increasing or decreasing) by electromagnetic transformers, while DC transformation needs power electronic devices. In reverse, DC system is easier and more efficient to integrate the renewable sources into DC bus, without phase synchronization and without reactive power [4,5]. In addition, the improvement of control technology of power electronic convertors is also helpful to the application of DC distribution system [6]. Regarding the power quality of DC microgrid, three well-known issues are typically considered to be important: voltage regulation, power sharing, and energy storage management [7]. Their importance may be even severer for standalone DC microgrid, and lead to energy management often complex due to uncertainties. These complexities and uncertainties involve an optimization strategy design and intelligent control.

Several research works have been published about standalone DC microgrid energy management and control. In [8], standalone DC microgrid, consisting of the wind turbine, photovoltaic (PV) source, and electrochemical storage, is mathematically modeled in the form of hybrid differential algebraic equations of Filippov type, to develop a multivariable nonlinear model predictive control-based load tracking and voltage regulation strategy. In [9], the authors proposed a coordinated and multivariable energy

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