Planning and Management of Distributed Energy Resources and Loads in a Smart Microgrid

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ABSTRACT

This paper addresses the issue of planning and management of a so-called smart microgrid, namely a group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the public grid. Special attention is devoted to the microgrid Energy Management System (EMS), which plays a crucial role in governing the power flows from the different generating sources and can resort to optimization procedures and algorithms in order to minimize the daily operating costs. The main features of the EMS platform suitably developed to control the University of Genoa test-bed facility called Smart Polygeneration Microgrid (SPM) are here illustrated and thoroughly discussed.

Keywords: Energy Management System (EMS), Management, Microgrid, Planning, Smart Polygeneration Microgrid (SPM)

INTRODUCTION

The power delivery system, the concept of sustainable energy, and the use of innovative technologies for distributed generation are key issues of state-of-the-art research on smart grids and Microgrids (MGs). MG research fits very well with ongoing smart grid activities throughout the world and several challenges could be faced by means of the employment of pilot test facilities installed worldwide.

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MG is an important technology to integrate distributed energy resources, including wind turbines, solar photovoltaic panels, and energy storage devices such as battery. A MG can connect and disconnect from the grid to enable it to operate in both grid-connected or island modes. MGs are receiving attention, due to the increasing need to integrate distributed generations and to ensure power quality and to provide secure energy to critical loads (Bracco et al., 2013; Bracco et al., 2014).

Energy Management System (EMS) of a MG is a comprehensive automated system primarily aimed at optimal resources scheduling: it is based on advanced IT technology and can optimize management of distributed power and energy storage devices within the microgrid.

In the specialized literature, many works are related to energy management system (EMS) for MGs. A centralized control system for a MG has been presented in Tsikalakis and Hazizargyriou (2008). The controller is used to manage the operation of the MG during interconnected operation, i.e., the production of local generators and energy exchanges with the distribution network are optimized. Two market policies are assumed to offer options for the demand for controllable loads, and this demand-side bidding is incorporated into the centralized control system. In Chakraborty et al. (2007), the energy management strategy of a renewable-based MG has been analyzed. A distributed power supply side model was proposed in Marnay et al. (2008) where a comparison between the installation and running costs of distributed generation and supply from the main grid has been carried out.

In Hajizadeh, and Aliakbar Golkar (2007), an online power energy management for a hybrid fuel cell/battery distributed generation system is presented. The online architecture consists of three layers: the first one captures the possible operations modes, the second is based on a fuzzy controller for power splitting between batteries and fuel cells, and the last one regulates each subsystem. In Teleke et al. (2010), a rule-based control strategy is designed for a battery energy storage system with photovoltaic arrays and a wind farm. The renewable sources can be dispatched hourly, based on forecasting of the solar and wind conditions. The rule-based controller determines the current reference for the converter that will charge/discharge the battery bank by using the state of charge (SOC) and the battery voltage. This system can deal with variability in the wind and solar generation.

The authors in Westermann and John (2007) describe a combination of wide-area measurement and ripple control for Demand Side Management (DSM). The proposed control systems moderate the impact of increased renewable sources on adjacent transmission grids. In Palma-Behnke et al. (2013), an energy management system based on a rolling horizon strategy for a renewable-based MG is proposed. The EMS provides online set points for each generation unit and signals for consumers based on a DSM mechanism. Moreover, the benefits of DSM are achieved by means of shifting demands to periods in more renewable resources are available.

In this paper, attention is focused on the operation of the University of Genoa Smart Polygeneration Microgrid (SPM). The SPM (Bracco et al., 2013; Bracco et al., 2014) is the test-bed facility at the Savona Campus of the University of Genoa, aiming at producing and managing in an efficient way clean energy for the university loads and to operate as a test bed for research, testing and development of management strategies and devices. SPM basically consists of different sources of power generation, electrical storage systems and electric vehicle charging stations. All the components of the MG test-bed are equipped with interfaces, which are either compatible with the new smart grid protocol IEC 61850 or connected via appropriate gateways.

In this paper, also, the performance of Decentralized Energy Management System (DEMS) is analyzed. DEMS has been specifically developed by Siemens for monitoring, operation, control and management of virtual power plants and microgrids. DEMS has been installed in the SPM operation center (Control Room) and guarantees the SPM functionalities.
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