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Multi-agent systems applied for energy systems integration: State-of-the-art applications and trends in microgrids

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HIGHLIGHTS

- Overview of multi-agent approach for smart-microgrid energy management and operation.
- Different state-of-the-art microgrid sub-problems tackled by MAS are revised and presented.
- Trends for future decentralized energy storage and service restoration in microgrids are highlighted.
- Future MAS applications requested by efficient microgrid integration into the grid.

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ABSTRACT

Mini/microgrids are a potential solution being studied for future systems relying on distributed generation. Given the distributed topology of the emerging smart grid systems, different solutions have been proposed for integrating the new components ensuring communication between existing ones. The multi-agent systems paradigm has been advocated as a useful and promising tool for a wide range of applications. In this paper, the major issues and challenges in multi-agent system and smart microgrids are discussed. We present a review of state-of-the-art applications and trends. By discussing the possibilities considering what has been done, future applications, with attention to renewable energy resources integration in emerging scenarios, are placed on the agenda. It is suggested that further studies keep growing in this direction, which will be able to decentralize the high complex energy system, allowing users to participate in the system more actively. This step may decentralize the infrastructure, giving more weight to society wishes, as well as facilitating maintenance, reducing costs and opening a the door for innovative ideas for low-cost based equipment. On the other hand, letting several combinatorial optimization problems opened to be improved and discussed along the next coming years.

Contents

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1. Introduction

Smart Grid (SG) is considered as the future of power grid able to manage production, transmission and electricity distribution. The task has been mainly done by using Information and Communication Technologies (ICT), Distributed Generation (DG) and Artificial Intelligence (AI). Due to the need of consistently adapting and integrating new tools to the current grid, SG has become a major challenge for developed and developing nations in both research and utilization aspects [1]. Investing in SG infrastructure is a key facilitator for public goods, such as decarbonisation and energy security [2]. SG are expected to play an important role in the resolution of many issues of current power grid systems [3,4]. As emphasized by Zhao et al. [5], power grids will become a mesh of networked Microgrids (MG) collaborating to deliver electricity to consumers and eventually, assisting stand-alone systems.

Research and development has been demonstrating the technical and economical feasibility of greener generation technologies based on wind, solar, hydrogen and hydro power. Integrating these technologies has become a priority in MG [6,7], not only because of introducing these Renewable Energy Resources (RER) but also because extra elements have been required, as pointed out by Farhangi [8]: sensor and metering network; network nodes with computation capabilities; switches or actuators which allow the grid setup to be changed and the capability of plug in or plug out new devices. Future MG may equip customers with distributed energy generation and storage systems that can change their overall demand behavior, promoting the development of several smart-microgrids. These tools will provide users the ability of taking profit of their generated energy as an important economic factor [9], helping them to turn into stand-alone systems and self-sustainable users. Providing autonomous assistance in order to aid complex decision making tasks will be required by an increasing number of MG users. Kyriakarakos et al. [10] defined concepts and discussed potential impacts of polygeneration microgrids, taking into account RER and sustainable Energy Storage Systems (ESS). The consideration of MAS was also suggested [11,12], in order to design an optimal polygeneration microgrid for a given amount of an investment and an autonomous collaborative system, respectively.

Coordination and control of these new emerging grid components remain a great challenge [13]. Advanced networking, as well as ICT, have been motivating the integration of the conventional power grid in smarter ways [14], inspiring the use of distributed Multi-Agent Systems (MAS). Autonomous control of SG systems may allow placing additional DGs without reengineering the whole system, and using it in the peer-to-peer model eliminates the requirement of a complex central controller and associated telecommunication facilities [15]. Logenthiran, Srinivasan & Wong underscored that MAS is one of the fastest growing domains in agent oriented technology which deals with autonomous decision modeling. Moreover, it has been showing to be crucial in SG operations [16]. MAS has spread to diverse SG applications in the field of power systems restoration, security and protection, control, monitoring, energy storage and maintenance scheduling, and electric power market simulation [17]. The need to integrate both fields of knowledge, MAS and SG, has increased extensively around the world in the recent years. Fig. 1 shows the number of publications relating MAS and SG in the Scopus database, performed on September 30th, 2015. The red point, for 2016, indicates expected values after evaluation of all 2016 submitted manuscripts.

In particular, the MAS paradigm can be adapted to model, control, manage or test the operation of MG [18]. The latter had

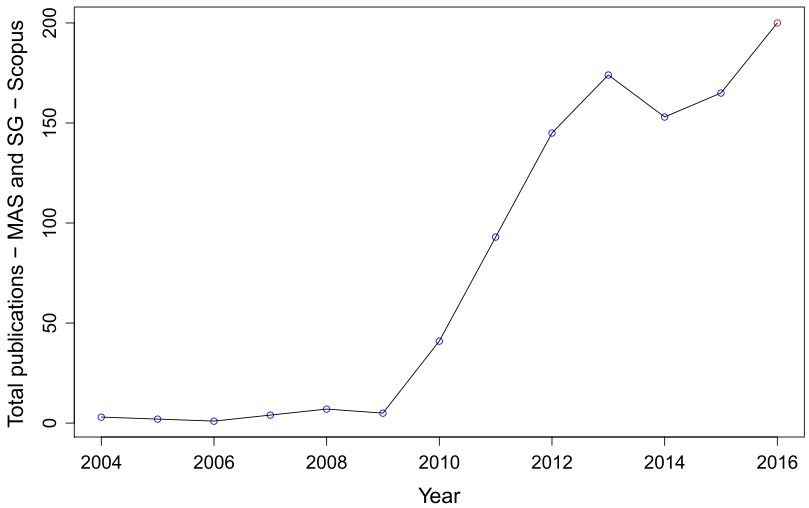

Fig. 1. Number of papers involving MAS and SG until September 13th, 2016.