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Editorial

Intelligent Energy Management of Electrical Power Systems

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Abstract: Smart grid implementation is facilitated by multi-source energy systems development, i.e., microgrids, which are considered the key smart grid building blocks. Whether they are alternative current (AC) or direct current (DC), high voltage or low voltage, high power or small power, integrated into the distribution system or the transmission network, multi-source systems always require an intelligent energy management that is integrated into the power system. A comprehensive intelligent energy system aims at providing overall energy efficiency with regard to the following: increased power generation flexibility, increased renewable generation systems, improved energy consumption, reduced CO_2 emission, improved stability, and minimized energy cost. This Special Issue presents recent key theoretical and practical developments that concern the models, technologies, and flexible solutions to facilitate the following optimal energy and power flow strategies: the techno-economic model for optimal sources dispatching (mono and multi-objective energy optimization), real-time optimal scheduling, and real time optimization with model predictive control.

Keywords: microgrids; multi-source systems; multi-energy systems; energy optimization; advanced control technologies; demand side management; energy monitoring; energy cost optimization; electric vehicles charging stations; building-integrated energy management; smart meter; blockchain

1. Introduction

Energy transition encourages the development of renewable energy sources. However, the growth of decentralized energy production reveals an increasing complexity for power grid managers, implying more quality and reliability to regulate electricity flows and less imbalance between electricity production and demand. The smart grid concept, defined as an electricity supply network that uses communications technology to detect and react to local power changes, represents the solution to such technical problems. To build key smart grid blocks and to overcome these problems, decentralized renewable energy production would allow intelligent energy management, local regulation including ancillary services as well as self-consumption, and therefore, fewer constraints for the public grid. Hence, the concept of multi-source energy systems, i.e., microgrids based on renewable energy sources, storage, controllable loads, and public grid connection, aims to actively participate in the smart grid implementation balance of electricity production and consumption. Microgrids are reliable and effective options for increasing the penetration of renewable energy while minimizing the cost of energy and the negative impact on the public grid.

Faced with the emergence of the smart grid and the imperative of implementing of intelligent energy management microgrids must be able to optimally manage power flows, take into account energy strategies, and imply scheduling and design optimization. On the other hand, microgrids

loads, in particular buildings as well as charging stations for electric vehicles (EVs), require a specific intelligent energy management controller.

This Special Issue presents the latest research on relevant topics and addresses challenging issues with the integration of intelligent energy management systems. There were 27 papers submitted to this Special Issue, and 13 papers were accepted, i.e., 48% acceptance rate. Various topics in intelligent energy management of electrical power systems for a sustainable and resilient power system have been addressed. The contributed articles belong to three broad groups: (i) multi-source systems optimization: scheduling, design, and system; (ii) power management of multi-source systems: applications for buildings and EVs charging station; (iii) required electric power intelligent components.

2. Advances on Intelligent Energy Management Systems

There are six papers focused on multi-source systems optimization regarding the techno-economic dispatching, system design, and sizing. A multi-source/multi-energy system including wind power, photovoltaic power, hydropower stations, and thermal power plants combined with energy storage devices is considered in [1], for which a multi-objective scheduling optimization model considering different operation strategies is presented. Taking into account the longest life cycle and the optimum economic efficiency, the proposed model provides effective decision-making support for designing the optimal plan for system operation. Aimed at achieving the most economic energy scheduling and based on stochastic model predictive control, [2] develops an interesting approach to coordinate scheduling of multi-source/multi-energy system. Scenarios for aggregated electric vehicles (EVs) and their battery degradation are taken into account and a finite-horizon optimal control solution is presented while the economic objective and operational constraints are included. Considering an integrated energy system, a standardized matrix modeling method is presented in [3]. Based on the proposed model, the system optimization can be achieved regarding the energy management, system design and sizing, as well as the system operation. Using a genetic algorithm with the Pareto front, an optimal design for hybrid photovoltaic (PV)-storage-grid-connected systems is developed in [4]. The optimization minimizes the total cost of ownership and the voltage common bus deviation while considering the direct and indirect costs for the prosumer and highlights the profitability of the optimal system configuration on storage prices. The energy-coupling relationship between the energy-supply side and the demand side is introduced in [5]. Taking into consideration economic performances, this paper proposes an optimized energy-conversion interface model that simplifies the complex multi-energy system into a multi-input–multi-output dual-port one and provides a decision-making method for system planning. A high-dimensional mixed-integer optimization problem is proposed in [6], in which, for a high-dimensional multi-source system, the power system unit commitment, i.e., the techno-economic sources scheduling, is solved by applying a novel binary competitive swarm optimizer.

The power management methods of multi-source systems lead often on application field such as the building sector or EVs charging stations. Four papers are included on this topic. A direct current (DC) microgrid based on PV-storage is presented in [7,8]. For the islanding operation mode that requires a backup power source, the classical diesel generator, which start-up is assisted by supercapacitors, is used in [7]; the proposed power management strategy controls a dynamic load as well as economic operating mode of the diesel generator. Based on mixed-integer linear procedure, [8] suggests the optimal operation planning of a DC microgrid supplying EVs optimizing daily operational costs considering the PV production and EVs exploitation forecast. On the other hand, EVs changing station may help the power grid to improve the automatic generation control performance by cost consensus algorithm applications [9] or to minimize the load peak by adopting an intelligent scheduling system [10].

An intelligent energy management system implies also many other components. Some of them, like electric springs, smart meter, and data, are presented in [11–13]. Reference [11] introduces the state of the art of electric springs as a new solution for stabilizing power grid fed by intermittent renewable

energy sources. Regarding data, two papers are included in this Special Issue. The result of the analysis presented in [12] shows that revealing characteristics from smart meter data is feasible and the proposed machine learning methods have a good accuracy. Concerning the blockchain-based energy trading in the electrical power system, the survey [13] tackles challenges like energy transaction, consensus mechanism, and system optimization. Although many problems still need to be solved, the blockchain concept combined with other technologies improves the blockchain-based energy exchange system to better meet the practical requirements of intelligent power systems.

3. Future Energy Managements Systems

In the years to come, more in-depth research in energy managements systems is expected. It can be anticipated that modern approaches like artificial intelligence and data mining will be investigated in large numbers of electrical power systems aiming to build more smart grids. In this case, appropriate technologies should be ready for integration and utilization of data and optimization methods in order to provide better control strategies.

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