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Editorial

Volume II: Energy Management Systems for Optimal Operation of Electrical Micro/Nanogrids

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1. Introduction

Electrical microgrids (MG) have emerged as one of the most promising solutions for the energy transition of electrical power systems. The technological paradigm on which electrical microgrids rely will enable greener and more efficient, flexible, and resilient power systems. At the same time, microgrids will enable more widespread and easier access to electricity worldwide, while also ensuring the continuity and reliability of operation. However, to achieve effective operation, especially under the high penetration of distributed energy sources (RES) and energy storage systems (ESS), microgrids need to be governed by appropriate energy management systems (EMS).

The basic functions of EMSs in micro- and nanogrids are the monitoring and forecasting of electrical power generation and load demand, assigning generation schedules for power sources and storage units, managing controllable loads, and, for grid-connected microgrids, dealing with the energy market. EMSs are thus a key solution to attaining the optimized and cost-effective operation of electrical microgrids, while satisfying their technical constraints [1,2].

Many contributions to energy management (EM) optimization in microgrid applications have been proposed in the technical literature exploring several methods (mathematics, fuzzy, heuristic/meta-heuristic, multi-agent-based, etc.) and considering different factors in their objective functions, such as the operational costs, storage system degradation, greenhouse gases (GHG) emission, and so on. Moreover, the unifying concept of Energy Management and Control Systems (EMCS) has been recently introduced referring to an overall microgrid-integrated system working in a flow, which includes data forecasting, energy management optimization, and operational setpoints production for implementation in the real-time control stage [1].

The central role of microgrids in the decarbonization of the energy sector keeps alive the scientific debate on power electronics-based solutions for the integration of renewable sources and storage systems, the coordinated sizing of low-carbon power sources with storage systems, and the most advanced power sharing techniques among such generation/storage units. Microgrid EM optimization techniques based on Artificial Intelligence (AI) and Machine Learning (ML) are also gaining increasing ground and relevance.

Volume II of this Special Issue on Energy Management Systems for Optimal Operation of Electrical Micro/Nanogrids represents the progression of a successful previously published Special Issue on the same topic and, consistent with it, maintains the aim to collect selected high-quality scientific contributions on hot topics related to the development of EMSs and control systems, particularly oriented to optimizing the operation of electrical micro/nanogrids.

In the role of Guest Editor, I have recognized the growing interest of the scientific community on EMSs in the field of micro/nanogrids; furthermore, I observed the relevance of the covered topics at different application scales and in different application domains such as utility power microgrids, nanogrids for residential, and also electrical shipboard

Citation: Di Piazza, M.C. Volume II: Energy Management Systems for Optimal Operation of Electrical Micro/Nanogrids. *Energies* **2024**, *17*, 1811. https://doi.org/10.3390/en17081811

Received: 20 February 2024
Accepted: 17 March 2024
Published: 10 April 2024

power systems (SPS) sector where the microgrid paradigm aims to increase the efficiency and environmental sustainability of maritime transport.

In the next section, a short survey of the articles published in this Special Issue is given to assist readers to quickly acquire information on the Volume's main contents and take advantage of the presented scientific achievements.

2. Short Review of the Contributions to This Special Issue

This Special Issue (SI) comprises a collection of seven scientific articles contributed by highly reputed international research teams. To ease the browsing of the SI's contents, the topics of the published articles can be grouped into the following three main categories:

1. RES integration in power grids;
2. AI/ML based techniques for MG optimal management;
3. Renewable/ESS coordinated sizing and management.

Three of the published articles deal with the first topic, i.e., [3–5].

In [3], Combe et al. propose the use of a single-stage three-phase buck-type rectifier to improve the connection of electrolyzers in AC grids with a high penetration of renewables. The electrolyzer is intended to produce hydrogen to balance energy production and consumption, mitigating the effects of RESs' variability. The proposed power converter was properly modeled, and a dedicated control strategy was developed to reduce the oscillation in the input current, while granting a large signal stability and the good dynamic performance of the converter. With the proposed solutions, the authors of [3] obtained a unitary power factor and a THD of 4% in steady-state conditions, as well as stable operation of the system under sudden variation of the grid voltage.

In [4], Ramos-Paja et al. detail their investigation into the integration of a small-power wind generation system in an AC grid, with a special focus on urban applications, using commercial equipment. The integrated system included a 140 W wind turbine, a permanent magnet synchronous generator (PMSG) equipped with an uncontrolled rectifier, a high-voltage gain flyback converter, and an inverter. By developing a suitable control to regulate the operation of the flyback converter, the authors demonstrated the feasibility of a wind generation system with the ability to supply its maximum power and to perform an effective rejection of current disturbance due to the grid connection.

The authors of [5], also focusing on the issue of RES integration in power grids, address the issue of voltage-disturbances mitigation in low-voltage (LV) distribution grids with a high penetration of photovoltaic (PV) generators in prosumer installations. In detail, they propose a simple and costless control method for 3- and 4-wire PV inverters, allowing for simultaneous PV active power transfer and compensation of load unbalance and reactive power. Due to the proposed control strategy, properly assessed by simulations, the prosumer installations results were balanced and merely active. The proposed solution reveals its advantage for both prosumers and distribution system operators (DSO), as it prevents PV systems from unwanted shut down and leads to an improvement in the grid power quality.

The topic of AI/ML based techniques for MG optimal management is the focus of two of the SI's articles [6,7].

In [6], Lo Franco et al. present a method to forecast the electrical power demand of a charging hub for the effective integration of electric vehicles (EV) in the power grid. Different parking scenarios were considered in the analysis, and different factors influencing the power demand were accounted for, such as the EV population, the users' behavior patterns, and the initial state-of-charge (SOC) of the battery. Using a combined probabilistic/ML-based approach, the forecasting of the power demand was obtained, and useful information on the significance of the different influencing factors was deduced.

The problem of frequency regulation in hybrid power systems, including PV generation, is proposed in [7]. In this work, an artificial neural network (ANN) model, whose learning performance was enhanced by means of a swarm optimization algorithm (i.e., bacterial foraging, BF), was used to design an automatic generation controller (AGC) aiming at correcting frequency variations due to rapid changes in the renewable generation or power demand. The regulator was tested in simulations under different operating conditions, and the obtained results demonstrated that the proposed BF-ANN-AGC worked well in all the considered case studies, outperforming both PID- and ANN-based AGCs in terms of the frequency offset, overshoot, and transit time.

Finally, articles [8,9] address the topic of renewable/ESS coordinated sizing and management.

In detail, the authors of [8] discussed the problem of the optimal management of a hybrid generation system based on fuel cells (FC) and batteries on a DC shipboard microgrid. They propose an EMS whose main task is to minimize the excursions of the FC operating point to preserve the health and life span of the power source. This objective was pursued while exploiting the battery's capability to handle power demand variations, according to a load leveling strategy, and to compensate for load demand forecasting errors. Simulation tests of the proposed EMS, referring to a real-world ship case study, showed the fulfilment of the management objective, the stability of the grid voltage, and the capability of the EMS to properly manage the microgrid under black start, transient, and faulty conditions.

This short survey of the SI contributions concludes with article [9], where Blasuttigh et al. present the results of their investigation into the optimal sizing of a power system, including PV and battery storage systems (BESS), which can be governed by a rule-based EMS. The application domain of this work is within the framework of renewable energy communities (REC); in particular, it refers to a jointly acted renewable self-consumers (JARSC) community. Both economic and environmental factors were considered, thus allowing several optimal sizing combinations of a PV/BESS system to be assessed for different PV power and storage capacities.

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflicts of interest.

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