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Editorial

Energy Management in the Multi-Source Systems

Awab Baqar *, Mamadou Baïlo Camara * and Brayima Dakyo *

GREAH Laboratory, University of Le Havre Normandie, 75 Rue Bellot, 76600 Le Havre, France
* Correspondence: awab_92@hotmail.com (A.B.); mamadou-bailo.camara@univ-lehavre.fr (M.B.C.); brayima.dakyo@univ-lehavre.fr (B.D.)

With the goals set for sustainable development and renewable energy technologies, major advancements have been observed in the domain of multi-source systems. Often termed as distributed power generation systems and hybrid energy storage systems, multi-source systems present numerous opportunities and technical challenges.

The importance of efficient energy management within multi-source systems is increasing by the day. With the development of the electric vehicle industry, more focus has shifted towards research and innovation of energy management methods. Given that, there is still a growing need to develop better models and energy management algorithms to optimize the energetic performance of the storage systems to increase their lifecycle time.

In the International Energy Agency (IEA) net zero emissions scenario, energy efficiency plays a key role. Ideally, the world must become one-third more energy efficient. To achieve such an ambitious target, a major push toward energy efficiency is necessary, especially in construction, transport, and industry. In the past few years, with the deployment of connected devices, such as sensors and smart meters, we have achieved better measurements and thus enhanced controls. More than 500 GW of demand response is needed in the market by 2030 to achieve the targets set in this scenario. The technologies needed to enable these measures are efficient hot water systems, smart charging of electric vehicles, and building energy management systems. These systems can deliver 20–30% of energy savings just by installing efficient technologies which are governed by energy management algorithms [1].

Therefore, it is clear by the policies and scenarios which are already laid out, that we need to investigate in detail and improve the existing technologies in an effective manner. Most of the systems to enable these technologies are already developed, but there is room for improvement. Furthermore, there is an increasing demand for efficient algorithms to capitalize on the resources already available. To achieve the goals in the net zero scenario, researchers need to focus on what exactly is the need of the hour. The COVID-19 pandemic slowed the development pace of these technologies considerably, which needs to be picked up again.

This special issue was intended to provide a platform for the researchers during the challenging times of COVID-19, to investigate and publish in the specific domain of Energy Management in Multi-source systems.

Recent studies on the ageing assessment of storage systems show that much work needs to be undertaken in this area. Supercapacitor ageing characterization and modelling have been presented in [2] by considering the influence of the current ripple rate, temperature and cycling factor. In Ref. [3], the authors target a similar problem but consider the influence of DC current ripples directly instead of finding the ripple rate; both studies consider the variations of resistance and capacitance of the supercapacitors according to temperature, current ripple, and state of charge. Battery ageing characterization in [4] follows similar principles and considers the effects of temperature and DC-current ripple rate as thermal and electrical constraints of batteries. These models can be used to predict the amount of degradation of batteries caused by electrical and thermal constraints. An estimation of open-circuit voltage and state of charge characterization of a lithium-ion battery

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has been presented in [5] under varying temperature constraints. An overview of characterization methods for supercapacitors modelling has been given in [6], where various characterization methods have been discussed according to different levels of modelling.

Currently, a lot of work has been undertaken for solving the challenges being faced within the microgrids, whether they are islanded or grid-connected. Ref. [7] presents a comparison between real-time energy management strategies based on adaptive equivalent consumption minimization strategy (A-ECMS) and stochastic dynamic programming (SDP) for a fuel-cell/supercapacitor-based hybrid microgrid. A rule-based energy management strategy for a multi-source system has been developed in [8] for application in a hybrid tramway, and it ensures the state of charge of the storage devices such as supercapacitors and batteries to stay within the defined limits. Jiang et al. [9] compare the energy management of grid-connected and standalone modes. A DC/DC converter design has been proposed for the power management of battery and supercapacitor based hybrid electric vehicles [10]; the power management strategy of the system is based on polynomial control for the power converters. Castaings et al. [11] have provided a comparison between different energy management strategies such as λ- control and filtering-based energy management of hybrid energy storage systems, and these strategies are used for real-time energy management. These strategies are not evaluated for energy efficiency and battery lifetime constraints.

A real-time power split strategy for energy management of batteries/supercapacitors has been provided [12]; this strategy is based on bandwidth filter and sliding mode control. Tani et al. [13] present a frequency splitting based energy management strategy in a microgrid consisting of a diesel generator, supercapacitors, wind turbine, solar photovoltaic generator, and lithium batteries. The energy management approach is based on splitting the load, PV, and Wind current into high and low frequencies, where the high frequencies are controlled by the supercapacitors and low frequencies are managed by the batteries. Xu et al. [14] have designed a Q-learning strategy for energy consumption and battery ageing minimization for an electric vehicle based on batteries and supercapacitors, and the authors also point out that research considering both battery degradation and energy consumption is still lacking. Yang et al. [15] present a deep reinforcement learning-based energy management strategy that is verified with the simulations based on a subway line in Beijing. The reward function of this strategy is based on energy savings and voltage stabilizing effects of the supercapacitors, and a Q-learning algorithm is used to emulate the control actions.

This special issue focuses on current advancements and emerging trends in multi-source systems based on distributed power generation systems or for transportation applications, with an emphasis on design optimization and optimal energy management.

Energy management of supercapacitors-batteries/fuel cell-based hybrid electric power supply system for an electric vehicle is presented in [16]. The energy management technique is based on the extraction of frequency components from the driving cycle of an electric vehicle. After passing these components through a low pass filter, the reference currents for supercapacitors, batteries and fuel cells are estimated based on high, medium, and low-frequency components, respectively. Hardware in loop test bench simulations results has also been presented with an adequate correlation between the simulations and experimental outcomes. The supercapacitors model used in this scenario considers the effect of varying temperatures and DC current ripple frequency up to 1 kHz.

A new tapped inductor based boost current converter topology has been studied [17]. The converter has been analyzed by means of theories, simulations, and experiments. The proposed converter has been compared to a conventional boost converter topology by testing both converters under similar constraints. The converter shows high efficiency and current conversion ratio. It has been deemed suitable for photovoltaic systems as it shows the capability of boosting the current output of the solar array. It can also be used in current sink applications.

Deligianni et al. [18] conducted a techno-economic analysis for the development of an autonomous power system based on photovoltaic and battery systems to be used in a shoreland electrode station of an HVDC link on the island of Stachtoroi. The proposed optimization methodology considers significant issues which are often overlooked by the classical methods, such as: Capital and Operational expenditures of (Inverters, PVs and chargers), PV-battery charging cycles, battery ageing, degradation, auto-discharge rate, battery economic lifetime and technical limitations of the system. Based on the configuration of electrical installation for lighting and auxiliary services, a new electrical installation configuration is proposed, which includes renewable energy sources and storage systems. A dedicated building has been recommended for the electrode station for the sake of limiting energy consumption, preventing electrochemical corrosion, protecting from environmental constraints, and reducing the risk of fire hazards by increasing the fire resistance by installing a firefighting system. In the end, a design process for the electrode station building has been proposed in detail.

Huotari et al. [19] provide an analysis of a novel power control methodology based on demand prediction and model predictive control (MPC) for a cruise ship. The problem is approached by a case study, where measured data of a cruise ship has been used. The hybrid system consists of fuel cells and batteries along with diesel generators with the goal of using power management to reduce local emissions. After comparing the results with that of an ideal scenario with optimal control, the average fossil fuel consumption was reduced by 68–74 percent with the proposed model and fully optimal control, respectively.

Solano et al. [20] have developed a test bench to simulate AC/DC microgrids in MATLAB Simulink, which has been made openly available for the scientific community to develop energy management strategies. The test bench includes models of a photovoltaic generator, fuel cell system, supercapacitor, and battery models on the DC side. Voltage source converters to couple DC with the AC side. The AC consists of a variable load and a synchronous generator. It also provides models of maximum power point tracking MPPT for the photovoltaic generators and droop controllers for the voltage source converters. Two case studies have been presented explaining the method of using the testbed to evaluate energy management strategies.

Overall, major developments have been observed over the past few years in the field of energy management of multi-source systems with the emergence of machine learning and data-driven energy methods. This issue is yet another link in the chain of research being carried out in this specific area. The papers presented in this issue address a broad range of problems that require ample attention from researchers.

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