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Editorial

Energy Harvesting and Energy Storage Systems

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Sustainable development systems are based on three pillars: economic development, environmental stewardship, and social equity. One of the guiding principles for finding the balance between these pillars is to limit the use of non-renewable energy sources. A promising method to resolve this challenge is harvesting energy from the ambient environment and converting it into electrical power. The contemporary development of novel energy generation technologies, such as solar, wind, and thermal energy, is in high demand to facilitate the replacement of fossil fuel energy resources with cleaner renewable sources. Energy harvesting systems have emerged as a prominent research area, and have continued to develop at a rapid pace.

Modern technologies, including portable electronic devices, electrical transportation, communication systems, and smart medical equipment, need efficient energy storage systems. Electrical energy storage devices are also used for smart grid control, grid stability, and peak-power saving, as well as for frequency and voltage regulation. Electricity generated from renewable sources (e.g., solar power and wind energy) cannot always deliver an immediate response to demand because of fluctuating power supplies. Hence, preserving the harvested electrical energy for future requirements has been suggested. The present status of electrical energy storage technologies is far from the necessary demands.

In this Special Issue, thirteen papers are published, covering various aspects of optimization algorithms, evaluations of wind energy turbines, electrostatic vibration energy transducers, battery management systems, thermoelectric generators, distribution networks, issues of renewable energy micro-grid interfacing, fuzzy-logic-controller-based direct power controls, parameter estimations of fuel cells, and ultra-low-power supercapacitors.

Sharma et al. [1] proposed a hybrid version of the whale optimization algorithm (WOA) and particle swarm optimization (PSO) algorithm (WOAPSO) for the parameter optimization of PV cells. The exploitation ability of PSO with adaptive weight function was exploited in the pipeline mode with a WOA to enhance the ability and convergence speed of the basic PSO. The performance of the proposed hybrid algorithm was compared with six different optimization algorithms in terms of the root mean square error and rate of convergence. The simulation result showed that the proposed hybrid algorithm not only produced optimized parameters at different irradiation levels, but also estimated the minimum root mean square error, even at a low level of irradiation.

The tunicate swarm algorithm (TSA) was employed to estimate the Photowatt-PWP201 PV panel module parameters under standard temperature conditions [2]. It was concluded that the TSA is an effective and robust technique to estimate the unknown optimized parameters of the solar PV module model under standard operating conditions. The simulation results were compared with four different pre-existing optimization algorithms: the gravitational search algorithm (GSA); a hybrid of the particle swarm optimization and gravitational search algorithm (PSOGSA); the sine cosine algorithm (SCA); and the whale

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Citation: Rajput, S.; Averbukh, M.; Rodriguez, N. Energy Harvesting and Energy Storage Systems. *Electronics* **2022**, *11*, 984. https://doi.org/10.3390/electronics11070984

Received: 16 March 2022
Accepted: 21 March 2022
Published: 23 March 2022

optimization algorithm (WOA). The comparison of results broadly demonstrated that the TSA outperforms the existing optimization algorithms in terms of the root mean square error (RMSE) and convergence rate.

Greenberg et al. [3] evaluated wind energy turbines using the volatility of wind and price. In their study, the real options analysis approach for the valuation of wind energy turbines was applied. It was hypothesized that the real options analysis (ROA) method is better than the alternative due to the nature of wind energy production uncertainties.

Ishida and Tanzawa proposed an integrated AC–DC converter in 1 V CMOS for electrostatic vibration energy transducer with an open circuit voltage of 10 V [4]. The proposed AC–DC converter did not require external components for rectification and power conversion. It can be integrated in the same IoT chip with a small overhead area of 0.1 mm^2. This converter can provide a better option for electrostatic energy harvesting where the cost is the highest priority.

Koketsu and Tanzawa designed a charge pump circuit and system with input impedance modulation for a flexible-type thermoelectric generator with high-output impedance [5]. The circuit system was also measured with a flexible-type TEG and a thermal source. The system converted thermal energy into power to 30 µW at 2.5 V. By adding a full-bridge rectifier between the energy transducer and the proposed converter, the control circuit could work even with other energy transducers such as piezoelectric or electrostatic vibration energy transducers with an AC equivalent voltage source and high-output impedance.

Lee et al. [6] proposed a battery efficiency calculation formula to manage battery states. The proposed battery efficiency calculation formula used the charging time, charging current, and battery capacity. An algorithm that can accurately determine the battery state was proposed by applying the proposed state of charge (SoC) and state of health (SoH) calculations. To reduce the initial error of the Coulomb counting method (CCM), the SoC could be calculated accurately by applying the battery efficiency to the open circuit voltage (OCV). During the charging and discharging process, the internal resistance of a battery increases and the constant current (CC) charging time decreases. The SoH can be predicted from the CC charging time of the battery and the battery efficiency, as proposed in this paper. Furthermore, a safe system was implemented during charging and discharging by applying a fault diagnosis algorithm to reduce the efficiency of the battery. The validity of the proposed BMS algorithm was demonstrated by applying it in a 3 kW ESS.

An ultra-low-power CMOS supercapacitor storage unit for energy harvesting applications was presented by Gogolou et al. [7]. The ultra-low current consumption of only 432 nA at 2.3 V proves that the proposed storage unit is ideal for energy harvesting systems, even for cases with a small input power range. Furthermore, extra modes can be added to the topology with the usage of external controls, expanding the operational capabilities of the proposed unit. For instance, the control of an additional charging unit for the backup battery is a highly beneficial mode that will be added in future studies.

Satish et al. [8] proposed a novel three-phase harmonic power flow algorithm for unbalanced radial distribution networks in the presence of D-STATCOM devices. This method used the basic concepts of circuit theory, which can easily be understood. In this study, the linear loads were modeled as a series combination of resistance and reactance, and non-linear loads were modeled as constant current sources, with the magnitude and angle obtained from the current spectra. The harmonic current injections from the D-STATCOM were assumed to be zero. The proposed FPFA and HPFA were tested on the IEEE-13 bus URDN, and the results were found to be in accordance with the literature. Test studies were carried on the IEEE−13 bus and IEEE−34 bus URDN, and the results of the case studies showed that there was an improvement in the fundamental voltage profile, a reduction in the fundamental and harmonic power loss, and a reduction in THD% with the integration of D-STATCOM devices.

Sharma et al. [9] introduced a novel opposition-based arithmetic optimization algorithm (OBAOA) for identifying the unspecified parameters of PEM fuel cells. The proposed algorithm was tested using ten benchmark test functions (seven unimodal and three multimodal). Furthermore, the convergence graph, as well as the I-V and P-V characteristic curves, supported the precision of the anticipated algorithm. The proposed OBAOA technique was easy to implement, with low computational complexity. The performance of the proposed algorithm was verified using the Friedman ranking test. The proposed formulation will pique the attention of both researchers and practitioners in the fuel cell community, due to its capacity to solve problems effectively.

Ahmad et al. [10] proposed a fuzzy logic controller (FLC)-based direct power control (DPC) method for photovoltaic (PV) cells, which was modelled by modulating microgrids' point of common coupling (PCC) voltage. They also introduced a modified grid synchronization method through the direct power calculation of PCC voltage and current, instead of using a conventional phase-locked loop (PLL) system.

Singh et al. [11] employed the sooty tern optimization (STO) algorithm for the parameter extraction of solar modules. They implemented the STO algorithm with a single-diode model on an R.T.C France solar panel and an SS2018 polycrystalline PV module. It was concluded that the STO is an efficient and reliable technique for estimating the unknown optimum parameters of a solar PV module model under typical operating conditions.

El-Ela et al. [12] discussed the economic and environmental issues of renewable energy micro-grid interfacing. The stochastic behavior of renewable resources increases the need to determine the optimum operation of microgrids. The optimal operation of a typical microgrid aims to simultaneously minimize the operational costs and the accompanying emission pollutants over a daily scheduling horizon.

Ammar et al. [13] reviewed energy-harvesting-driven edge devices using task-offloading approaches. This paper includes a literature review of state-of-the-art joint energy-harvesting and task-offloading approaches in fog edge computing systems, research efforts on task offloading in fog edge computing, and the design of patient-centered care systems. The authors investigated energy-harvesting technologies and energy-storage strategies for IoMT devices.

We would like to take this opportunity to appreciate and thank all authors for their outstanding contributions, and the reviewers for their fruitful comments and feedback. We are thankful to the Editorial Board of the *Electronics* journal for the opportunity to edit this Special Issue. Special appreciation should also be given to the Editorial Office staff for their hard and precise work in maintaining a rigorous peer-review schedule and ensuring the timely publication of this Special Issue.

Conflicts of Interest: The authors declare no conflict of interest.

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