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Editorial

Editorial Board Members' Collection Series: Smart Energy System Design

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1. Introduction

The collection series presents various emerging approaches for designing growing renewable energy (RE), energy storage (ES), and smart transportation with electric vehicles (EVs) in the power and automobile industries. This editorial discusses various design, infrastructure, and technological aspects of energy storage and electric vehicles. In recent years, smart energy system development has gained momentum; these systems reduce greenhouse gas (GHG) production with no tailpipe emissions and improve energy efficiency and air quality, making them environmentally beneficial and crucial for climate change. EV utilization and energy storage not only pose challenges to smart energy systems but can also act as catalysts for their enhancement. Emerging technological advances create the capability to transform the transportation industry as well as grid energy demands. Power generation from renewable energy resources (RESs) plays a major role in producing sustainable green power and reducing dependency on fossil fuels; in turn, this leads to various technical, economic and environmental benefits.

The renewable energy and EV market is set to expand in accordance with governmental initiatives and ambitious plans. EV charging stations play an important role in the effective utilization of EV ecosystems, enabling easy access to charge the EVs in different places including commercial, residential and public areas. These charging stations integrate EVs into the existing power grid. Effective load management strategies, such as smart meters with the option of time-of-use pricing, smart and dynamic charging, and fast charging technologies, play an important role in handling the increased demand from charging stations, especially in peak load demand hours. Therefore, the proper location and sizing of charging stations encourages faster EV adoption, thus promoting green transportation practices. The intermittent nature of wind speed, solar irradiation and EV loads introduces uncertainties to the power grid. Therefore, energy storage devices such as fuel cells, batteries, etc., must be used for energy balancing. EV charging patterns provide additional load fluctuations to the power grid; they also vary based on charging infrastructures and user behaviours, which may further increase the challenges in maintaining grid stability. One of the biggest challenges for EV users is the driving anxiety that comes from predicting the single-charge driving range.

Smart energy systems integrating multiple energy sectors are considered a promising paradigm for providing a comprehensive and optimized solution for an achievable, affordable, and sustainable energy system in the near future. Although extensive studies on the definition, implementation, and optimization of these systems have been conducted, designing and managing smart energy systems remain critical challenges. Thus, this collection aims to bring together the most recent research on a variety of exciting topics such as modern power grid control and operation; renewable energy grid–microgrid power generation; intelligent transportation systems; energy harvesting and wireless power transfer technologies; innovations and challenges in the transition to net zero energy; electronic equipment related to energy systems; distributed energy resource (DER) power converter technologies;

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energy storage and electric vehicles; the application of intelligent control strategies in energy systems; and big data, artificial intelligence and cybersecurity in power systems.

El Harouri et al. [1] focused on the large-scale integration of more affordable and environmentally friendly energy demands for residential consumers by considering the state of charge (SoC) of EVs and the amount of power supplied by the PV system. In this work, a combination of fuzzy logic controller (FLC) and proportional integral (PI) controller is developed to control the residential system with the help of a bi-directional buck-boost converter; this controller is effective in minimizing the current and voltage ripples in the system. A rule-based energy management system (EMS) strategy is developed to control the flow of energy between various components of residential systems. All the possible power transfer scenarios between home-to-vehicle and vehicle-to-home modes of operation are examined and validated in this work. The obtained results on the proposed EMS show a reliable and stable solution which can handle or reduce the grid intervention.

Sambhi et al. [2] evaluated the proposed hybrid energy generating system for economic, environmental, and technical analysis. This analysis is performed on power generation from RERs (solar energy) and hydrogen-based energy by considering on- and off-grid operating conditions. The proposed hybrid energy system has a load of 400 kWh/day, including 74.27 kW of peak load, and a hydrogen load of 10 kg/day, including 1.86 kg/h of peak load. Sensitivity analysis is also performed, including on the size of the PV system, number of batteries, CO_2 emissions, renewable fraction, and hydrogen tank capacity. In the future, this work could be continued by including government subsidies and energy and government tariffs.

Maklakov et al. [3] developed a novel reactive power compensation (RPC) approach by using a regenerative controlled synchronous motor drive (SMD) and voltage source inverter. This work presented the mathematical formulation and block diagrams of three-level neutral point clamped (3L-NPC)-based SMD models. All the works reported in the literature do not consider reactive power generation when designing these models. This work presented the possibility of RPC with 3L-NPC-based SMD. This was tested on the main drive of a metal plate hot rolling mill. The obtained results show that, during the breakdown, an SMD has a reactive power equivalent to 16% of the total rated power and is used as a part of an industrial smart grid.

Rashid et al. [4] presented a comprehensive review of applications of various phase change materials (PCMs) such as solar stills, air heaters, collectors, and chimneys. As solar irradiation is uncertain, the phase change materials are used in various types of solar energy systems. These materials are used in solar applications for thermal energy storage. This work focused on the current practical implications of PCMs in various solar thermal systems. The maturity of PCMs and their incorporation into solar power applications for thermal energy storage are discussed. Recent technical advancements in PCMs make them suitable for use in producing solar energy, despite their limited availability and high costs.

Liu et al. [5] present a systematic review of electrical energy pricing and its impact on the energy landscape. Modern hybrid power networks are evolving by integrating various intelligent control methods and communication and information systems, which motivates us to move towards smart electrical power grids. This work provides the various methods, frameworks, and recent developments related to energy trading and pricing. The main objective of this work is to review energy trading for microgrid-to-microgrid, peer-to-peer pricing related to the centralized power grid, as well as different pricing approaches. It provides an overview of and deep insights into the current pricing frameworks and their various limitations in present market operations.

Viswa Teja et al. [6] proposed a maximum power point tracking (MPPT) control algorithm by using an artificial neural network (ANN) for a solar battery-powered EV. The proposed system's performance is examined by analysing the data under various load conditions receiving constant variables like torque and speed. A solar PV system is required to meet the energy requirements in a day. The proposed ANN-based MPPT is used to regulate a solar PV module and increase its output. Using the proposed controller can increase solar PV module efficiency where torque ripples and reduced currents are examined on the opposite end. The proposed approach provides various advantages for EV applications which require optimal torque and consistent velocity to satisfy different loading conditions in a day.

Gómez et al. [7] present a comprehensive review assessing hydrogen as an effective alternative for reducing GHG emissions, especially in the transportation sector (on-board applications). Fuel cell EVs (FCEVs) have significant potential for storing and converting chemical energy into electrical energy with zero emissions and thus for solving the climate crisis and making the roads and environment as clean as possible. The proposed work analysed the modern technology and innovations behind hydrogen storage and FCEV techniques for use in the road transportation sector. For this, FCEVs must have a storage capacity of (5-10) kgs of hydrogen to achieve a driving range of 500 kms. Chemical and physical energy storage (ES) approaches are more valuable to the hydrogen economy; however, compressed hydrogen storage is the most advanced approach for the transportation sector in on-board applications.

Park et al. [8] present and review the field experiment results of a Korea Electric Power Corporation (KEPCO) project, the aim of which was to create a new scheme called transmission system operator (TSO)—distribution system operators (DSOs)—distributed energy resource aggregators (DERAs), and namely the TSO-DSO-DERA interaction. This experiment was performed using a prequalification algorithm, which can be used to test realistic grid operating conditions. The obtained results confirm that the proposed algorithm is very effective and robust in nature, that it can be used to solve real-world grid problems and that it can be useful for DSOs in providing a reliable power supply to distribution networks. The proposed, prequalification approach can also support DERA's participation in the wholesale electricity market.

Hu et al. [9] present a detailed overview of electric grid modelling, including uncertainties, their impact on the system and their mitigation. In power systems, uncertainties arise from RERs, loads and EV loads; they play significant roles in maintaining grid stability, reliability, and energy and economic efficiency. The emerging power networks utilize an advanced metering infrastructure, which reduces the risk of cyberattacks. This work presented a comprehensive review of the uncertainties related to climate factors, asset management, and cyberattacks; it also described various techniques to mitigate these issues. This work also presented scenario-based approaches for demand response and energy storage systems, as well as reserves for regulating service to mitigate modern power system uncertainties. This work explored trade-off strategies to improve the reliability and computational speed which influence the planning and operation of future hybrid power grids.

Marpaung et al. [10] present a power generation technology based on a solid-state thermos electric strategy to generate electrical energy from a low-temperature geothermal-based heat source. The aim of this work is to design, operate and test a small-scale, portable power generation system which can produce power by using a heat source with a low-temperature steam or water phase. The various parameters utilized for developing this device are electric voltage and current, hot- and cold-side temperatures, load resistance and measurement time. The proposed device can act as an alternative to renewable energy and can be operated to produce stable power.

Gomez-Redondo et al. [11] analyse and present a comparative review of an AC microgrid. This work focused on reviewing the standard grid connection methods that are applicable to microgrids and control schemes. AC microgrids utilize hierarchical control systems to provide grid-connected and islanded modes of operation. With the recent advancements in battery technologies and the increasing popularity of DC loads with solar PV systems, the future adoption of hybrid microgrids is a promising solution. This work also presents an experimental setup with parallel inverters as a control scheme for testing fault detection techniques.

2. Conclusions

In recent years, the integration of renewable-based distributed energy resources (DERs), such as wind turbines, solar photovoltaic (PV) units, and electric vehicles (EVs), is growing rapidly, as these technologies have substantial advantages. Energy storage systems (ESSs) can be considered the optimal solution for facilitating renewable power and EV integration. Renewable energy resources (RERs), ESSs, and EVs are becoming increasingly popular, as they are environmentally friendlier and more sustainable. Future advancements and the continually advancement of EV technology may lead to the development of EVs with longer driving ranges with dynamic or single-charge options. The purpose of this collection, "Smart Energy System Design", is to provide a comprehensive overview of smart energy system design; the latest advancements, opportunities, challenges, and potential applications of energy storage; renewable energy; EVs; big data; artificial intelligence; internet of things; and machine learning technologies. All of the manuscripts reviewed in this Editorial Board Collection series are of practical importance for the development of smart energy systems.

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