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Editorial

Solar Power System Planning and Design

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Received: 20 December 2019; Accepted: 2 January 2020; Published: 3 January 2020

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1. Introduction

With growing concerns about greenhouse gas emissions, the security of conventional energy supplies, and the environmental safety of conventional energy production techniques, renewable energy systems are becoming increasingly important and are receiving much political attention [1]. Photovoltaic (PV) and concentrated solar power (CSP) systems for the conversion of solar energy into electricity are—in particular—technologically robust, scalable, and geographically dispersed, and they possess enormous potential as sustainable energy sources [2]. Despite the advances in PV and CSP systems, inappropriate planning and design could impede the extensive penetration of solar energy. Systematic planning and design considering various factors and constraints are necessary to deploy PV and CSP systems successfully [3].

This Special Issue on solar power system planning and design includes 14 publications from esteemed research groups worldwide. The research and review papers in this Special Issue fit in the following broad categories: resource assessment, site evaluation, system design, performance assessment, and feasibility study.

2. Resource Assessment

Solar radiation is the most important parameter to be considered when installing PV or CSP systems. Therefore, it is necessary to assess solar resources by analyzing and forecasting the spatiotemporal distribution of solar irradiance. Wang et al. [4] proposed an improved deep learning model based on discrete wavelet transformation (DWT), convolutional neural network (CNN), and long short-term memory (LSTM) for day-ahead solar irradiance forecasting. In the case study—which used two datasets from the Elizabeth City State University and Desert Rock Station in the United States—the performance of the proposed model, named DWT–CNN–LSTM, was compared with six other solar irradiance forecasting models. The results showed that DWT–CNN–LSTM is highly superior for solar irradiance forecasting, especially under extreme weather conditions.

Analyzing sky dynamics by processing a set of images of the sky dome is a new trend for solar resource assessment [5,6]. Valentín et al. [5] proposed a methodology based on implementing several image processing techniques to achieve a robust and automatic detection of the sun's position from a set of images acquired by a low-cost artificial vision system. The methodology could detect the position of the sun not only on clear but also on cloudy days, even if the sun was completely occluded. Richardson et al. [6] validated the all-sky imager technology using data obtained from three geographically diverse locations: in Golden, Colorado on the rooftop of the Energy Systems Integration Facility (ESIF) building at the National Renewable Energy Laboratory (NREL); in San Antonio, Texas at the CPS Energy microgrid facility of the Joint Base San Antonio (JBSA) and the Engineering Building of University of Texas at San Antonio (UTSA); and in the Canary Islands, Spain at Tenerife and Caleta de Sebo. The operations at the three locations provided several improvements to the UTSA SkyImager regarding weatherproofing techniques, environmental sensors, maintenance schedules, and optimal deployment locations.

Choi et al. [3] reviewed geographic information system (GIS)-based studies on solar resource assessments, especially for solar radiation mapping. GIS is beneficial for spatial and temporal analyses of solar resources while implementing location-specific technologies. The solar radiation analysis can be performed for individual points such as stations and for large areas represented by many pixels. The GIS analysis could also be conducted for specific administrative districts.

3. Site Evaluation

It is necessary to increase the effectiveness of installing solar power plants by prioritizing and selecting suitable locations to maximize electricity generation and minimize the damage that may occur. The results of such site evaluation can help solar utility companies, energy companies, and policymakers select potential sites for the construction of solar power plants [3].

Chen et al. [7] proposed an evaluation model of demand-side energy resources (DSER) for urban power grids based on geographic information. The commonality and individuality indices for five kinds of DSER, revolving wind power generation, photovoltaic power generation, electric vehicles, energy storage, and flexible load, were selected based on geographic information. Then, the weight of each sub-index of the commonality and individuality indices was determined by the analytic hierarchy process (AHP) and entropy weight method. Finally, the weighted overlay was generated according to the weights and quantized values of each index, and a comprehensive score was obtained from the commonality indices. The results depicted that the evaluation model is beneficial for the planning of the city and the power grid.

The installation of PV panels on the ground can cause some problems, especially in countries where there is not enough space for installation. As an alternative, floating PV, with advantages in efficiency and for the environment, attracted attention. Kim et al. [8] analyzed the water-level data from 3401 reservoirs in South Korea and selected suitable reservoirs for floating PV systems, with an average reservoir water depth greater than 5 m and minimum water depth greater than 1 m. The results were utilized to estimate priorities and potentiality prior to the actual floating PV installation and detailed analysis.

GIS is useful for site evaluations when installing solar power plants for PV or CSP on the regional scale. Choi et al. [3] reviewed the GIS-based methods for determining suitable locations for solar power plants. In most site evaluation studies, solar radiation is the primary consideration. However, it is also necessary to consider economic, environmental, technical, social, and risk factors. These factors can be used to exclude unsuitable regions through a Boolean overlay and can be employed in various multiple-criteria decision analysis (MCDA) methods to estimate suitability indices [3].

4. System Design

Before installing a solar power system, it is crucial to ensure that the system is not over- or undersized. Therefore, the designer should investigate the viability of the system carefully to operate in optimum conditions regarding produced unit costs and power reliability. Alsadi and Khatib [9] reviewed the sizing procedures of grid-connected and standalone PV systems, including system component modeling, available optimization software, optimization criteria, optimization methods, and sizing constraints. The study revealed that PV modeling and battery modeling are essential in system sizing optimization to predict the systems' performances.

The performance of a PV system depends significantly on the tilt angle of the PV panels. Chou et al. [10] conducted a wind-load analysis using wind tunnel experiments and numerical simulations for a stand-alone panel at high tilt angles. The effects of wind direction were also investigated. The findings of this study will be useful for the detailed structural design of offshore PV panels.

5. Performance Assessment

Chamkha and Selimefendigil [11] performed a numerical analysis of a photovoltaic–thermal (PV/T) unit with SiO_2–water nanofluid. The coupled heat conduction equations for the layers and convective heat transfer equations for the channel of the module were solved using the finite volume method. The effects of various particle shapes, solid volume fractions, water inlet temperature, solar irradiation, and wind speed on the thermal and PV efficiency of the unit were analyzed. The performance characteristics of the solar PV–thermal unit determined by the radial basis function artificial neural network were found to be in excellent agreement with the results obtained from computational fluid dynamics modeling.

Gulkowski et al. [12] carried out a comparative analysis of energy production by a grid-connected experimental PV system composed of various technology modules, which operates in the temperate-climate meteorological conditions of eastern Poland, for the year 2015. The study revealed that the copper indium gallium diselenide (CIGS) technology demonstrated the highest energy production and performance ratio, as well as the lowest observed temperature-related losses. These results can be useful for the prediction of electric energy production by different PV technologies at high latitudes under temperate climate conditions.

Rouibah et al. [13] determined the performance and viability of direct normal irradiation for three solar tower power plants to be installed in the Algerian highlands and the Sahara (Béchar, El Oued, and Djelfa regions). Each plant, with the annual production specification of 20 MW, is equipped with a supply of molten salt, an external receiver, and a field of heliostats. Results showed that there is a strong and direct relationship between the solar multiple, power generation, and storage capacity hours.

Machine learning methods were successfully applied in PV output prediction models. Xie et al. [14] proposed a hybrid short-term forecasting method based on the variational mode decomposition (VMD) technique, the deep belief network (DBN), and the auto-regressive moving average (ARMA) model to improve forecasting accuracy. The results showed that the hybrid forecasting method offers better accuracy and stability than the single prediction methods. Additionally, Mei et al. [15] developed an ultrashort-term forecasting model based on the phase space reconstruction and deep neural network (DNN) by considering the characteristics of the net load. The performance of this model was verified using real data, with superior accuracy in forecasting the net load under high PV penetration rates and different weather conditions.

Solar potential assessment using GIS can be placed in three different categories: (1) physical potential, which is the total amount of solar energy reaching a target surface or the total solar radiation on a surface or rooftop; (2) geographic potential, which is the spatial availability of a surface or building rooftop where solar energy can be obtained; and (3) technical potential, which represents the total amount of electricity considering the technical characteristics of the PV system. Choi et al. [3] reviewed 39 published articles on GIS-based solar potential assessment.

6. Feasibility Study

Within the agriculture sector, current solutions for groundwater pumping are primarily based on diesel technologies, with remarkable fossil-fuel dependence and emissions that must be reduced to fulfill both energy and environmental requirements. The integration of PV power plants into groundwater pumping installations was recently considered as a suitable alternative. Rubio-Aliaga et al. [16] presented a feasibility study with a multidimensional analysis of PV solar power systems connected to the grid as a groundwater pumping solution, including net-metering conditions and benefit estimations, in Castilla-La Mancha (Spain). Different surplus energy sale scenarios were analyzed based on crops typical in this location, the corresponding annual water requirements, and common grouping areas. The study found that PV power plants connected to the grid for the use of surplus energy could generate non-negligible global revenues: 10–18 million €/year with legislation promoting net-metering and 5–10 million €/year under the current legislation framework in Spain.

Funding: This work was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2018R1D1A1A09083947).

Acknowledgments: This Special Issue would not have been possible without the contributions of professional authors and reviewers and the excellent editorial team of Applied Sciences.

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

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