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Editorial

Advanced Analytics in Renewable Energy

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1. Introduction

This Special Issue, entitled "Advanced Analytics in Renewable Energy", covers research in this field and shows how to apply it to many different professional areas, e.g., engineering and management. Each paper in this Special Issue is contributed by a different author from across the world and covers a different area of analytics applied to renewable energy. This Special Issue connects the analytic principles with business practice and provides an interface between the main disciplines of engineering/technology and the organizational, administrative, and planning abilities of management in renewable energy. It also refers to other disciplines such as economy, finance, marketing, behavioral economics, and risk analysis. This Special Issue is of particular interest to researchers, engineers and economists who are developing new advances in analytics, but also to practitioners working on this subject.

2. Advanced Analytics in Renewable Energy

Rapid changes in electricity power markets have increased the production costs of coal-fired power plants and pushed their production to the limits of profitability. For power plants currently in operation, a possible approach to cope with this issue is to introduce novel methods that increase the plant's reliability and availability. Coal mills are a subsystem that should ensure a plant's availability without unexpected breakdowns. Remediation-based maintenance is defined as a set of actions performed after fault detection that do not require instant shutdown due to safety reasons [1]. The aim of paper [2] was to provide a scientific confirmation that by implementing a novel remediation-based maintenance strategy, electricity production breakdowns can be significantly reduced. First, the performance of the proposed maintenance method was proved in a simulation where coal mills were modeled by generalized stochastic Petri nets. The maintenance strategy was then experimentally verified in a 220 MW coal-fired power plant located in Croatia, where the plant's availability, reliability and efficiency were increased.

Diversifying the energy mix of Bangladesh is becoming indispensable not only to improve its energy security, but also for more sustainable economic development. Paper [3] focused on mapping the wind potential of the southern coastal areas of Bangladesh to estimate the wind energy potential, along with the reduction in carbon emissions due to wind energy. Analysis of the carbon footprint was based on the annual energy production (AEP) from the selected low-wind turbine generators (WTGs). The time series-measured and -predicted wind data were incorporated with the high-resolution mesoscale and microscale wind resource mapping technique at 60, 80, and 100 m above ground level (AGL). Coupling mesoscale and microscale modeling provided reliable mapping results for the commercially exploitable wind resources and was verified by ground-based wind measurements. The results reveal that, among the selected areas, two sites named Charfashion and Monpura have a promising annual mean wind speed of 7.3 m/s at 100 m AGL for energy generation. Different WTGs with ranges of 1–3.3 MW were used to estimate the wind energy generation capacity at different sites in the study area. A WTG with a 1 MW wind energy generation capacity installed at 60 m AGL in the selected site has the potential to produce

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2.79 GWh/year of clean energy, reducing the production of CO_2 by 1781.689 tons per year, whereas a 3.3 MW WTG at 80 m AGL can produce 18.99 GWh/year of energy, reducing CO_2 production by 12,098.54 tons per year, and a 1.6 MW WTG at 100 m AGL produces 11.04 GWh/year of energy, cutting CO_2 production by 7035.028 tons per year. With its reliable scientific and time-tested wind energy estimation method, this research is very important for the development of wind energy in the southern coastal areas of Bangladesh to meet the increasing energy demands through initiating the development of renewable energy to improve the energy security and reduce the carbon emissions of the country.

The integrated electricity and heating system (IEHS) can satisfy the diversified energy demand and improve energy efficiency through electro-thermal synergy and complementarity, which is beneficial for energy transformation and global climate governance. To reduce the operation cost, renewable energy source (RES) abandonment, and purchased electricity of IEHS, an optimal dispatching method of IEHS with multiple functional areas considering the flow regulation of the heat network is proposed in paper [4] Firstly, the functional area of IEHS is classified and the functional area's load characteristics are analyzed. Secondly, a heat network model considering refined resistance and dynamic characteristics is constructed and the operation regulation modes of the heat network are analyzed. Thirdly, an optimal dispatching model of IEHS with multiple functional areas considering heat network flow regulation is established to minimize the operation cost of IEHS with multiple functional areas while considering the penalty cost of RES abandonment and the time-of-use electricity price. Finally, a certain region in China is taken as a case study to verify the effectiveness of the proposed optimal dispatching model. The case study shows that the quality regulation mode of the heat network considering flow change in multiple stages can effectively reduce RES abandonment by 2.4%, purchased electricity by 5.4%, and the system operation cost by 1.7%. In addition, compared with the independent dispatching of each functional area, the joint dispatching of IEHS with multiple functional areas can reduce the amount of RES abandonment by 95.2% and purchased electricity by 66.5%, and lower the operation cost of IEHS by 23.6%.

Paper [5] employs the multiple random feature kernel mean p-power algorithm (MRFKMP) for the voltage source converter (VSC) control of a three-phase four-wire grid-tied dual-stage photovoltaic-hybrid energy storage system (HESS) to achieve multiple objectives during various induced dynamic conditions. The proposed control enables the VSC to accomplish manifold goals, i.e., reactive power compensation, power quality enhancement, load, power balancing at a common coupling point and grid voltage balancing during unity power factor mode of operation. The proposed system is scrutinized under steady-state and numerous dynamic states such as irradiation variation, a specified power mode, abnormal grid voltage, load, and grid voltage unbalancing. The seamless control facilitates the swift resynchronization of the grid as well as maintaining stability during islanding and re-synchronization operations while satisfying the necessary load requirements. The associated HESS, consisting of a battery and an ultra-capacitor, is competent enough in managing the interruptions occurring on the grid, load and photovoltaic side. The DC bus voltage is controlled by the PI controller, which is tuned by the generalized normal distribution algorithm and kept at the desired level during diverse operating conditions. The optimized DC bus generates an accurate loss component of current and further enhances the VSC performance. The proposed system is investigated by simulation and found to be acceptable as per the IEEE 519 standards.

Typhoons and other natural disasters affect the normal operation of power systems, and thus it is an important goal for strong and intelligent power grid construction to improve the ability of power systems to resist typhoons and other natural disasters. In particular, an effective coordinated and optimized dispatching strategy for a multi-source power system is very helpful to cope with the impact of typhoons and other natural disasters on power system operation. Given this background, a typhoon wind circle model considering the temporal and spatial distribution of typhoons is established in paper [6] to obtain the input wind speed of the wind farm at first. Second, based on

the initial input wind speed of wind farms, a typical scenario set of wind power output is constructed to reflect its fluctuation and uncertainty. Next, an optimal coordinated dispatching model of a multi-source power system with wind, hydro and thermal power based on the conditional value at risk (CVaR) is established with the target of minimizing the total cost of system dispatching, in which a 72 h pre-dispatching mode is studied to optimize the system operation for 72 h on the day before, on and after the typhoon. Finally, a revised 24-node transmission network system in a coastal area with a typhoon serves as a case for demonstrating the effectiveness of the proposed model, and the simulation result shows that the proposed model can take advantage of the coordination and complementarity of the multi-source power system and decrease the total cost of system dispatching and improve the renewable energy consumption level.

Paper [7] provides a techno-financial evaluation of two sites in Malaysia: Kudat, located on the coast of the northernmost part of Sabah, the state of East Malaysia with promising wind potential, and Putrajaya in the Klang Valley region, with moderate wind potential at high elevations, similar to the dominant cities in Malaysia. Three small-scale wind turbines are evaluated, taking into account a nominal electrical power generation below 100 kW. The research is focused on 220 residential households. The software used to perform the evaluation is Hybrid Optimization of Multiple Energy Resources (HOMER). The research novelty is the examination of the non-hybrid small-scale turbines at high elevations for regions with low wind speed such as Malaysia. Regardless of the wind farms' financial profit, this study used net present cost (NPC) analysis in all cases. This research demonstrates the feasibility of small-scale wind turbines mounted at high elevations for generating sufficient energy. The results indicate that in both areas, the RX-20KH3 model is the best option, and the costs of the FH-5000 and RX-20KH3 farms are proportionate for a renewable project. Furthermore, with government support, the WES80 farm could be suitable.

In paper [8], the optimal decision-making process in photovoltaic (PV) system location selection in Saudi Arabia is described. First, to identify the criteria that influence the decision of selecting a suitable location for the PV system, the geographical information system (GIS)-based multi-criteria decision making (MCDM) approach is used. Next, to assess the weights of the criteria that present different aspects of the investigated locations, 4 major criteria and 11 sub-criteria are proposed, and the analytic hierarchy process (AHP) is applied to develop a comparison decision matrix. Finally, the order preference by similarity to ideal solution (TOPSIS) technique evaluates and classifies 17 cities (such as Riyadh and Jeddah) in Saudi Arabia. The result shows that Tabuk city in the north of Saudi Arabia is the best location. Among the 17 cities, the performance score of seven cities is above or equal to 80%, and Tabuk city has the highest score with 87%. This analytical approach could contribute as an early planning to locate suitable sites for the selection of a PV system region in Saudi Arabia.

Studies about the importance of renewable energy resources, including wind and solar energy, are becoming increasingly important [9]; however, these energy sources are unstable and volatile in nature, and are usually integrated with conventional energy sources, such as hydropower, forming hybrid power generation systems that maintain a stable grid. Short-term changes in wind speed or solar radiation intensity have a great impact on the stability of hybrid systems, and have been reported in the literature. However, reliable models to manage such systems are lacking, and previous studies have regarded the hour scale as the minimum baseline for systematic change [10]. In paper [11], hybrid power systems are proposed that are controlled on very short time intervals. The results of a feasibility analysis of the proposed model indicate the viability of complementary hybrid systems in controlling and maintaining the stability, which are subjected to short durations of fluctuations in wind or solar radiation. The simulation results indicate that the influence of the shutdown of the wind turbine, with the regulation effect of the hydro power, is three to five times greater than that of the short-term wind turbulence fluctuation. When the hydro turbine is adopted to adjust the short-term fluctuation of solar radiation, the effect on the system was suppressed to 0.02–0.2 times that of the former.

Clean and renewable energy is developing to realize the sustainable utilization of energy and the harmonious development of the economy and society. Microgrids are a key technique for applying clean and renewable energy. The operation optimization of microgrids has become an important research field [12]. Paper [13] reviews the developments in the operation optimization of microgrids. The authors first summarize the system structure and provide a typical system structure, which includes an energy generation system, an energy distribution system, an energy storage system and energy end users. Then, they summarize the optimization framework for microgrid operation, which contains the optimization objective, decision variables and constraints. Next, the paper systematically reviews the optimization algorithms for microgrid operations, of which genetic algorithms and simulated annealing algorithms are the most commonly used. Lastly, literature bibliometric analysis is provided; the results show that the operation optimization of microgrids has received increasing attention in recent years, and developing countries have shown more interest in this field than developed countries have. Finally, the authors highlight future research challenges for the optimization of the operation of microgrids.

3. Future Works

Despite the closure of this Special Issue, a thorough investigation on the issues related to advanced analytics in renewable energy is expected in the near future. Thereby, achievements relating to advances in advanced analytics in renewable energy pose ongoing challenges to the research community.

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