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Editorial: Control, operation, and trading strategies for intermittent renewable energy in smart grids

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Editorial on the Research Topic
Control, operation and trading strategies of intermittent renewable energy in smart grids

1 Introduction

To achieve the goal of carbon neutrality and resolve the Research Topic of the global energy crisis, large numbers of intermittent renewable energy sources, such as wind turbines and photovoltaic generators, have been widely installed in modern power grids (Van Soest et al., 2021). The stochastic nature of renewable energy production has raised significant reliability concerns and brought about significant financial risks for various decision-makers, and the use of power electronic devices in renewable energy integration also poses major challenges for power system control and operation (AlAshery et al., 2019). To mitigate the uncertainties caused by intermittent production of renewable energy, it is necessary to utilize resources and approaches promoting flexibility, such as battery storage and price-responsive demand, to explore novel market mechanisms at both wholesale and retail levels, and to investigate advanced modeling and optimization techniques (Jin et al., 2018).

The major challenges in the control, operation, and trading of intermittent renewable energy resources in smart grids are the uncertainties and complexities inherent in the power transmission, distribution, and consumption processes (Bevrani et al., 2010). Moreover, given the worldwide backdrop of power industry deregulation, decision-makers in the domain of intermittent renewables also need to consider volatile electricity prices in retail and wholesale markets, as well as the random behaviors of other strategic participants. Under these circumstances, it is necessary to develop advanced control, operational, and trading strategies for intermittent renewable energy resources based on state-of-the-art smart grid technologies.

This Research Topic reports on the latest advances in the area of control, operation, and trading of intermittent renewable energy resources in smart grids to resolve potential difficulties and challenges; more forty articles related to this area have been published. As shown in Figure 1, accurate forecasting and modeling methods could provide a foundation in the form of

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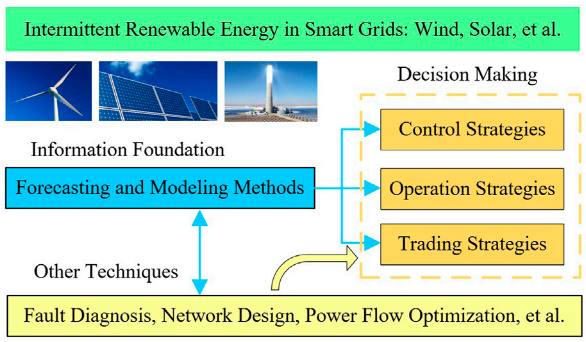

FIGURE 1
Overall framework of techniques for the integration of intermittent renewable energy sources into smart grids.

reliable information for the control, operation, and trading of intermittent renewable energy resources. Additionally, various other techniques, such as fault diagnosis, network design, and power flow optimization, could also increase stability and the economic efficiency of decision-making in power grids with significant dependence on renewable energy. Considering these issues, the articles published under this Research Topic can be divided into five categories: forecasting and modeling methods, control strategies, operational strategies, trading strategies, and other techniques.

2 Forecasting and modeling methods

With the rapid development of renewable energy sources, such as wind and solar power, accurate prediction of the output of these weather-sensitive renewable energy sources has become increasingly important. Huang et al. propose a novel direct method for deterministic and probabilistic wind speed forecasting based on an explainable neural network; they also verify its feasibility and effectiveness using data from real wind farms in Belgium, which indicates that the method has strong potential for practical applications in real electrical power and energy systems. Xu et al. develop a simplified average model of a large photovoltaic power station for electromagnetic transient analysis, considering high- and low-voltage fault ride-through, and verify the accuracy and effectiveness of the proposed model by carrying out simulation studies. Kang et al. develop a solar irradiance prediction method based on deep learning, namely the Feature-enhanced Gated Recurrent Unit, which does not require auxiliary data, but only time series data on solar irradiance; they report that, based on samples of solar irradiance data in Lyon, France, their model offers better predictions than a baseline model.

3 Control strategies

Since renewable energy systems rely primarily on power electronics converters to connect to the power network, these replace traditional generator units relying on a large rotating axis to provide inertia support. This means a reduction in the overall inertia of the power system, which poses challenges for maintaining stable control of the system. Chu et al. propose an integrated control strategy based on active support, which can achieve grid connection stability for voltage source converters used in renewable energy generation. Wang et al. develop a control strategy based on active support of renewable energy sources, which can provide VSC-based renewable energy units with similar levels of inertia support to those achieved with traditional synchronous generators. Wen et al. propose a voltage compensation-based two-level hierarchical adaptive control strategy for power systems employing large-scale wind power generation, which can mitigate the loss of transient stability caused by the use of a modular multilevel converter. Li et al. present a perturbation observer-based robust non-linear damping control scheme for a doubly fed induction generator–based wind farm, enabling damping of the inter-area oscillations of multi-area power systems. Wen et al. propose a control strategy for PV grid-connected inverters, based on the model predictive control algorithm, that can overcome the issues arising from frequent power oscillations in the system. To enhance the resilience of the power grid, Shi et al. propose a generation rescheduling scheme based on optimal emergency control that considers the risk-based dynamic security constraint and reactive power constraints. Zhao et al. propose a droop-based active voltage control strategy for VSCs in large-scale RES-integrated power systems, which may enable VSCs to continue to operate and regulate the voltage at the point of common coupling during a fault without causing overcurrent. Xie et al. develop a high-precision bus voltage control strategy based on extended state observation, load current estimation, and grid voltage differential feedforward. Finally, Qian et al. develop an adaptive droop control strategy in which the control variables are the voltage references and droop coefficients of the modular multilevel converters, and a multiple-objective particle swarm optimization method is applied to solve the problem and compute the Pareto frontier.

4 Operation strategies

Intermittent renewable energy resources pose a major challenge to the safe, stable, and efficient operation of power grids, which increases the complexities of developing operating strategies for various players. Li et al. propose a stochastic hydro unit commitment model for a price-taker hydropower producer in a liberalized market with the objective of maximizing total revenue. Qin et al. establish an optimal configuration model for an active distribution network to ensure the stable and continuous operation of a grid involving multiple types of energy. Wang et al. establish a master–slave game bilevel optimization model considering the relationship between the power company and the park-integrated energy system user, in which the output uncertainty of renewable energy in the park is handled by adjustable robust optimization. Du et al. establish a system for bi-level co-expansion planning in integrated electricity and heating systems, considering demand response, which can minimize expenses on both the investment and operational levels. Yang et al. propose a methodology combining the multi-dimensional firefly algorithm with local search, referred to as LS-MFA, to solve the UC problem; the success of the proposed method is proven *via* experimental studies considering 10 machines over multiple 24-h periods. Xue et al. establish a coordinated economic dispatch strategy for primary and secondary heating systems, considering supplemental heat from the boiler. Zhang et al. perform a simulation and economic analysis of a high-temperature heat storage system for a thermal power plant and discuss the principle of solid heat storage technology. In order to meet the needs of users connected with renewable energy, Xue et al. construct an integrated energy system using a two-layer optimization method for operational strategy development and capacity allocation in the integrated energy system; the optimization results obtained *via* the proposed methods are compared with those obtained *via* a traditional energy supply system, with the findings indicating that the proposed methods can achieve the lowest costs in terms of system investment while satisfying the reliability and safety constraints. Ye et al. adopt a simulation approach in order to take EVs into account in the domain of demand-side uncertainty, which can significantly improve the efficiency of multi-energy dispatching. Finally, Shen et al. propose novel methods to determine the optimal capacity configuration of a hybrid energy storage system; this approach combines ensemble empirical mode decomposition and empirical mode decomposition.

5 Trading strategies

With the goal of facilitating coordination between the carbon and electricity markets and achieving carbon reduction goals, Yang et al. develop a cooperative trading strategy for carbon-emitting power generation units participating in carbon and electricity markets; in doing so, they explore the process of interaction between electricity prices and carbon prices. Duan et al. investigate a multi-stage robust clearing model, considering renewable energy output uncertainty, and propose an effective reserve calculation method for engineering implementation in order to calculate unit reservations efficiently without breaking the security constraints. As an approach to handling the challenges inherent in the Energy Internet (EI), Wang et al. adopt a blockchain perspective for the design of an analysis framework for EI technology that consists of five dimensions. Game theory offers significant insight in the study of decision optimization among multiple decision-making bodies; against this backdrop, Huang et al. conduct a critical survey on applications of game theory in the electricity market and renewable energy trading. Finally, in order to facilitate large-scale wind power consumption in electricity markets, He et al. establish a detailed demand response (DR) model that includes price-based DR and incentive-based DR, where incentive-based DR includes load shifting and load curtailment; their simulation results indicate that the proposed trading method can make effective use of wind power and reduce system costs.

6 Other techniques

Transformers play a crucial function from generation to consumption in linking renewable energy with energy from other sources; Wang et al. present a unified framework of intelligent algorithms for the assessment of transformer conditions. Dissolved gas analysis is an effective technique for the diagnosis of early faults in oil-immersed transformers. Zhang et al. present a review on the application of artificial intelligence techniques for DGA-based diagnosis and for computing solutions to intractable problems in early transformer fault diagnosis. Lyu et al. design a method to reduce the computational complexity of the extraction process and improve the computational efficiency of the relevant power flow algorithm. Zhang et al. present a variable weight synthesizing assessment model that combines the G1 method with the entropy weight method. Liang et al. study a smart sensing network edge computing model in the context of the ubiquitous power Internet of Things, presenting an improved multi-node-cluster strategy for optimization of cooperative scheduling. False data injection attacks commonly target smart grids; Aziz et al. analyze six hybrid supervised learning techniques for the detection of such attacks, using six different boosting and feature-selection methodologies. Zheng et al. design an optimal reconfiguration strategy for thermoelectric power generation systems under heterogeneous temperature difference conditions based on a particle swarm optimization algorithm. Information security plays an indispensable role in smart grids, and Kou et al. focus on encryption techniques that can ensure information security is maintained. Tian et al. propose a steady-state information method for fault line selection in small current grounding systems; their method is based on Optimization Spiking Neural P Systems. Based on the end-to-end learning paradigm, Ye et al. propose an intelligent method for the detection of substation insulator defects. Bushings are indispensable components in high-voltage direct current transmission systems; Teng et al. investigate the influence of HVDC bushing insulation properties on the distribution of electro-thermal coupling fields. With the goal of improving power quality and reliability in smart grids for sensitive industrial loads, Zhang et al. explore new design methods for correcting unbalanced power distribution networks. Separately, Zhang et al. propose a bald eagle search algorithm for optimal reconfiguration of centralized thermoelectric generation arrays. Elshenawy et al. propose a system of two interconnected AC microgrids based on three renewable energy sources, namely wind, solar, and biogas energy. Yang et al. propose a distributed topology recognition method that is fault-tolerant to measurement failures. Zhao et al. present a dynamic frequency response-constrained optimal power flow model that can be used to quantitatively evaluate the frequency stability margin during a primary frequency control period following an under-frequency event. With the objective of improving the resilience of power systems, Mei et al. propose a mixed-integer linear programming model with network connectivity constraints for a minimum backbone grid.

7 Conclusion

In summary, various types of research article relating to the implementation of renewable energy in smart grids have been published under this Research Topic. Control and operational strategies are investigated in 21 articles, meaning that more attention has been paid to these areas of research compared with others. Moreover, various players and applications involved in the control, operation, and trading of renewable energy resources have been investigated in detail; these investigations will contribute to the development of the next-generation low-carbon smart grid.

Author contributions

DX drafted the editorial. BC, ZL, XF, CW and DL revised the editorial and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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