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Editorial: Power system operation and optimization considering high penetration of renewable energy

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Editorial on the Research Topic
Power system operation and optimization considering high penetration of renewable energy

As the global energy landscape undergoes a transformative shift towards sustainability, the integration of renewable energy sources (RES) into power systems has become a pivotal imperative. The high penetration of RES, characterized by their intermittency and unpredictability, introduces a myriad of challenges to the traditional operation and optimization paradigms of power systems. In this Research Topic, we have curated a Research Topic of original research articles that delve into the complexities and propose innovative solutions for the operation and optimization of power systems in the context of high RES penetration.

Yu et al. initiate our exploration by presenting a carbon metering method for distribution networks that accounts for harmonic influences. Recognizing the increased consumption of power equipment and the questioning of carbon measurement accuracy due to harmonics, their research underscores the necessity for accurate carbon verification in the face of distorted power quality. This work is crucial for the establishment of a fair carbon trading market and the construction of precise carbon verification systems.

Zhou et al. further the discourse by introducing a time-synchronized carbon flow metering scheme for electric power transmission, transformation, and distribution networks. Their study elucidates the impact of time deviation on carbon metering, proposing a satellite synchronization method to enhance the accuracy of carbon flow allocation and measurement. This contribution is vital for future research ideas and technical routes that aim to achieve more precise carbon accounting in power systems.

Dai et al. shift the focus to the prediction challenges posed by distributed photovoltaic (PV) generation systems. They propose a spatio-temporal prediction method based on a deep learning neural network model, demonstrating higher prediction accuracy through the CNN-LSTM approach. This method is particularly significant for enhancing PV power generation technology and optimizing energy structure amidst environmental concerns.

Li et al. address the operational challenges in power systems caused by the increasing penetration of intermittent renewable energy. They propose a multi-regional interconnected transmission network optimization method based on the analytical

target cascading (ATC) approach. This method not only tackles the coupling nonlinear problems effectively but also promotes the consumption of renewable energy, offering a robust solution for complex transmission network optimization.

In the realm of energy storage systems, Sun et al. propose a switching control strategy based on multi-level logic judgment. Their research aims to improve the utilization rate and economic benefits of energy storage systems, ensuring safe and stable operation of power grids. This strategy is particularly relevant for power systems with high proportions of renewable energy integration, where energy storage plays a critical role in maintaining grid stability.

Zhang et al. present a novel phasor measurement method that utilizes soft synchronization with temporal pulse signals. Their software-based approach offers a simpler and cost-effective alternative to traditional hardware-based phasor measurement units (PMUs), advancing the practices of synchronized phasor measurement in power grid monitoring.

Shen et al. tackle the Research Topic of time delay in ancillary services of distribution photovoltaic generation systems. They propose a data-driven time-delay compensation strategy using the long short-term memory (LSTM) method, which significantly improves the frequency performance of PV ancillary services and demonstrates strong generalization ability for varying delay times.

Li et al. introduce a power system data-driven dispatch method that integrates an improved scenario generation model considering time-series correlations and "N-1" security. Their approach, which leverages a time-generative adversarial network (GAN), ensures the effective training of agents in handling "N-1" branch contingencies and addresses the limitations of traditional data-driven methods.

Xu et al. present a Stackelberg game-based three-stage optimal pricing and planning strategy for hybrid shared energy storage (HSES). Their model addresses the pricing and planning Research Topic for HSES operators, aiming to increase revenues in the context of new energy stations (NESs) facing the challenges of intermittency and volatility.

Chen and Chen develop a nonparametric probabilistic forecasting based stochastic scheduling approach for integrated electricity and gas systems (IEGS). Their method integrates the advantages of nonparametric probabilistic forecasting to address the randomness of wind power, establishing a stochastic optimal scheduling model that is efficient and reliable.

Wei et al. propose a novel multistage planning-operation model for HVDC-connected two-area systems. Their approach aims to unlock the potential flexibility in the HVDC transmission system and increase renewable penetration, offering a robust and non-anticipative solution to accommodate uncertainty in renewable generation.

Deng et al. construct a bi-layer wind-CCUS-battery expansion stochastic planning framework that considers a source-load bilateral carbon incentive mechanism based on the carbon emission flow theory. Their research provides a reference for the future carbon emission reduction path of the power system, particularly for the quantitative analysis of carbon emission reduction of CCUS.

Hua et al. introduce a smart home load scheduling system that integrates solar photovoltaic generation and demand response in smart grids. Their comprehensive demand response model, which includes an energy consumption scheduler (ECS), optimizes the operation of smart appliances using various optimization algorithms, enhancing the efficiency of smart home energy management.

Li et al. propose an adaptive ADMM-based entire-process distributed restoration method for transmission and distribution systems considering CVaR. Their method aims to maximize the total restoration benefits of TSs and DSs while addressing multiple uncertainties during the restoration process, ensuring faster convergence and higher restoration benefits.

Ye et al. present a novel robust optimization method for new distribution systems based on adaptive data-driven polyhedral sets. Their approach reduces conservatism and enhances the robustness of optimization results in the face of renewable energy output uncertainty.

Xiao et al. explore the strategic behavior of renewable energy companies equipped with private energy storage (ES) systems in market competition. They introduce a bilevel strategic behavior model to examine the impacts of strategic pricing and constraints on market equilibria, revealing the potential widespread adoption of strategic constraints among RE companies.

Hu et al. propose a service scheduling strategy for microservice and heterogeneous multi-cores-based edge computing apparatus in smart grids with high renewable energy penetration. Their strategy addresses the challenges of service scheduling for edge computing apparatus (ECA), ensuring efficient utilization of computing resources and reduced service response time.

Ai et al. introduce a novel flexibility assessment model for power grids with high renewable energy penetration. Their study addresses the uncertainty associated with wind and PV, proposing an improved cohesive hierarchical cluster analysis method and developing models for flexibility resources and demands.

Luo et al. present a dynamic reconfiguration model and method for load balancing in the snow-shaped distribution network (SDN). Their strategy considers distributed generators (DGs) and an energy storage system (ESS) to mitigate load unbalanced conditions and reduce active power loss.

Du et al. introduce a data-driven adaptive load frequency control (DD-ALFC) approach for isolated microgrids, proposing a priority replay soft actor critic (PR-SAC) algorithm to implement DD-ALFC. Their method achieves higher adaptability and robustness in complex microgrid environments, improving both frequency control and economic efficiency.

Cai et al. propose a two-stage low-carbon optimization scheduling method for power systems that considers demand response under multiple uncertainties. Their approach effectively reduces operating costs and carbon emissions while balancing the economic and environmental aspects of power system operation.

Wu et al. introduce an adaptive compound power quality disturbance (PQD) detection framework for renewable energy systems. They develop optimal mode decomposition (OMD) and an improved attention convolutional neural network (IACNN) to enhance the detection of PQDs, demonstrating high accuracy and real-time performance.

He et al. analyze and quantitatively evaluate the frequency support capabilities of wind turbines in power systems. Their

research focuses on the inertia support and primary frequency regulation capabilities of wind turbines, proposing key metrics to assess the transient frequency support capability.

Fu et al. propose a station-network cooperative planning method for urban integrated energy systems (UIES) based on an energy flow model. Their bi-level model optimizes the siting and sizing of energy stations and the topology of supply networks, with a solution method based on the Karush-Kuhn-Tucker condition.

Wang et al. present an optimal operation strategy for flexible interconnected distribution grids based on improved virtual synchronous control techniques. Their approach addresses the challenges posed by the randomness of distributed photovoltaic power, enhancing DC bus voltage stability and proposing power coordination optimization strategies.

In summary, this Research Topic provides a comprehensive examination of the challenges and opportunities in the operation and optimization of power systems with high RES penetration. The diverse research presented here offers innovative strategies and tools that are essential for the successful integration of renewable energy into the power grid, paving the way for a more sustainable and efficient energy future.

Author contributions

SL: Writing–original draft, Writing–review and editing. ZL: Writing–review and editing. YD: Writing–review and editing. JZ: Writing–review and editing.

Conflict of interest

Author SL was employed by State Grid Zhejiang Electric Power Co., Ltd.

The remaining 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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