Guest Editorial: Optimization, Control and AI Technology for Digital and Low-Carbon Power Systems

Modern power systems are facing a growing integration of distributed energy resources (DERs), mainly driven by energy transition, decarbonization and economic benefits. The deployment of Internet of Things devices transforms the conventional power system into a digitized, cyber, intelligent one, which plays a significant role in grid control and operation and enables numerous smart-grid applications.

The stochastic nature of distributed renewable power generation poses challenges for power system operation, while coordinating the dispatch and control of various DERs to reduce operating costs and carbon emissions is essential to improve energy utilization efficiency. Also, the large-scale connection of DERs increases the complexity of distribution networks, which requires more advanced and efficient approaches for system analysis, fault diagnosis and operational optimization. In this sense, smart monitoring and control systems can also be applied to transmission power networks, enhancing safety and robustness.

Energy Internet technology has laid a solid foundation for data-driven analysis, allowing power systems to enter a "data-intensive" era. Currently, huge amounts of data from various sources have been a driving force, enabling big data analytics and artificial intelligence on smart-grid applications such as planning, operation, energy management, trading, system reliability and resiliency enhancement, system identification and monitoring, fault intelligent perception and diagnosis, and cyber and physical security.

This Special Issue publishes state-of-the-art works related to all aspects of theories and methodologies in optimization, control and AI technology for digital and low-carbon power systems.

State Identification of Power Systems

The stochastic nature of distributed renewable generation makes the operation of power system face the challenge of uncertainty. Thereby, it is of great significance to monitor and identify the real-time state of the new power system. The paper 'The real-time state identification of the electricity-heat system based on borderline-SMOTE and XGBoost' by X. Pei et al. proposes a state identification method based on multi-class data equalization and extreme gradient boost for systems. The optimal hyperparameters of the model are obtained based on the K-fold cross-validation and grid search.

Promoting low-carbon power systems through gas-fired power plants

Reducing carbon emissions is one of the goals of modern power system operation. Power generation by natural gas, compared with that by coal, has the characteristics of cleanness, efficiency and low carbon. This makes gas-fired power plants popular for undertaking peak regulation tasks in the power systems. The paper 'Key problems of gas-fired power plants participating in peak load regulation: a review' by G. Wang et al. reviews the key problems faced by gas-fired power plants participating in peak load regulation. This paper provides suggestions for the coordinated development of electricity and carbon market in the future, which is of great significance for the low-carbon development of power system.

High precision time synchronization in power systems

In order to realize the low-carbon operation of the power system and improve the utilization rate of energy, it is necessary to meet the requirements of high-precision time synchronization in the power system. The paper 'Research on high precision synchronous output technology of multi-reference source weighted synthesis in power system' by L. Teng et al. presents a multi-reference source weighted improved noise model and the high precision output method. The synthesized frequency offset or the time precision of output can be optimized as the objective function by weighted classification algorithm and genetic algorithm.

Detection method to ensure power system against data attack

While ensuring the low-carbon operation of the power system, it is crucial to ensure the safe operation of the system, that is, not to be attacked by data. The paper 'Detecting smart meter false data attacks using hierarchical feature clustering and incentive weighted anomaly detection' by M. Higgins et al. outlines a methodology for detecting attacks on industrial load smart meters. This paper investigates how to improve corporate fraud detection in smart data through clustering and an incentive-weighted detection approach. The simulation results show that the model has a good detection rate. The paper points out that this model will be a useful 'future proofing' of the model for contemporary power systems.

Methods to reduce microgrid network security risks

Microgrid is a distributed energy system. Building a microgrid is one of the important ways to achieve low-carbon operation of the power system. The microgrid under study currently is accompanied by a significantly elevated network security risk. To solve this problem, the paper 'Self-supervised pre-training in PV systems via SCADA data' by Y. Wang et al. proposes a false data injection attack detection and alarm method based on active power output. The detection algorithm is capable of detecting attacks at any location within the microgrid and mitigating the impact of communication delay. The paper develops a simulation model to demonstrate the effectiveness of the proposed method.

Autonomous learning method of photovoltaic power generation data

The use of distributed energy can contribute to the low carbon operation of the power system. Photovoltaics (PV) can drive the development of distributed energy and a low-carbon energy transition. In terms of operation and intelligent maintenance of the PV system, the deficiency of labeled data poses a major challenge. The paper 'Distributed elastic recovery strategy of AC/DC hybrid microgrid under false data injection attack' by D. Wang et al. proposes a self-supervised pre-training approach for autonomous learning of the Supervisory Control and Data Acquisition (SCADA) data representations for PV systems. Through a comprehensive analysis of the raw SCADA data, the method proposed in this paper can achieve high-quality data representation learning without requiring any pre-labeling. The paper points out that the proposed approach can be applied to numerous downstream data-driven tasks in large-scale PV systems, which has important implications for promoting a low-carbon transition in power systems.

Fault detection method of power system

In power system, Fault detection is an important research field in low carbon operation. By identifying and solving faults in the power system in a timely manner, the reliability and efficiency of the system can be improved. In addition, energy waste and carbon emissions can be reduced, which can promote the sustainable development of the power system. The paper 'Learning the geometry of short-circuit faults in power systems for real-time fault detection and classification' by J. Naranjo et al. presents a technique to characterize different types of short circuit faults in a power system for real-time detection based on the geometry of the curve generated by the Clarke transform of the three-phase voltages of the power system. In this paper, the accuracy of the model was tested under different measurement conditions, yielding satisfactory results.

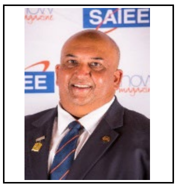
Quantitative analysis method of power substitution influencing factors

Power substitution is one of the means to realize the low-carbon operation of power system. The current research lacks a quantitative analysis method for the factors affecting electricity substitution. To expand the depth and breadth of electricity substitution, the paper 'Decomposition analysis on factors affecting electricity substitution in Guangdong province, China' by H. Chen et al. proposes a decomposition model of the factors affecting electricity substitution based on Logarithmic Mean Divisia Index method. The paper has certain reference significance for the development of new power systems.

Conclusion

The selected papers in this special issue cover a variety of new technologies to promote the low-carbon operation of the future power system, which can promote the safe, stable and low-carbon operation of the power system. In the future, the theories and methods of optimization, control and AI technology of new power systems can attract great interest to meet the challenges faced by power systems in terms of safe and stable operation.

Guest Editor Biographies



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