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Editorial: Data-driven situational awareness and decision making for smart grid operation

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Editorial on the Research Topic
Data-driven situational awareness and decision making for smart grid operation

1 Introduction

Recent advancements in information and communication technologies have greatly helped strengthen the capability of modern smart grids in online situational awareness and decision making against potentially risky/insecure conditions. In particular, the extensive configuration of various advanced sensing devices has enabled the Research Topic of massive operational information to improve the observability of the grids. With huge volumes of operational information available, emerging computational intelligence and machine learning technologies can be leveraged to augment the intelligence level of system-wide situational awareness and decision making, thereby making the grids smarter than ever before.

Considering the need for addressing challenges related to the above new trend, we thus launched this Research Topic to provide a worldwide platform that collects innovative works reporting recent advances in data-driven intelligent situational awareness and decision making for smart grid operation. After an extensive call-for-paper and peer-review process of more than 1 year, we have accepted 16 papers in total for publication. All the accepted papers have been categorized into two groups according to their subjects: 1) system dynamics awareness, control, and protection; and 2) system optimized dispatch, operation, and restoration. Specific highlights of each paper are summarized in the following.

2 Part I: system dynamics awareness, control, and protection

In the article "*Online correction of transient voltage security region boundary based on load parameter variations in power systems*", Zhang et al. proposed a data-driven transient

voltage security region (TVSR) estimation approach with the impact of composite load model and distributed photovoltaic (PV) power parameters. The relationship between TVSR boundary and load-leading parameters combination scenarios is further mined through the CatBoost learning framework. A more accurate TVSR boundary can be provided by this approach.

In the article "*Stator single-line-to-ground fault protection for powerformers based on HSGC and CNN*", Liu et al. proposed a novel single-line-to-ground fault protection framework with a convolutional neural network (CNN) and the hub-and-spoke grid data converting algorithm (HSGC). HSGC is applied to convert one-dimensional time series to two-dimensional grid-structured ones, and the CNN is trained to extract the features for fault identification. The scheme can accurately detect faulty powerformers.

In the article "*Improved unscented Kalman filter based interval dynamic state estimation of active distribution network considering uncertainty of photovoltaic and load*", Wu et al. proposed an interval dynamic state estimation (IDSE) approach for the interval state estimation of active distribution networks (ADNs) to handle the increasing penetration of distributed PV generations. Through the unscented Kalman filter method, the proposed approach is able to track the dynamic status of an ADN accurately.

In the article "*Deep learning model-transformer based wind power forecasting approach*", Huang et al. proposed a deep learning-based model transformer for wind power forecasting to address the uncertainty and fluctuation of large-scale penetrated wind power. By training a neural network architecture based on the attention mechanism, the wind power forecasting approach can provide more accurate results with better efficiency than other deep learning methods.

In the article "*A neural network-based adaptive power-sharing strategy for hybrid frame inverters in a microgrid*", Deng et al. proposed a novel microgrid framework with hybrid parallel-connected inverters, including capacitive-coupling inverters (CCIs) and inductive-coupling inverters (ICIs). An adaptive power sharing approach was further proposed to reduce power loss. Rapid and accurate power sharing can be achieved through a neural network-based control layer. Case studies and experimental results verified the efficacy of the proposed approach.

In the article "*Online prediction and control of post-fault transient stability based on PMU measurements and multi-task learning*", Liu et al. proposed an integrated approach for online transient stability prediction and real-time emergency control, in which the gated recurrent unit (GRU) based predictor is applied in post-disturbance transient stability prediction. The case study results show that the GRU-based predictor can provide accurate prediction results, and the control scheme can keep the synchronism of the power system.

In the article "*Enhancing transient stability of power systems using a resistive superconducting fault current limiter*", Alashqar et al. proposed a resistive superconduction fault current limiter (SFCL) to enhance the stability of interconnected power systems to address the weakness of existing approaches. The case study results show that the proposed approach is able to keep the stable operation of the power system without tuning power system stabilizers.

In the article "*Virtual inertia based hierarchical control scheme for distributed generations considering communication delay*", Zhou et al. proposed a virtual inertia-based hierarchical control scheme in which the impact of communication delay caused by distributed generations is considered. The proposed approach is validated to be effective through case studies with time delay considered.

3 Part II: system optimized dispatch, operation, and restoration

In the article "*Data-driven reliability evaluation of the integrated energy system considering optimal service restoration*", Dai et al. proposed a data-driven reliability improvement and evaluation method for integrated energy systems (IES) combining a three-state reliability model and an optimal service restoration model (OSR). The reliability model considers the transitional process and partial failure mode using the historical measurement data, while the OSR model determines the best repairment moment for minimizing the load curtailment.

In the article "*Robust dispatching model of active distribution network considering PV time-varying spatial correlation*", Ma et al. proposed a robust ADN dispatch model considering the dynamic spatial correlation and uncertainty of PV. The PV spatial correlation is described by a dynamic conditional correlation generalized autoregressive conditional heteroskedasticity model. The PV uncertainty is modeled by a time-varying ellipsoidal uncertainty set. A mixed integer robust program is constructed to realize the robust optimal dispatch.

In the article "*Adaptive robust economic dispatch and real-time control of distribution system considering controllable inverter air-conditioner clusters*", Chen and Liu proposed an adaptive robust economic dispatch (ARED) model and a real-time decentralized control strategy for distribution systems that utilize the adjustable capabilities of controllable inverter air-conditioner (IAC) clusters. The ARED model is solved by the constraint generation algorithm. The real-time control of IAC clusters is used to hedge against stochastic renewable fluctuation after every round of ARED decisions.

In the article "*Coordination of network reconfiguration and mobile energy storage system fleets to facilitate active distribution network restoration under forecast uncertainty*", Xu et al. proposed a coordinated network reconfiguration and mobile energy storage system (MESS) fleets dispatch model considering the renewable and load uncertainty to increase the ADN resilience after natural disasters. This framework consists of the uncertainty description by an ellipsoidal uncertainty set and a robust restoration model incorporating the MESS and network reconfiguration in the form of mixed-integer linear programming.

In the article "*Hosting capacity of distributed generation based on holomorphic embedding method in distribution networks*", Xie et al. proposed a DG hosting capacity assessment method based on a directional holomorphic embedding method that describes the voltage constraint region and judges DG hosting capacity under a single scenario. The cumulative distribution curve is statistically obtained using the Monte Carlo method, which represents the relationship between the level of voltage violation risk and DG hosting capacity.

In the article "*Transactive energy system: Concept, configuration, and mechanism*", Zhou et al. introduced the basic concept of a transactive energy system (TES). The TES configuration is described

from the perspectives of its physics, information, transaction, and regulation. The TES mechanism allows participants to conduct various transactions with any other party to the extent that regulatory policy permits. Finally, some challenges to the development of TESs are discussed.

In the article "*Accommodation capacity evaluation of renewable energy in power systems considering peak and frequency regulation*", Yu et al. proposed an evaluation method of renewable energy accommodation capacity (REAC) based on a source-network-storage interaction model. The deep peak regulation and frequency response of thermal power units are explicitly modeled and incorporated in the REAC evaluation.

In the article "*A data-driven hybrid interval reactive power optimization based on the security limits method and improved particle swarm optimization*", Chen et al. proposed a data-driven hybrid approach based on the security limits method (SLM) and the improved particle swarm optimization (IPSO) to solve the reactive power optimization with interval uncertainty. The historical data is processed to obtain the boundary of the optimal uncertainty set. In the optimization model, the continuous and discrete variables are alternately solved via SLM and IPSO.

4 Summary

The past few years have witnessed significant progress in the field of data-driven smart grid situational awareness and decision making. By soliciting the above research efforts, we have formed a paper Research Topic to report the state of the art in this field from two major aspects. Nonetheless, the high potential of data-driven technologies has not been thoroughly unlocked, especially the advancing artificial intelligence methods that could be sufficiently leveraged to systematically mine and discover knowledge from massive complicated operational scenarios of complex power grids. We hope this Research Topic can also play a crucial role in enlightening more related innovations and findings in both industry and academia.

Author contributions

LZ: Writing–original draft, Writing–review and editing. YS: Writing–original draft, Writing–review and editing. XZ: Writing–original draft, Writing–review and editing. YZ: Writing–review and editing. XL: Writing–review and editing.

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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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