Guest Editorial: Machine Learning in Power Systems

Introduction
Recent years have seen great advances in sensor technologies and their implementation in power systems, and have produced a considerable number of useful data sets in this time. These datasets offer new opportunities to leverage machine learning to reveal unknown power system characteristics and improve the situational awareness and the operability of power grids. Although machine learning has been widely used in image processing, voice recognition and autonomous driving, its application to power systems is still at an initial stage. Machine learning has been used to solve problems such as state estimation, contingency screening, demand control, economic dispatch, and cybersecurity. But there are many outstanding challenges, such as obtaining big datasets for learning, certifying learning performance, and convincing power engineers to use learning-based decisions.

This Special Issue covers interdisciplinary research for novel machine learning algorithms and their applications to power system analysis, operation and control. It includes nine papers on various topics that have both research and engineering values, such as fault analysis, cybersecurity, system stability, forecasting, and microgrids. These papers have provided machine learning-based solutions to power system problems and benchmarked the performance with classical techniques.

Papers in this Special Issue
Ananthan and Santos present a novel application technique for implementing a model-based approach efficiently to estimate the fault location and fault resistance using an artificial neural network-based approach. A key highlight of the proposed approach is the ability to identify the location of a fault present on neighbouring lines using the measured through-fault current. The study also presents representative scenarios to demonstrate the capability and potential of the proposed approach.

Hao gives a comprehensive review of arcing-HIF detection in distribution network-based AI. First, characteristics and models of arcing-HIF are analysed; the arcing-HIF database construction method is also explained. Next, arcing-HIF detection methods based on AI are summarised in detail, including data acquisition, feature extraction and classifier selection. Then, a set of criteria are proposed to evaluate the reliability of the arcing-HIF detection algorithm. Finally, the future trends and challenges to arcing-HIF detection are also fully accounted for. This review is a valuable guide for researchers who are interested in arcing-HIF detection-based AI.

Ruben et al. present a hybrid data-driven physics model-based framework for real-time monitoring in smart grids. In order to enhance the robustness of false data injection detection, this study presents a framework that explores the use of data-driven anomaly detection methods in conjunction with physics model-based bad data detection via data fusion. Multiple anomaly detection methods working at both the system level and distributed local detection level are fused. The fusion takes into consideration the confidence of the various anomaly detection methods to provide the best overall detection results.

Darbandi et al. propose a real-time stability condition predictor based on a feedforward neural network. The conjugate gradient backpropagation algorithm and Fletcher–Reeves updates are used for training, and the Kohonen learning algorithm is utilised to improve the learning process. By real-time assessment of the network features based on the minimum redundancy maximum relevancy algorithm, the proposed method can successfully predict transient stability and out of step conditions for the network and generators, respectively.

Zhang et al. propose a deep recurrent neural network (DRNN) method to forecast day-ahead electricity prices in a deregulated electricity market to explore the complex dependence structure of the multivariate electricity price forecasting model. The proposed method can learn the indirect relationship between electricity price and external factors through its efficient, diverse function and multi-layer structure.

Hagmar et al. develop a machine learning-based method for a fast estimation of the dynamic voltage security margin (DVSM). The DVSM can incorporate the dynamic system response following a disturbance and it generally provides a better measure of security than the more commonly used static voltage security margin (VSM). To overcome the computational difficulties in estimating the DVSM, this study proposes a method based on training two separate neural networks on a dataset composed of combinations of different operating conditions and contingency scenarios generated using time-domain simulations. The trained neural networks are used to improve the search algorithm and significantly increase the computational efficiency in estimating the DVSM. The machine learning-based approach is thus applied to support the estimation of the DVSM, while the actual margin is validated using time-domain simulations.

Liu et al. propose a hierarchical control optimisation learning method with consideration of the multi-agent game. Firstly, the multi-energy microgrid is taken as the research object, the microgrid system architecture was analysed, and the multi-agent partition in the system is pursued based on different economic interests. Secondly, for the technical aspects involved in the integrated energy regulation and management, the management layers of the multi-energy microgrid are divided, and the functions of different management layers are analysed. Based on this, the regulation functions are realised by considering the Nash Q-learning and the artificial intelligence method of Petri-net. Finally, the learning and decision-making ability of the method through practical cases are analysed.

Blakely and Reno focus on applying machine learning to the phase identification task, using a co-association matrix-based, ensemble spectral clustering approach. The proposed method leverages voltage time series from smart meters and does not require existing or accurate phase labels. This work demonstrates the success of the proposed method on both synthetic and real data, surpassing the accuracy of other phase identification research.

Radhakrishnan et al. improve the primary frequency response in networked microgrid operations. They investigate the use of a reinforcement-learning-based controller trained over several switching transient scenarios to modify generator controls during large frequency deviations. Compared to previously used proportional–integral controllers, the proposed controller can improve the primary frequency response while adapting to changes in system topologies and events.

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area and the authors aim to undertake further research in this field. They also like to thank the IET Editorial Office for their help and support that made this Special Issue possible.

**Guest Editor Biographies**

Zhaoyu Wang is the Harpole-Pentair Assistant Professor at Iowa State University. He received the B.S. and M.S. degrees in electrical engineering from Shanghai Jiaotong University in 2009 and 2012, respectively, and the M.S. and Ph.D. degrees in electrical and computer engineering from Georgia Institute of Technology in 2012 and 2015, respectively. His research interests include power distribution systems and microgrids, particularly on their data analytics and optimisation. He is the Principal Investigator for a multitude of projects focused on these topics and funded by the National Science Foundation, the Department of Energy, National Laboratories, PSERC, and Iowa Energy Center. Dr. Wang is the Secretary of the IEEE Power and Energy Society (PES) Award Subcommittee, Co-Vice Chair of PES Distribution System Operation and Planning Subcommittee, and Vice-Chair of PES Task Force on Advances in Natural Disaster Mitigation Methods. He is an editor of IEEE Transactions on Power Systems, IEEE Transactions on Smart Grid, IEEE PES Letters and IEEE Open Access Journal of Power and Energy, and an associate editor of IET Smart Grid.

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