Guest Editorial: Applications of Artificial Intelligence in Modern Power Systems: Challenges and Solutions

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WITH the increasing integration of renewable energies, power electronic devices and flexible loads, modern power systems are becoming more sophisticated and facing higher uncertainty. Traditional model-based methods cannot fully satisfy the analysis and control requirements of modern power systems duo to its complexity and uncertainty. At the same time, with the deployment of smart meters and advanced sensors, an unprecedented amount of data is generated by the power systems all the time. The generated data have great value and can make up for the deficiency of the traditional physical model based approaches. Driven by data, artificial intelligence can directly learn from data, and needs no simplifications and/or assumptions of the physical model. Great success has been achieved in the fields of artificial intelligence in recent years, bringing new opportunities of applying the state-of-the-art machine learning technologies to power systems. This special section focusses on some of the emerging technologies to solve existing challenges and solutions for the application of artificial intelligence in modern power systems. Thirteen articles included in this special section are summarized as follows:

In the paper entitled "Reinforcement Learning and Its Applications in Modern Power and Energy Systems: A Review", the authors make a comprehensive review of applications of reinforcement learning in modern power and energy system. The basic ideas and various types of methods of reinforcement learning, deep reinforcement learning and multi-agent deep reinforcement learning algorithms are first illustrated, respectively. Then their applications for the optimization of smart power and energy distribution grid, demand side management, electricity market and operational control are discussed in detailed. Finally, the challenges and prospects of reinforcement learning in modern power and energy system are presented.

In the paper entitled "Artificial Intelligence Based MPPT Techniques for Solar Power System: A review", an overview of the applications of artificial intelligence methods for the optimal control strategy extraction of maximum power point tracking of solar PV systems is presented. The background of the maximum power point tracking is firstly illustrated, followed by the artificial intelligence based maximum power point tracking technologies in recent years. After that, the comparison between various artificial intelligence based control methods is illustrated with detailed analysis of advantages and disadvantages.

In the paper entitled "A Data-driven Method for Transient Stability Margin Prediction Based on Security Region", a convolutional neural network based method is proposed for transient stability assessment utilizing the computer-vision-based power flow image and geographic information system. The classification network is first utilized to classify the input data to several categories, based on which the forecasting network predicts the stability indices. Simulation results on IEEE 39 and 118 bus system demonstrate the effectiveness of the proposed approach.

In the paper entitled "An End-to-end Transient Recognition Method for VSC-HVDC Based on Deep Belief Network", an end-to-end transients identification model based on deep belief network is proposed. The proposed method can automatically learn the inherent characteristic from data, without the manual feature extraction procedure which is easily affected by the experience of engineers. Data of similar transmission lines are utilized to enlarge the training datasets and improve the generalization ability of the proposed method. Simulation results demonstrated that the proposed method can satisfy the requirements of transient recognition with respect to speed and reliability.

In the paper entitled "Data-driven Transient Stability Assessment Model Considering Network Topology Changes via Mahalanobis Kernel Regression and Ensemble Learning", an ensemble learning is proposed for transient stability assessment method considering the topology change. The ensemble model is a weighted sum of multiple sub-models, each building the affine rule from power flow and topology structure data to critical clearing time. The weights are calculated according to the similarity between the topology and samples. The proposed method fully exploits the value of historical data and its decision procedure is understandable.

In the paper entitled "Reconstruction Residuals Based Long-term Voltage Stability Assessment Using Autoencoders", the authors propose a novel method which merely needs secure data based on autoencoders to evaluate voltage stability. The authors use a long-short-term memory encoder to obtain the features of input data and then introduce a moving strategy which can make insecure features more similar

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to secure features. After that, an LSTM decoder is used to decode these features and evaluate voltage stability. Finally, they conduct extensive experiments in the IEEE 57-bus standard testing system to prove the superiority of the proposed method.

In the paper entitled "Robust Voltage Control Considering Uncertainties of Renewable Energies and Loads via Improved Generative Adversarial Network", a robust voltage control method is proposed to deal with the uncertainties of load demand and renewable energy generations based on improved generative adversarial network and wolf pack algorithm. The generative adversarial network is first trained utilizing the real and predicted data. Then the well-trained generator is applied to generate a large amount of scenarios which are then solved by the wolf pack algorithm for voltage control.

In the paper entitled "Power System Flow Adjustment and Sample Generation Based on Deep Reinforcement Learning", a deep reinforcement learning based power flow generation and adjustment method is proposed. A discriminator is first trained to judge the convergence of power flow, based on which the value function is built. After that, the reinforcement learning algorithm is utilized to develop a power flow adjustment strategy. Compared with traditional methods, the control strategy can be automatically developed without manual intervention and dependency on an accurate system model.

In the paper entitled "A Data-driven Method for Fast AC Optimal Power Flow Solutions via Deep Reinforcement Learning", a deep reinforcement learning based optimization strategy for distribution network is proposed. Imitation learning is first utilized to train the weights of the neural networks. After that, the proximal policy optimization (PPO) algorithm is used to develop the optimization strategy based on the initial weights. Simulation results on two power systems demonstrate the effectiveness of the proposed approach and its potential for assisting operators in the real-time dispatching.

In the paper entitled "Doubly-fed Deep Learning Method for Bad Data Identification in Linear State Estimation", a novel method based on doubly-fed deep learning to address bad data identification problems for linear state estimation is proposed. The method consists of two feedback-pipelines. One is a short-term deep neural network which captures short-term data patterns and updates by online training. The other is a long-term deep neural network which captures historical patterns and events scenarios. To verify the superiority of the method, they conduct numerous experiments in IEEE 39-bus System and Jiangsu provincial power system under different scenarios including normal operating conditions and different kinds of events.

In the paper entitled "Optimal Control of Microgrids with Multi-stage Mixed-integer Nonlinear Programming Guided Q-learning Algorithm", a mixed-integer nonlinear programming guided Q-learning based approach is proposed for the minimization of the total operating costs of a pilot stochastic and dynamic microgrid. The optimization problem is formulated as a Markov decision process (MDP), which is then solved by the Q-learning algorithm. To reduce the negative influence caused by the discretization of state-action pairs, a commercial solver is utilized to solve the sub-problems to find more accurate solutions. Three case studies with different objective functions are used to demonstrate that the proposed method is effective in minimizing multiple operating cost. Comparative tests with conventional Q-learning algorithm demonstrate the superiority of the proposed MINLP guided Q-learning.

In the paper entitled "Residential HVAC Aggregation Based on Risk-averse Multi-armed Bandit Learning for Secondary Frequency Regulation", a power system frequency stability control strategy utilizing demand side resources is proposed. The authors adopt the risk-averse multi-armed bandit approach to cope with the uncertainty. This approach can develop a novel and reliable frequency regulation strategy by learning residential behavior. Comparative tests with several traditional methods demonstrate that the proposed method performs more efficient in secondary frequency regulation, and is more robust to the considered users' random behaviors.

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