Applications of Artificial Intelligence in Renewable Energy Systems

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GUEST EDITORIAL

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1 | INTRODUCTION

Owing to the strong uncertainty and fluctuation of renewable energy generations, renewable energy systems are becoming more sophisticated. Traditional model-based methods will be difficult to address the analysis, scheduling and control problems of future renewable energy systems.

In recent years, with the development of smart grid, more and more data are collected by the power system operators through smart metering and advanced sensing devices. It motivates the utilization of artificial intelligence (AI) methods, which can directly learn useful information from massive data to deal with the complex non-linear problems without assumptions and simplifications.

In line of with this trend, this special issue aims to present state-of-the-art studies on application of AI in renewable energy systems. There are in total 17 papers accepted for this special issue after carefull peer-to-peer reviews. The special issue can be divided into three general topics, the summary of which is given as follows.

2 | TOPIC A—APPLICATION OF AI-BASED METHODS FOR OPTIMIZATION AND CONTROL OF POWER AND ENERGY SYSTEMS

Paper 'Carbon Emission Flow Oriented Multitasking Multi-Objective Optimization of Electricity-Hydrogen Integrated Energy System' proposes a multi-objective optimization method for the operation of electricity-hydrogen integrated system. An improved multitasking multi-objective optimization algorithm is proposed to exploit the implicit information of different optimization tasks. Comparative tests demonstrate that the proposed method can achieve better convergence performance than traditional methods.

Paper 'Research on Short-term and Mid-long term Optimal Dispatch of Multi-energy Complementary Power Generation System' proposes an optimization method for the optimal dispatch of multi-energy complementary power generation system. The improved cuckoo search, hybrid firefly and particle swarm optimization methods are utilized for the short-term and mid-long-term scheduling, respectively. Comparative tests demonstrate that the proposed method can achieve joint scheduling of the multi-energy complementary power generation system.

Paper 'Dynamic Exploitation Gaussian Bare-Bones Bat Algorithm for Optimal Reactive Power Dispatch to Improve the Safety and Stability of Power System' proposes a reactive power dispatch method based on the Gaussian bare-bones bat algorithm. Simulation tests are carried out on IEEE 14-bus, 57-bus and 118-bus system to evaluate the performance of the proposed method. The comparison results demonstrate the robustness and effectiveness of the proposed reactive power dispatch method.

Paper 'A "spatial-temporal" bi-layer optimal control strategy of large-scale EVs in a multi-area VPP oriented to Dual Carbon Target' proposes a spatial-temporal bi-layer control method for the daily dispatching of large-scale electric vehicle. Simulation tests demonstrate that the proposed method can effectively guide the charging behaviours of the electric vehicles, mitigate the load fluctuations and lower carbon transaction and energy costs.

Paper 'Design and Analysis of Genetic Algorithm and BP Neural Network Based PID Control for Boost Converter Applied in Renewable Power Generations' proposes a PID control strategy for boost converter based on genetic algorithm and back-propagation neural network. The proposed method combines the global optimization ability of genetic method and the adaptive characteristics of neural network. Comparative tests are carried out to validate the effectiveness of the proposed method.

Paper 'Distributed Deep Reinforcement Learning for Integrated Generation-Control and Power-Dispatch of Interconnected Power Grid with Various Renewable Units' proposes a deep reinforcement learning-based approach for the energy management of interconnected power system. A swarm intelligence-based deep deterministic policy gradient method is utilized to determine the control decisions. Comparison results on a west China two area load frequency model and an England two-area model validate the effectiveness of the proposed method.

Paper 'Data-driven Optimal PEMFC Temperature Control via Curriculum Guidance Strategy-based Large-scale Deep Reinforcement Learning' proposes a temperature control strategy of proton exchange membrane fuel cell based on deep reinforcement learning. A data-driven controller is built based on the curriculum guided deep deterministic policy gradient

method. Comparative tests demonstrate that the proposed method can achieve better stack temperature control performance than other benchmark methods.

Paper 'Data-Model Driven Rescheduling Considering Both Rotor Angle Stability and Transient Voltage Stability Constraints' proposes a rescheduling method of large-scale power grid based on deep reinforcement learning. A Markov decision process is first modelled considering the transient stability constraint. Then, an improved distributed distributive deep deterministic policy gradients method is applied to solve the Markov decision process. Comparative tests are carried out on the New England 39-bus system and an actual power grid to verify the effectiveness of the proposed method.

3 | TOPIC B—APPLICATION OF AI-BASED METHODS FOR PARAMETER IDENTIFICATION, STATE ESTIMATION AND FAULT DETECTION OF POWER SYSTEMS AND ELECTRICAL EQUIPMENT

Zhang et al., in their paper 'Long Short-Term Memory-Based Robust and Qualitative Modal Feature Identification of Non-Stationary Low-Frequency Oscillation Signals in Power Systems', propose a fast low-frequency oscillation identification method. The low-frequency oscillation and attenuation factor are first divided into 12 and 4 segments, respectively. Then, a two bi-directional long-short-term memory neural network is utilized to learn the oscillation identification task. Comparative results demonstrate the effectiveness of the proposed and its advantages over other benchmark methods.

Paper 'Few-shot Learning Based Multi-weather-condition Impedance Identification for MPPT-controlled PV converters' proposes a model agnostic meta-learning-based impedance identification method of PV converters. The proposed method can adjust its initial model utilizing data recorded under different weather conditions. When finishing the training process, the training model can adapt to new conditions using few samples. Comparison results demonstrate the effectiveness and superiority of the proposed approach.

Paper 'A Compressed Sensing and CNN-based Method for Fault Diagnosis of Photovoltaic Inverters in Edge Computing Scenarios' proposes a fault diagnosis method of PV inverters based on the compressed sensing method and convolutional neural network. To evaluate the performance of the proposed method, tests are carried out on an edge-cloud semi-physical experiment platform. Comparison results demonstrate the advantages of the proposed method over other benchmark methods.

Paper 'Fault detection and classification on insulated overhead conductors based on MCNN-LSTM' proposes a fault classification method of overhead insulated conductors based on multi-channel convolutional neural network and long-short term memory network. Convolutional neural network with different filter lengths is used to extract features from the frequency components and three-phase signals. The extracted features are then fed into the long-short term memory networks to determine the fault types. Comparative tests demonstrate that the proposed method can outperform other fault detection and classification methods.

Paper 'Active and passive hybrid detection method for power CPS false data injection attacks with improved AKF and GRU-CNN' proposes a detection method for false data injection attacks of cyber-physical system based on an improved adaptive Kalman filter and convolutional neural network. Comparative tests on a simulation system demonstrate the accuracy and effectiveness of the proposed method.

Paper 'Cluster Division in Wind Farm through Ensemble Modelling' proposes a clustering method for the wind turbines in a wind farm. Blending and extreme gradient boosting are combined to select the clustering indicators and simplify the model and density-based spatial clustering of applications with noise is applied to achieve the clustering results. Simulation tests verify the effectiveness of the proposed method.

Ahmed et al., in their paper 'An Effective Model Parameter Estimation of PEMFCs Using GWO Algorithm and its Variants', propose a parameter identification method for proton exchange membrane fuel cells. Grey wolf optimization method and its variants are applied to evaluate the unknown parameters of the fuel cells. Comparative tests are carried out with those well-known parameter identification methods to verify the effectiveness of the proposed method.

4 | TOPIC C—APPLICATION OF AI-BASED METHODS FOR FORECASTING THE RENEWABLE ENERGY GENERATIONS

Paper 'A Reliable Method of Wind Power Fluctuation Smoothing Strategy Based on Multidimensional Nonlinear Exponential Smoothing Short-Term Forecasting' proposes a wind power fluctuation smoothing method based on the short-term forecasting results. The multi-dimensional non-linear exponential smoothing prediction method is first utilized to obtain the forecasting results of wind power. Then, a frequency conversion entropy strategy is used. Simulation results verify the reliability and feasibility of the proposed method.

Paper 'A deep-learning based Solar Irradiance Forecast Using Missing Data' proposes the solar irradiance forecasting method based on recurrent neural networks utilizing historical climate and irradiance data. Comparative tests are carried out on an open access dataset considering different input factors. Comparison results demonstrate the advantages of the proposed method over other benchmark methods.

5 | SUMMARY/CONCLUSION

All the papers selected for this special issue show that widespread adoption of AI algorithm in renewable energy

systems is achieved, especially in optimization and control, parameter identification and fault detection applications. Meanwhile, there are many challenges that exist in this filed, which requires further attentions, such as the interpretability of the AI algorithms. Future work can help accelerate their application in practical renewable energy systems and realise their full potential.

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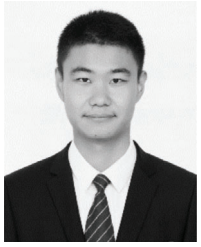

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