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Editorial: AI-Driven zero carbon cyber-energy system

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Editorial on the Research Topic
AI-Driven zero carbon cyber-energy system

The increasing pressure from the energy crisis and environment pollution has led to the urgency of energy structure and technology upgrades. As a future energy development trend, Cyber-Energy System (CES) focuses on deeply integrating multiple types of energy resources (including electricity power, heat, cooling, and gas, etc.) and advanced communication technology to improve the energy utilization efficiency, reduce the costs and emissions, and increase the proportion of renewable energy resources. Since AI technology is both suitable for solving model-driven and data-driven research problems, it fits well with the features of CES such as diversified information date and interdependent infrastructures. By reasonably utilizing AI and multi-energy conversion technology, it is entirely possible for CES to achieve low (even zero) operation in the processes of energy generation, conversion, transmission, distribution, and consumption. Meanwhile, zero carbon in CES requires innovation in many aspects, including policy, markets, modeling, planning, control, and operation, which brings many new challenges.

The aim of this Research Topic is to address and disseminate state-of-the-art research and opportunities regarding the application of AI and multi-energy conversion technology to achieve low/zero system operation for CES. Through a rigorous peer-review process, 10 articles have been accepted, which are summarized as follows.

In the article "A Deep Learning Approach to the Transformer Life Prediction Considering Diverse Aging Factors," He et al. investigated the aging phenomenon of power system transformers, whose representative degeneration variables were extracted from real transformer operational data. Combined with the average life of the equipment, the extracted features were used as indicators for transformer reliability evaluations. A deep learning–based approach was developed by using a convolutional neural network for effective equipment life prediction. The performance of the transformer life prediction model was verified using field-test data.

In the article "Autonomous underwater vehicle docking system for energy and data transmission in cabled ocean observatory networks," Sun and Han presented an active landmark tracking framework to improve the accuracy and reliability of short-range docking between autonomous underwater vehicles (AUVs) and a docking station (DS) in cabled ocean observatory networks (COON). The proposed framework included a two-stage docking algorithm based on convolutional neural networks (CNN) to estimate the 3D relative position and orientation between the AUV and DS during docking, as well as an extended Kalman filter and Hungarian matching algorithm to improve the robustness of the system. The effectiveness of the proposed framework was demonstrated through experiments in both a pool and a lake.

In the article "Distributed Low-Carbon Energy Management Method for Port Microgrid Based on We-Energies under Polymorphic Network," Teng et al. proposed a port microgrid based on we-energies and its polymorphic distributed low-carbon energy management. Firstly, a polymorphic energy management system was established for a port microgrid based on we-energies to guarantee information interaction between neighbors. Further, considering the characteristics of we-energies, the operating cost function was constructed. In addition, a port microgrid low-carbon energy management model was constructed. Finally, a distributed solution method was proposed to reduce port carbon emissions and to help the development of the green low-carbon port.

In the article "Green Polymorphic Cooperative Formation Strategy of Low-Carbon Unmanned Surface Vessels," Lu et al. constructed a multi-lateral cooperative control system for USVs in a polymorphic network to achieve topological scalability of multi-USVs. A multi-lateral distributed control protocol was proposed. With the help of a MAS (Multi-Agent System) model and an Ad-Hoc network, green, energy-saving, and scalable autonomous cooperative formation of the future USVs was structured.

In the article "Intelligent Decoupling Control Study of PMSM Based on the Neural Network Inverse System," Da-Wei et al. established a decoupling control system model of a permanent magnet synchronous motor neural network inverse system. The data collected from the analytical inverse system of the PMSM model was used to analyze and compare the prediction accuracy and running time of the neural network, so as to optimize the structure and parameters of the neural networks. The results showed that the permanent magnet synchronous motor decoupling control system based on an RBF neural network inverse system has better dynamic and static decoupling performance and robustness.

In the article "Polymorphic Distributed Energy Management for Low-Carbon Port Microgrid With Carbon Capture and Carbon Storage Devices," Shan et al. proposed a polymorphic distributed energy management method for a low carbon port microgrid with a carbon capture and carbon storage device. First, this paper presented a low carbon port microgrid in a polymorphic network environment to realize an information interaction among energy subjects in different modes and to improve the network communication performance. Further, an energy management model of the low-carbon port microgrid was constructed considering the additional carbon capture and carbon storage device in the port. In addition, a distributed energy management method was proposed for different port microgrid operation modes.

In the article "Energy Management Without Iteration—A Regional Dispatch Event-Triggered Algorithm for Energy Internet," Tan proposed a region scheduling event triggering algorithm (RDETA). With RDETA, the energy management does not need to iterate with each asynchronous communication and does not rely on a global synchronous clock. In addition, the RDETA is capable of using regional communications and regional energy dispatching. Therefore, the size of the dispatch area can be adjusted automatically according to the extent of the energy problem. Simulation results and theoretical analysis demonstrated the effectiveness of the proposed algorithm.

In the article "Intelligent Command Filter Design for Strict Feedback Unmodeled Dynamic MIMO Systems with Applications to Energy Systems," Feng et al. proposed a command-filtered control scheme for multi-input multi-output strict feedback non-linear unmodeled dynamical systems. Therein, a dynamic signal combined with radial basis function neural networks was considered, which enabled handling of the dynamic uncertainties. The command filter was further employed to prevent explosions. The authors showed that the proposed method possessed better suitability than single-input single-output strict feedback non-linear systems.

In the article "Low carbon economic dispatch of power system at multiple time scales considering GRU wind power forecasting and integrated carbon capture," Ding et al. proposed a three-stage economic dispatch framework, based on the Carbon Capture and Storage (CCS) technique and the multi-timescale Gated recurrent unit (GRU) wind power forecasting model. In the proposed framework, the CCS plants were equipped with conventional thermal power plants to enable low carbon emission and flexible regulation capability. Meanwhile, the AI-based GRU forecasting technique with higher accuracy and less training time efficiently facilitated optimal system dispatches. Based on the corresponding 3-stage GRU wind power forecasting, a three-stage dispatch modeling with day-ahead, intra-day, and dynamic stages was developed for the power system with large integration of CCS and wind plants to improve the system operation and control, further achieving low wind curtailment, load loss, and dispatching costs.

In the article "Measurement Error Estimation for Distributed Smart Meters Through a Modified BP Neural Network," Xia et al. presented a measurement error estimation method for distributed smart meters by using a modified BP neural network. The considered BP neural network was designed by reasonably combining the internal activation function, iterative step size, and other relevant parameters. Several experiments were considered to demonstrate the feasibility and effectiveness of the constructed distributed smart electricity meter system.

Author contributions

YL, JZ, RF, and BH are responsible to summarize articles 1–3, 4–5, 6-7, and 8–10, respectively. YL is also responsible to write and check the whole paper.

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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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