Facing the challenges of new-type power systems

On the morning of April 23, 2022, at the 90th-anniversary celebration of the Department of Electrical Engineering at Tsinghua University, the inauguration ceremony of the international academic journal *iEnergy* was held. The second issue of *iEnergy* arrived, publishing 14 papers, including three news and views, two highlights, one letter, four review articles, and four original research articles.

The relationship between global climate change and human activities has become the focus of today's international issues. Global climate change is related to the vital interests and economic development of various countries—it is imperative to respond to climate change. In September 2020, at the United Nations General Assembly, China recommitted to achieving a carbon peak by 2030 and carbon neutrality by 2060. Currently, more countries are upgrading carbon neutrality goals into national strategies, and more than 120 countries and regions globally have proposed their carbon neutrality routes. The carbon here does not simply refer to carbon dioxide (CO_2) but includes several primary greenhouse gases represented by CO_2. Greenhouse gas emissions severely affect the earth's living environment. The United Nations Intergovernmental Panel on Climate Change proposed the CO_2 equivalent standard to measure the environmental impact of these gas emissions uniformly. CO_2 equivalent means the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas. The carbon in carbon peaking and carbon neutrality refers to the CO_2 equivalent. Take sulfur hexafluoride (SF_6), it is widely used as an insulation gas in power apparatuses, its equivalent value is 22,200, meaning that reducing one ton of SF_6 emissions is equivalent to reducing CO_2 emissions by 22,200 tons.

Carbon peaking and carbon neutrality will accelerate the formation of new industrial structures, production methods, lifestyles, and spatial patterns that save resources and protect the environment and will especially bring considerable challenges to the power-energy system. Low-carbon energy transformation and high-quality developments are critical opportunities and challenges facing today's world. Building a new-type clean, low-carbon, safe, controllable, flexible, efficient, intelligent, friendly, open, and interactive power system is critical. We invited Prof. Yinao Su (pp. 145), academician of the Chinese Academy of Engineering (CAE), former director of the Energy and Mining Engineering Division of CAE, to share his views on China's carbon peaking, carbon neutrality, and the energy development strategy. He briefly introduced the preliminary results obtained by him and his team along with the basic concepts, essential understandings, data prediction, scenario analyses, realization pathways, and strategic planning of China's carbon peaking and carbon neutrality. We invited Mr. Chuangjun Li (pp. 149), Director of the Department of New and Renewable Energy, National Energy Administration, who analyzed China's strategies and initiatives to foster high-quality leaping development of renewable energy.

In 2025, China will increase the proportion of nonfossil energy in total energy consumption to approximately 20%; therefore, it is imperative to facilitate the high-quality development of renewable energy sources. Renewable energy will develop from two sides: large-scale centralized and adjacent distributed renewable energy sources. The new-type power systems will challenge the power system's resilience, i.e., power grids' ability to anticipate, withstand, adapt, and recover from high-impact, low-probability events. Prof. Nikos D. Hatziargyriou and his team (pp. 158) from the National Technical University of Athens presented a review of microgrids for enhancing power system resilience. They summarized long-term and short-term measures that system operators can employ for resilience reinforcement and highlighted the challenges and future research requirements for improving microgrid-based power system resilience.

Interconnecting hundreds of gigawatts of renewables severely affect power grids, such as widespread intermittency and uncertainty, compromised situational awareness, and destabilized electricity markets. These unprecedented challenges call for transformative analytics to support the resilient operations of power systems. Prof. Peng Zhang (pp. 170) from Stony Brook University and Brookhaven National Laboratory reviewed the newly emerging application of quantum computing techniques in power systems, which will ignite new hopes of revolutionizing power system computations. Prof. Qiuye Sun (pp. 257) from Northeastern University proposed an unintrusive modeling method based on a two-stage generative adversarial network for integrated energy systems.

On the one hand, new-type power systems face the problem of benefit redistribution between the entire industry's different links and chains. Prof. Qixin Chen (pp. 188) and his collaborators from China, Netherland, and USA reviewed the recent developments of competition and equilibrium in power markets under decarbonization and decentralization, including modeling methods, practical settings, and solution techniques in equilibrium analysis.

The wide application of power electronics is another crucial feature of new-type power systems. Prof. Zhengming Zhao (pp. 243) from Tsinghua University proposed a low-voltage, ride-through (LVRT) control strategy for multiport power electronic transformers (PET). The PET is endowed with LVRT capability in power-generation and power-consumption states, differing significantly from the traditional power-generation systems, such as photovoltaic or wind power.

Over the past decades, ambient energy harvesting has attracted increasing interest in realizing self-powered systems to meet large-scale energy demands. Prof. Zhonglin Wang from Beijing Institute of Nanoenergy and Nanosystems at Chinese Academy of Sciences and Prof. Yunlong Zi (pp. 236) from the Chinese University of Hong Kong developed a nonlinear triboelectric nanogenerator with a broadened bandwidth for effective harvesting of vibration energy.

Energy storage technology can efficiently integrate renewable energy into the grid and is vital to achieving carbon neutrality. Prof. Shengwei Mei (pp. 143) from Tsinghua University reported that China's national demonstration project for compressed-air energy storage achieved a milestone in industrial operation. On May 26, 2022, the world's first nonsupplemental combustion compressed-air energy storage power plant, the Jintan Salt-cavern Compressed-Air Energy Storage National Demonstration Project, was officially launched. As one of the most potential energy storage technologies, Li-ion batteries have significantly influenced society and were recognized by the 2019 Nobel Prize in Chemistry. Metal electrodes with high-specific capacity and low reduction potential are candidates for next-generation high-specific-energy batteries. Prof. Kai Jiang and his team (pp. 204) at Huazhong University of Science and Technology reviewed the interfacial engineering of metal electrodes for high-specific energy and long-lifespan batteries. Prof. Canbing Li (pp. 223) from Shanghai Jiao Tong University and his collaborators designed flame-retardant stable composite phase-change materials for battery thermal management systems, which is hopeful to realize an efficient and feasible approach toward exploiting a multifunctional phase-change material for thermal management systems for energy storage fields.

We will encounter various technical bottlenecks in developing new energy and power systems. Let us face and solve the challenges of new-type power systems for a better tomorrow.

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