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Guest Editorial: Transition towards Deep Decarbonisation of Modern Energy Systems

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GUEST EDITORIAL

Guest Editorial: Transition towards deep decarbonisation of modern energy systems

1 | INTRODUCTION

The decarbonisation of modern energy systems is key to reducing global greenhouse gas emissions and hence mitigating climate change. While governments worldwide have taken significant initiatives towards decarbonisation and announced their carbon peaking and neutrality targets and plans, significant techno-economic challenges remain along the pathway to achieve this decarbonisation goal. Energy systems generally encompass multiple energy carriers, diverse temporal and spatial resolutions, and heterogenous energy entities. This necessitates a suitable design and control of the interfaces between electricity, natural gas, transportation, and heat networks, as well as the transportation, water and agricultural systems. Meanwhile, digital technologies such as big data, machine learning, blockchain, ICT, and IoT are receiving much attention as they can aid the decarbonisation process. Cyber-physical systems as an orchestration of these novel technologies further increases the efficiency of energy provision, thereby optimising economic feasibility and environmental impact.

This IET Smart Grid special issue on Transition Towards Deep Decarbonisation of Modern Energy Systems invites a broad spectrum of contributors from universities, industry, research laboratories, and policymakers to develop and present novel solutions and technologies that will facilitate and advance the agenda of deep decarbonisation of modern energy systems. This special issue solicits original research papers that target at, but are not restricted to, the following aspects. It is worth noting that this special issue places an emphasis on addressing the mutual research interests of academics and industry.

2 | PAPERS IN THE SPECIAL ISSUE

In this special issue, we have received 17 papers, all of which underwent peer review. Of the submitted papers, only seven have been accepted and nine have been rejected. Thus, the overall submissions were of high quality, which marks the success of this special issue.

The seven accepted papers focus on different aspects of different means of decarbonisation of modern energy systems, which can be clustered into three main categories: energy storage, energy markets, and energy Internet. The papers laying in the first category focus on how the most prominent flexibility sources including electric vehicle and energy storage technologies can be adopted safely and economically to aid the energy system decarbonisation. The papers in this category are of Sun et al., Chen et al., and Rolando et al. The second category of papers looks at how the flexibility potential of distributed energy resources can berealised through suitable participation in energy and ancillary service markets, so as to support renewable energy integration and low-carbon transition of energy systems. These papers are of Wang et al. and Shan et al. The last category of papers exhibits the evolution of smart grids towards the energy Internet and demonstrates their benefits towards decarbonisation. These papers are of Bu et al. and Ghiasi et al. A brief presentation of each of the paper in this special issue is as follows.

Sun et al. established an integrated evaluation model of the electric vehicle charging process. The comprehensive fuzzy evaluation method is used to comprehensively analyse the monitoring data of the electric vehicle charging process, and the weight is determined based on the grey correlation method and the expert scoring mechanism. They analyse five sets of charging data in Nanjing through calculation examples and output the integrated health degree of the electric vehicle charging process, so that the equipment can be maintained in a targeted manner, which effectively proves the practicability and reliability of the assessment model.

Chen et al. introduce an intelligent energy management method to deal with the hydrogen-dominant hybrid energy system with low-carbon consideration. Specially, both the new type of fuel cell, solid oxide fuel cell, and chemical battery are subtly modelled to construct a high-efficient hybrid energy system. In addition, an energy management method based on deep reinforcement learning techniques is proposed to guide the intelligent operation with self-adaptive performance to capture the various complex dynamic operation features in hybrid energy systems. The simulation results show the good economic benefit and low carbon advantages achieved by the highly efficient use of hydrogen and the proposed energy management strategy.

Rolando et al. provide a literature review about the current development trends of mobile energy storage technologies, with their corresponding battery energy storage systems, which gives an overview not only to understand the different type of models but also to identify future challenges and applications in the industrial sector. Additionally, a solid explanation of the DT focussed on battery systems for EVs is discussed, highlighting some study cases, characteristics and technological opportunities. Further research is encouraged to enable monitoring of battery operating systems through the implementation of digital twins and to increase lifetime assessment.

Wang et al. propose an energy storage rental strategy for renewable energy communities (REC) to participate in the frequency regulation market (FRM). Firstly, the FRM is modelled considering the regulation capacity and mileage price. Then, the rental model for REC is built considering capacity rental costs and ES using costs. Finally, the whole model is demonstrated with the REC, which has 35 MW photovoltaic and 113 MW wind turbine. The results show that under different rental and market prices, the REC can effectively choose the optimal rental strategy and its profits can mostly be raised by 19.63%.

Shan et al. reviewed current flexibility-related topics and proposes one P2P flexibility market filling in the current gap. A flexibility market is constructed combining the pricing strategy and matching strategy of the mature and successful real-world P2P business models, accommodating the penetration of distributed energy resources. A dynamic pricing strategy is proposed where prices are fluctuated according to the features and portfolio of market players. Moreover, the segmentation tendency of the flexibility market is also discussed considering energy products as pure commodities following the disintegration from the TSO to DSO.

Bu et al. use the power system's dynamic carbon emission factors to release information on energy consumption and carbon emission to building users. At the same time, the differential effects of the building envelope and external temperature in the Building Information Modelling were considered. An optimisation method of building the low-carbon energy consumption strategy considering both the building and power carbon emission was established to improve the comprehensive carbon reduction ability of the building and power system. The simulation results show that the proposed method effectively coordinates the building virtual energy storage and demand response.

Ghiasi et al. emphasise the use of the Internet for evaluating misallocation of energy and the effect it can have on CO_2 emissions. A detailed overview is presented regarding the evolution of smart grids in junction with the employment of IoE systems, as well as essential components of IoE for decarbonisation. Also, mathematical models with simulation are provided to evaluate the role of IoE for reducing CO_2 emission.

3 | SUMMARY

All of the seven papers selected for this special issue show that various forms of renewable and flexible technologies and suitably designed energy markets have paved the way for the global energy system decarbonisation. Yet, continued research efforts are deemed necessary to foster proper harvesting of the full value stream of these emerging technologies and achieving real net zero.

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Chenghong Gu is a reader with the Department of Electronic and Electrical Engineering, University of Bath, UK. Previously, he was an EPSRC research fellow with the University of Bath. His major research interest is in power economics and markets, multi-vector energy systems, smart grid planning and operation. He worked with DECC UK to quantify the value of demand response to the energy system under 2050 pathways. He has been involved in the design of the network pricing method—LRIC (Long-run incremental cost pricing) for Western Power Distribution, which has been adopted by the wide UK power industry. Dr Gu has attracted funding over £1.3m of which 615k is as PI, from national and international funding organisations such as EPSRC, National Grid, Shanghai Electric, and British Council. Dr Gu has more than 90 peer-reviewed journal papers in top energy systems journals, example, IEEE Transactions on Power Systems, Smart Grids, Industrial Informatics, Industrial Electronics, and Applied Energy. He is the Subject Editor for IET Smart Grid and the editor for Nature Scientific Report.

Dan Wu received the Bachelor's degree in Electrical Engineering and Automation from the Huazhong University of Science and Technology, Wuhan, China, in 2012. He received the Master's degree from the University of Wisconsin-Madison, WI, USA in 2014 and received his PhD degree in Power Engineering from the University of Wisconsin Madison, WI, USA, in 2017. He was a Postdoctoral Associate at the Department of Mechanical Engineering at the Massachusetts Institute of Technology (MIT), MA, USA from 2017 to 2019 and now continues his research at the Laboratory for Information and Decision Systems (LIDS) at MIT. Dr. Wu's research aims at improving reliability, efficiency, and resiliency of the future electrical power and multi-energy systems though advanced mathematical modelling and tools. Specifically, his work includes non-linear optimisation methods in power system applications, failure cascade modelling for interdependent energy system, multiple equilibria computations in transient stability analysis, voltage stability analysis on manifolds, loadability region and linepack depletion modelling for natural gas networks.

Goran Strbac is a Professor of Energy Systems at Imperial College London, with extensive experience in advanced modelling and analysis of operation, planning, security, and economics of energy systems. He led the development of novel advanced analysis approaches and methodologies that have been extensively used to inform industry, governments, and regulatory bodies about the role and value of emerging new technologies and systems in supporting cost effective evolution to smart low-carbon energy future. He is currently the director of the joint Imperial-Tsinghua Research Centre on Intelligent Power and Energy Systems, leading author in IPCC WG 3, member of OFGEM RIIO-2 Challenging Group, member of the UK Smart System Forum, member of the European Technology and Innovation Platform for Smart Networks for the Energy Transition, and member of the Joint EU Programme in Energy Systems Integration of the European Energy Research Alliance. He co-authored four books and published over 200 technical papers.

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Peng Zhang received his Ph.D. degree in Electrical Engineering from the University of British Columbia, Vancouver, BC, Canada. He is a SUNY Empire Innovation Professor at Stony Brook University, New York. He has a joint appointment at Brookhaven National Laboratory as a Staff Scientist in the Interdisciplinary Sciences Department. He is an affiliated Professor of Computer Science and affiliated Professor of Applied Mathematics and Statistics at Stony Brook University. Previously, he was a Centennial Associate Professor and a Francis L. Castleman Associate Professor at the University of Connecticut, Storrs, CT, USA. He was a System Planning Engineer at BC Hydro and Power Authority, Canada, during 2006–2010. His research interests include programmable microgrids, networked microgrids, quantum-engineered power grids, AI-enabled resilient grid operations, power system stability and control, cyber security, formal methods and reachability analysis, and software-defined networking. Prof. Zhang is an individual member of CIGRE. He is an editor for the IEEE Transactions on Power Systems, the IEEE Transactions on Sustainable Energy, the IEEE Power and Energy Society Letters, and the IEEE Journal of Oceanic Engineering.

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Yi Tang received his B.S., M.E., and Ph.D. degree from the Harbin Institute of Technology, Harbin, China, in 2000, 2002, and 2006, respectively. Since 2006, he has been with the School of Electrical Engineering, Southeast University, Nanjing, China. His research interests include smart grid, power system security, power system stability analysis, renewable energy systems, and cyber physical system. He is also the director of the Power System Automation Research Institute and has undertaken more than 80 science and technology projects such as the National Natural Science Foundation of China and National Key R&D Projects. He has won more than 10 science and technology awards at the provincial and ministerial level. For publications, more than 100 SCI and EI papers as the first/corresponding author are published, and 38 national invention patents are authorised. He is a member of the editorial board of the Automation of Electric Power System, Power System Technology, Electric Power Information and Communication Technology, Protection and Control of Modern Power Systems, and other academic journals. He is a member of the Renewable Energy Integration and Operation Committee of China Society of Electrical Engineering, Artificial Intelligence and Electrical Application Professional Committee of China Electrotechnical Society, Intelligent Energy System Committee of China Artificial Intelligence Society, Shore Power Facilities Standardization Technical Committee of Energy Industry, and executive director of Jiangsu renewable energy society.

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