Received: 15 February 2022 | Revised: 15 February 2022 | Accepted: 15 February 2022

IET Renewable Power Generation

DOI: 10.1049/rpg2.12434

The Institution of Engineering and Technology WILEY

EDITORIAL

Guest Editorial: Enhancing hosting capability for renewable energy generation in active distribution networks

Driven by the accelerating deployment of distributed energy resources (DERs), advanced information and communications technologies (ICTs), and demand-side response (DR), modern power systems have been transforming from a one-way energy supply chain to a two-way energy system. The continuous integration of DERs into a low-voltage distribution network brings profound challenges to its secure and economic operation, including technical issues with protection placement and coordination, voltage and power violation, power quality, and energy losses. To overcome these challenges, tremendous endeavours have been devoted to enhancing the accommodation capability for renewables in distribution networks. In addition, DERs, including both generation and storage resources, are gaining increasing attention to support the operation of bulk power grids by providing ancillary services, particularly in frequency regulation.

To help researchers and engineers have a better overview of the state-of-the-art on the accommodation of renewables in power distribution networks, this special issue solicits original and novel research on enhancing hosting capability for renewable energy generation in active distribution networks. After undergoing a thorough peer review process, eleven papers were finally accepted on topic areas of operation and planning of distribution networks, modelling of DERs, virtual power plants, electricity market design, and demand-side management. A brief discussion of the authors' contributions is presented as follows.

1 | TOPIC A: OPERATION AND PLANNING OF DISTRIBUTION NETWORKS WITH A HIGH PENETRATION OF RENEWABLES

Paper 1 by Yu et al. investigates a data-driven cooperative load frequency control (DC-LFC) framework to realize the collaboration between the microgrid controller and the power distributor in an island microgrid. An innovative multi-agent distributed deep reinforcement learning algorithm is designed and adopted for modelling participants of the DC-LFC framework. Compared with the traditional LFC framework that uses an independent controller and power distributor, the proposed method deploys centralized training to facilitate the coordination between agents, thus reducing the frequency oscillation. The results show that the proposed strategy can improve the frequency stability of the island microgrid and reduce its power generation costs.

A dynamic controller-based methodology for frequency regulation in a microgrid with renewable energy sources (RES) is proposed in Paper 2 by Dehghani et al. The uncertainty of RES is considered, and a dynamic output feedback microgrid controller is designed. An algorithm based on searching the controller design space is presented to find the suitable controller gains. Different from existing research, which can only find a feasible controller, the proposed algorithm can find the optimal controller parameters using the direct search idea. Finally, simulations are carried out, and the results demonstrate the efficiency of the proposed algorithm in achieving optimal frequency regulation.

In Paper 3 by Tang et al., the overvoltage and three-phase unbalance issues are studied in low-voltage distribution networks with a high penetration of distributed photovoltaics (PVs). An accurate method of calculating the sensitivity matrix considering shunt admittance is proposed in hybrid AC/DC low-voltage distribution networks (LVDNs) with a three-phase four-wire structure. The sensitivities of AC and DC lines are decoupled by voltage source converters (VSCs) due to their flexibility in active and reactive power control. Then, a voltage control method is developed for hybrid AC/DC LVDNs to address the overvoltage and unbalanced issues, which takes advantage of the three-phase four-wire sensitivity matrix and considers the constraints of VSC capacity and DC power flow. Simulations are performed to verify the proposed sensitivity calculation method and voltage control method.

Paper 4 by Guo et al. studies the enhancement of current-controlled inverters (CCIs) against harmonic instability issues in power grids with a low short-circuit ratio (SCR). This research finds that the harmonic instability of CCIs can be prevented by configuring part of the energy storage system (ESS) converters in the distribution network as voltage-controlled inverters (VCIs). The control and capacity planning methods for VCI/ESS are both proposed, which can give the required minimum VCI/ESS capacity for a specific stability margin and SCR range. Finally, the effectiveness of the proposed method is verified by hardware-in-the-loop (HIL) simulations and experiments.

2 | TOPIC B: MODELLING OF DERS AND VIRTUAL POWER PLANTS (VPP) IN ACTIVE DISTRIBUTION NETWORKS

The integrated local energy system (ILES) has been extensively recognized as an effective way to reduce carbon emissions and improve the efficiency of renewable energy utilization. Paper 5 by Ma et al. proposes an optimal low-carbon scheduling model for the ILES, including an oxygen-enriched combustion plant (OECP) and generalized energy storages (GESs), to reduce carbon emissions, improve the renewable energy consumption level and reduce the operating costs of the ILES. In particular, the cooperation mechanism between OECP and power to gas (P2G) is established, and the complementarity between multiple energy sources is utilized to improve the level of renewable energy consumption. Case studies are performed to verify the effectiveness and advantages of the proposed model.

Paper 6 by Zhong et al. proposes a framework to promote the VPP flexibility provision that leverages the dynamic line rating (DLR) technique, where the flexibility region of the VPP is defined as the allowable range of active and reactive power output that the VPP can execute subject to operating constraints of the distribution system. Through the DLR, the current carrying capacity of the distribution network is dynamically adjusted subject to actual environmental conditions, which helps remove barriers of transmission limits that hinder the integration of distributed flexibility. A convex hull-based method with an explicit accuracy guarantee is proposed to approximate the flexibility region with the DLR. Case studies are carried out on standard IEEE test feeders with real-world operation data to validate the proposed framework.

3 | TOPIC C: ELECTRICITY MARKET DESIGN FOR THE RENEWABLE GENERATION INTEGRATION

Paper 7 by Luo et al. proposes a social relationship-aware P2P energy trading system for end energy users, aiming at integrating non-financial factors into the P2P energy market design. The proposed market mechanism first establishes a social network model based on the historical energy trading records of participants. Then, a data-driven social network model is established to represent the bilateral social relationships of the market participants. Based on the social relationship values, a set of bidding and market clearing mechanisms are proposed to facilitate end-to-end energy trading for the participants. Numerical simulations show that the proposed system can provide support for energy users to integrate social relationship considerations into P2P energy trading together with price signals.

A new double-market parallel trading mechanism is proposed in Paper 8 by Jiang et al. to improve the efficiency of existing competitive electricity market mechanisms. Two sub-markets, including a price-searching market for buyers (PSMB) and a price-searching market for sellers (PSMS), are designed in the proposed market mechanism. Transactions in these two sub-markets are conducted simultaneously and independently, while the clearing prices in these two sub-markets are mutually interacted. The proposed market mechanism can integrate traditional trading methods while ensuring the parallel operation of the two sub-markets. The results show that the proposed mechanism can provide market entities with more chances to win contracts, enhance market liquidity, and maximize social welfare.

Energy-as-a-service (EaaS) is emerging as a new business model in power systems that motivates electricity end-users to play an active role and participate in electricity transactions. In Paper 9 by Crasta et al., a transactive energy (TE) trading model for microgrids is introduced and simulated, where the objective is to supply microgrid demands through TE trading. Simulations are carried out to study the behaviour of market participants and evaluate the performance of the TE model under various parametric conditions.

4 | TOPIC D: DEMAND-SIDE MANAGEMENT IN DISTRIBUTION NETWORKS WITH HIGH RENEWABLES

To overcome the limitations of centralized demand response programs in accommodating a large number of scattered small-scale end-users, Paper 10 by Yan et al. proposes a blockchain-based framework of demand response programs. The consensus mechanism, encryption algorithm, and smart contract of blockchain are applied to the process of invitation, bidding, and settlement in demand response. Suggestions on the development of demand response integrated with blockchain are also put forward, such as enriching the market-oriented varieties of demand response programs, establishing the credit management mechanism, and building the blockchain-based power trading platform.

To solve the problems caused by the uncertainty of the resources in an active distribution system, Paper 11 by Zhang et al. proposes a distributed robust co-optimization model for the demand side resources and soft open points (SOPs), which realizes the combination of investment economy and operation robustness. The original nonlinear programming problem is reformulated into a mixed integer linear programming model and solved using the column and constraint generation (CCG) algorithm. Finally, the effectiveness of the proposed model is verified through simulations, and the result demonstrates that the co-optimization model can achieve the combined benefits of demand side resources and SOPs.

5 | SUMMARY

All of the papers selected for this Special Issue show significant progress in enhancing the hosting capability for renewables in power distribution systems. Numerical experiments with real-world data are adopted in most of the papers to demonstrate the application of proposed models and algorithms in practice. Meanwhile, there are still challenges that need further

research efforts, such as the modelling of carbon emissions in distribution systems and the interaction mechanism between transmission and distribution networks with high renewables. Future research work can further release the potential of renewables in active distribution networks and finally contribute to a decarbonized, cost-effective, and robust energy system.

ACKNOWLEDGEMENTS

We are thankful to the contributing authors for submitting their manuscripts and the reviewers for their dedicated efforts in reviewing submissions to this Special Issue. We would like to offer our special gratitude to the Editor-in-Chief and to the Editorial Office of IET Renewable Power Generation for their valuable advice and assistance.

CONFLICT OF INTEREST

The authors have no conflict of interest to disclose.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

GUEST EDITOR BIOGRAPHIES

Jiajia Yang is a Senior Research Associate at the School of Electrical Engineering and Telecommunications, University of New South Wales, Australia, where he received the Ph.D. degree in electrical engineering in 2018. His research interests include power system operation and optimization, renewable energy generation integration, power economics and electricity market. He serves as an Associate Editor of Energy Conversion and Economics.

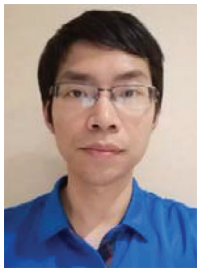
Zhao Yang Dong is a professor with Nanyang Technological University, Singapore. His previous roles include SHARP professor of energy systems at the University of New South Wales (UNSW) Sydney where he was also director of UNSW Digital Grid Futures Institute and ARC Research Hub for Integrated Energy Storage Solutions. He was Ausgrid Chair and director of Ausgrid Centre for Intelligent Electricity Networks providing R&D support for the Smart Gird, Smart City national demonstration project of Australia. His research interest includes power system planning and stability, smart grid/micro-grid, load modelling, renewable energy grid connection, electricity market, computational methods applications in power engineering problems. He has/had served as editor/associate editor for a number of IEEE transactions and IET journals. He is a Fellow of IEEE.

Fushuan Wen has been a full professor in Zhejiang University, China since 1997, and is a part-time distinguished professor in Hangzhou Dianzi University, China, and a part-time professor in Tallinn University of Technology, Estonia. He is listed in "Most Cited Chinese Researchers" in six consecutive years from 2015 to 2020 by Elsevier. He is the Editor-in-Chief of Energy Conversion and Economics, the deputy Editor-in-Chief of Automation of Electric Power Systems, and serves as the editor, subject editor and associate editor of several international journals. He is a Fellow of IEEE. His research interests include power industry restructuring, power system alarm processing, fault diagnosis and restoration strategies, smart grids and electric vehicles, as well as artificial intelligence applications in power and integrated energy systems.

Ramteen Sioshansi holds the B.A. degree in economics and applied mathematics and the M.S. and Ph.D. degrees in industrial engineering and operations research from University of California, Berkeley, Berkeley, CA, USA, and an M.Sc. in econometrics and mathematical economics from London School of Economics and Political Science, London, U.K. He is a professor in Department of Integrated Systems Engineering and Department of Electrical and Computer Engineering and an associate fellow in Center for Automotive Research at The Ohio State University, Columbus, OH, USA. His research focuses on renewable and sustainable energy system analysis and the design of restructured competitive electricity markets.

Mohammad Reza Hesamzadeh received his Docent (Higher Doctorate) from KTH Royal Institute of Technology, Sweden, and his PhD from Swinburne University of Technology, Australia, in 2013 and 2010, respectively. He was a Post-Doctoral Fellow at KTH in 2010-2011 where he is currently a faculty member. He is also a Faculty Affiliate at Program on Energy and Sustainable development (PESD), Stanford University and Research Affiliate at German Institute for Economic Research (DIW Berlin). Dr Hesamzadeh is a senior member of IEEE, and a member of informs, IAEE and Cigre. He has won several awards for his papers in different professional events and conferences. He has published two books and numerous papers on electricity market design and analysis. He also served as editor of IEEE Transactions on Power Systems and Guest Editor of several other journals. Dr. Hesamzadeh has been providing advice and consulting services on different energy market issues to both private and government sections over the last several years.

Qixin Chen is a Tenured Associate Professor in the Department of Electrical Engineering at Tsinghua University, China. He currently serves as a deputy director of Energy Internet Research Institute at the same University. He is a Fellow of IET. His research interests include power market mechanism design and analysis, smart grid operation, dispatch and planning, low carbon electricity technology, etc.



Yue Zhou is a Lecturer in Cyber Physical Systems in the CIREGS centre of School of Engineering of Cardiff University. His research interests include power system demand side response, peer-to-peer energy trading, and distributed ledger technology (blockchain). He serves as a Subject Assistant Editor of the journal Applied Energy, and an Associate Editor of the journal IET Energy Systems Integration. He is also a Standing Director of Power Grid Operation & Control Subcommittee of IEEE PES Power System Relaying & Control Satellite Committee - China.

Jiajia Yang[1]
Z. Y. Dong[2]
Fushuan Wen[3]
Ramteen Sioshansi[4]
Mohammad Hesamzadeh[5]
Qixin Chen[6]
Yue Zhou[7]

[1] *University of New South Wales, Sydney, Australia*
[2] *Nanyang Technological University, Singapore*
[3] *Zhejiang University, Zhejiang, China*
[4] *The Ohio State University, Columbus, Ohio, USA*
[5] *KTH Royal Institute of Technology Campus Haninge, Stockholm, Sweden*
[6] *Tsinghua University, Beijing, China*
[7] *School of Engineering, Cardiff University, Cardiff, UK*

Correspondence
Jiajia Yang, University of New South Wales, Sydney, Australia.
Email: jiajia.yang@unsw.edu.au