DOI: 10.1049/stg2.12081

GUEST EDITORIAL

Blockchain technologies empowering peer-to-peer trading in multi-energy systems: From advanced technologies towards applications

In efforts to decarbonise electricity, transport, and heating sectors, policy makers facilitate the integration of renewable energy sources and demand side management in multi-energy systems. With the support of the smart grid, an increasing number of consumers start to produce, store, and consume energy using zero-carbon electricity and heating sources, for example, solar panels, electric vehicles, and air source heat pumps, giving them the new role of multi-energy prosumers. A flexible local energy market structure and intelligent operations of smart grid are crucial factors for accommodating the role of multi-energy prosumers. The blockchain technologies, for example, smart contracts and hypothetical technology, pave the path for the peer-to-peer (P2P) energy markets, which are open and accessible to prosumers with enhanced automation, security, and privacy. The state-of-the-art research and scientific innovations bring these advanced blockchain technologies towards applications into multi-energy systems.

This special issue aims to solicit the innovative research on the blockchain empowering peer-to-peer trading in multi-energy systems. The scope of the research includes a single (multiple) energy vector(s) (e.g., electricity, gas, or heat), technologies (e.g., blockchain, smart contracts, or machine learning), theories (e.g., P2P trading mechanisms, pricing schemes, communication protocols, or consensus mechanisms) and applications (e.g., blockchain platforms or prosumer-centric energy scheduling).

There are in total six papers accepted for publication in this Special Issue after the careful peer-review and revision process. The selected papers are broadly categorised into three topics, with details provided as follows:

1 | TOPIC A: DESIGN OF BLOCKCHAIN PLATFORMS AND PROTOCOLS FOR PEER-TO-PEER ENERGY TRADING

'Research on Key Technologies of P2P Transaction in Virtual Power Plant Based on Blockchain' proposed by Li *et al.* analysed the consensus mechanism and smart contract of the blockchain technology in order to support the transaction interaction between internal resources of virtual power plants. The interactions of multiple energy sources within the virtual power plants, including the solar photovoltaic, hydro power, wind power, storage equipment, and electric car, were modelled by the game theory. These energy sources optimally complement each other in a manner of the P2P energy trading under the designed blockchain networks.

'Evaluating the Added Value of Blockchains to Local Energy Markets–Comparing the Performance of Blockchain-Based and Centralized Implementations' proposed by Zade *et al.* investigated the potential applications of blockchain technologies on the local energy markets. A comparative performance analysis between a blockchain-based and a central local energy market was performed to highlight the requirement of local energy markets for blockchain technologies. A periodic double auction and settlement mechanism was designed to support the operation of blockchain-based local energy markets. The simulation results demonstrated that the computational efficiency and security of current blockchain technologies were unable to fulfil the requirements of local energy markets.

'Dual-Blockchain Based P2P Energy Trading System with an Improved Optimistic Rollup Mechanism' proposed by Yu *et al.* designed a dual-blockchain system for P2P energy trading to address the scalability issue caused by the long computational time of current blockchain technologies. The system consists of a primary blockchain and a secondary blockchain, in which the primary blockchain is responsible for storing transactions of P2P energy trading while the compute-intensive tasks are executed in the secondary blockchain. An Improved Optimistic Rollup mechanism was also proposed to facilitate the co-operation of the dual blockchains for improving the computational efficiency and ensuring the correctness and security of transactions. A prototype implemented on Fisco Bcos and Alibaba Cloud was developed to validate the proposed system.

2 | TOPIC B: ARTIFICIAL INTELLIGENCE IN SUPPORTING PROSUMER-CENTRIC LOCAL ENERGY SYSTEM

'A Multi-Objective Multi-Agent Deep Reinforcement Learning Approach to Residential Appliance Scheduling' proposed by Lu *et al.* designed a multi-objective reinforcement learning algorithm for the demand side management of residential prosumers. The multiple preferences of appliances were optimally scheduled by the deep Q-network, including the electricity cost, peak demand, and punctuality. The proposed model could reduce the cost and peak power while improving the punctuality, compared to the rule-based approach for appliance scheduling. This research provides a potential solution to optimally control increasing numbers of residential prosumers and targets on individual prosumers' preferences.

3 | TOPIC C: MANAGEMENT OF DISTRIBUTION NETWORKS WITH THE UPTAKE OF PEER-TO-PEER ENERGY TRADING

'Design Choices in Peer-to-Peer Energy Markets with Active Network Management: A Comparative Analysis of Allocation Methods in Representative German Municipalities' proposed by Regener *et al.* assessed the management of distribution networks and design of P2P energy markets in terms of the user acceptance, economic performance, practicability, and their ability to relieve the grid congestion. The competing allocation mechanisms were analysed under network constraints using multiple key performance indicators, including the communal revenues or welfare distribution. An agent-based simulation framework built on data from three German reference municipalities was performed. With the growing number of distributed energy resources and new electrical loads at the sectoral contact points, the research highlights current implementation obstacles and promising concepts on P2P energy trading.

'Prosumer-Centric Energy Storage System and High Voltage Distribution Network Topology Co-Optimization for Urban Grid Congestion Management' proposed by Zhang *et al.* co-optimised the energy storage systems and high voltage distribution networks to overcome the challenges brought by the involvement of prosumers and distributed renewable energy sources. A bi-level optimisation model was designed, through which the AC optimal power flow was solved in the upper level to reduce the network congestion and a mixed-integer second order cone programming model was built in the lower level for the high voltage distribution network reconfiguration. The proposed model is able to reduce the frequency of network reconfiguration while maintaining the transmission congestion.

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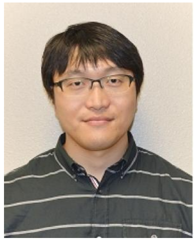

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