Guest Editorial
Introduction to the Special Section on Transactive Approaches to Integration of Flexible Demand and Distributed Generation

I. Introduction

ELECTRICITY as a sustainable energy carrier plays a central role in the most effective transition scenarios towards a sustainable energy system. To harness this potential, the current electricity infrastructure needs to be rigorously reengineered into an integrated and intelligent electricity system: the smart grid. In the future grid, demand response and response from distributed generation and storage is expected to be used on a large scale to perform active management of distribution grids and to balance the fluctuating power generation of renewable energy sources. Key elements of the smart grid vision are the coordination mechanisms. Through these, vast numbers of devices, currently just passively connected to the grid, will become actively involved in system-wide and local coordination tasks. In this light, market-based, transactive approaches are emerging as strong contenders for orchestrating the coordinated operation of so many devices.

In a transactive energy system, one is using value as a key operational parameter, i.e., operational decisions are made through an exchange of value-based information captured in transactions between participants. Whereas transactive or market-based coordination mechanisms are already used on the level of bulk power production, trade and transmission across the globe, the use of these mechanisms at the distribution level, integrating numerous flexible devices into the power system, is still a topic needing scientific advancement. Research into transactive energy is strongly interdisciplinary, involving the state of the art in power engineering, computer science, (micro-)economics and control engineering.

This Special Section brings together researchers and practitioners from industry, research laboratories and academia to present and discuss challenges and opportunities related to market-based and transactive approaches to the integration of flexible demand and distributed generation and storage. We followed a two-stage reviewing process. First, around 90 two-page extended abstracts were received and reviewed by the Guest Editorial Board. Of these, 32 led to an invitation to submit a full paper. Finally, we accepted 15 papers in this Special Section.

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The papers in this special section present multiple viewpoints on the topic of transactive energy systems. We group the papers into seven sub-topics: 1) Energy Collectives, Peer-to-Peer Trading and Prosumer Participation, 2) Design of Trading and Pricing Mechanisms, 3) Transmission–Distribution Interaction, 4) Technology Perspectives and Field Testing, and 5) Assessing and Comparing Transactive Energy Approaches. In the following, brief summaries of the papers are presented.

II. Energy Collectives, Peer-to-Peer Trading, and Prosumer Participation

1) "Energy Collectives: a Community and Fairness based Approach to Future Electricity Markets," by Fabio Moret, and Pierre Pinson, presents a community-based electricity market structure based on the concept of energy collectives and allowing prosumers to actively optimize their assets according to their preferences. The work introduces a third-party that supervises the interfacing with market and system operator and monitors the collective agreements between community members. Fairness indicators used in telecommunication systems have been adapted to assess community fairness in energy simulation studies.
2) "Multi-Class Energy Management for Peer-to-Peer Energy Trading Driven by Prosumer Preferences," by Thomas Morstyn, and Malcolm D. McCulloch, proposes a peer-to-peer energy market platform allowing prosumers to express heterogeneous preferences which could be financial, social, philanthropic or environmental. The multi-class energy management problem is solved in a distributed manner realizing scalability and prosumer data privacy. Receding-horizon Model-based Predictive Control has been used for a real-time implementation.
3) "Decision support for small players negotiations under a transactive energy framework," by Tiago Pinto, Ricardo Faia, Mohammad Ali Fotouhi Ghazvini, Joao Soares, Juan Manuel Corchado, and Zita Vale, proposes a decision support model to be used by small players in the electricity market to optimize their position in multiple alternative or complementary markets, for instance a combination of local markets, bilateral trades and wholesale markets

(through aggregators). For validation purposes, the approach is implemented in a multi-agent simulation framework running scenarios based on real data.

III. Design of Trading and Pricing Mechanisms

1) "Swing Contracts with Dynamic Reserves for Flexible Service Management," by Shanshan Ma, Zhaoyu Wang, and Leigh Tesfatsion, present a novel day-ahead market mechanism with regulation reserve zones and based on swing-contracts. In a swing-contract, an owner of dispatchable assets offers a set of viable power paths permitting greater flexibility in real-time. Market clearing optimizes both power and reserve needs and is performed through mixed integer linear programming.
2) "Eliciting Multi-dimensional Flexibilities from Electric Vehicles: A Mechanism Design Approach," by Bo Sun, Xiaoqi Tan, and Danny H.K. Tsang, present a novel auction scheme for coordinated electric vehicle (EV) charging. The scheme takes into account three types of EV flexibility: shift in fixed energy demand within the plug-in time horizon, energy-flexibility and deadline-flexibility. The resulting multi-dimensional flexibility problem is solved as a social welfare maximization problem.
3) "Pricing Mechanism for Flexible Loads using Distribution Grid Hedging Rights," by Sarmad Hanif, Philipp Creutzburg, Hoay Beng Gooi, and Thomas Hamacher, propose a pricing mechanism for a local, distributionlevel market system. Their mechanism combines distribution locational marginal prices and ex-ante scenario-based hedging rights. The proposed mechanism improves market competition, alleviates congestion and incorporates the inter-temporal energy requirements of flexible loads.
4) "A Dynamical Systems Approach to Modeling and Analysis of Transactive Energy Coordination," by Md Salman Nazir, and Ian Hiskens, develops an aggregate model of Distributed Energy Resources (DERs) under transactive control and a set of Markov transition equations over discrete ranges of price levels and their associated DER operating states. The proposed method demonstrates that power oscillations arising from synchronization of thermostatically controlled loads can be effectively avoided.

IV. Transmission–Distribution Interaction

1) "Aggregator Operation in the Balancing Market Through Network-Constrained Transactive Energy," by Junjie Hu, Guangya Yang, Charalampos Ziras, and Koen Kok, presents a coordination model that enables aggregators to participate in the system-wide, transmission-level, balancing market while avoiding congestion and voltage level violations locally in the distribution network.
2) "Local Energy Markets: Paving the Path Towards Fully Transactive Energy Systems," by Fernando Lezama, Joao Soares, Pablo Hernandez-Leal, Michael Kaisers, Tiago Pinto, and Zita Vale, proposes and evaluates a transactive energy system that integrates wholesale and local energy markets. Through an integrated transactive energy simulation, possible models for local market negotiation with active consumer participation are considered.

V. Technology Perspectives and Field Testing

1) "Autonomous Resilient Grids in an IoT Landscape – Vision for a Nested Transactive Grid," by Khosrow Moslehi, and Ranjit Kumar, present a design vision approaching autonomous power grids as an Internet of Things, with intelligence distributed among its components. The distribution grid is compartmentalized in a nested set of virtual microgrids each capable to act as a market while safeguarding the local grid constraints.
2) "A Distributed Electricity Trading System in Active Distribution Networks Based on Multi-Agent Coalition and Blockchain," by Fengji Luo, Zhao Yang Dong, Gaoqi Liang, Junichi Murata, and Zhao Xu, proposes a distributed electricity trading system for electricity prosumers within a distribution network. In a two-layered approach, a multi-agent system is used to negotiate electricity trading contracts between prosumers, while secure contract settlement is ensured by a Blockchain-based settlement system.
3) "A Graph-Based Loss Allocation Framework for Transactive Energy Markets in Unbalanced Radial Distribution Networks," by Alexandros Nikolaidis, Charalambos Charalambous, and Pierluigi Mancarella, presents a graph-based transparent loss allocation framework that harmonizes the physical attributes of the distribution grid with the underlying financial transactions in distributed market settings, which can be used to guarantee economic efficiency and fairness in future distributed transactive energy markets.
4) "Distributed Optimization Algorithm for Residential Flexibility Activation – Results from a Field Test," by Ana Soares, Oscar Somer, Dominic Ectors, Filip Aben, Jan Goyvaerts, Milo Broekmans, Fred Spiessens, Dennis Goch, and Koen Vanthournout, present results from a field test which uses transactive control based on dual decomposition. Control is considered at two levels: at the level of the residential customer's assets providing flexibility and at the district level for congestion management. In the latter case, the residential end users respond to flexibility requests from the Distribution System Operator through an Aggregator.

VI. Assessing and Comparing Transactive Energy Approaches

1) "Performance Evaluation for Transactive Energy Systems using Double-auction Market," by Jianming Lian, Huiying Ren, Yannan Sun and Donald J. Hammerstrom, propose a systematic performance evaluation procedure based on a comprehensive set of quantitative and qualitative performance metrics. The method compares performance of

different transactive energy systems under practical conditions such as information uncertainties, network effects, individual rationality, etc.

2) "Simulation-Based Valuation of Transactive Energy Systems," by Qiuhua Huang, Thomas McDermott, Yingying Tang, Atefe Makhmalbaf, Donald Hammerstrom, Andrew Fisher, Laurentiu Marinovici, and Trevor Hardy, propose a method to assess the value of transactive energy systems in specific use case scenarios, in order to increase the understanding of this value and to compare different transactive energy schemes and approaches in a systematic way. The method is based on an open-source co-simulation platform.

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