Guest Editorial Special Section on Real-World Challenges of TSO-DSO Coordination

POLICY directives and technological innovations have fostered the emergence of a hierarchical market structure, which consists of centralized and decentralized markets. It is envisioned that energy resources will be free to participate in all market structures at the same time to extract the maximum value to the grid and monetize their services. Under this market architecture, grid operators can procure energy services from assets connected both at transmission and at distribution level in a coordinated way. This structure requires an efficient network management and optimization, also for the benefit of Distributed Energy Resources (DERs) in the transition to a decarbonized economy. The same pool of resources may be used by Transmission System Operators (TSOs) and Distribution System Operators (DSOs), so actions by both can mutually affect each other.

Hence, TSOs and DSOs need to coordinate their activities in order to make the hierarchical market structure a reality. The volume of energy services procured by TSOs and DSOs by distribution-connected DERs has been increasing in recent years, posing real challenges in dealing with registration, bidding, interconnection power flows, conflicting objectives and adverse effects in each other's network operation and settlements issues. To keep the overall system operation secure and stable, distribution systems need to provide the available flexibility at the interface with the overlaying transmission grid following TSO instructions. At the same time, DSOs should be allowed to use the DER flexibility to avoid congestions and security problems in their own distribution systems. Moreover, multi-control-area cooperation among different TSOs and coordination between TSOs and energy producers who are providing cross-border services are essential to promote future market designs.

The aim of this Special Section is to publish original papers that range from innovative research advances tackling real-world challenges of TSO-DSO coordination to real-world demonstrations of the operation of integrated, system-based and coordinated markets and platforms. These platforms can be jointly set up by TSOs and DSOs together with suppliers and aggregators, for trading several grid services.

In response to the call for papers for this Special Section, 106 extended abstracts were received and evaluated: 49 were accepted for full paper submission and 57 were rejected. After a comprehensive review process, 14 high-quality full papers were finally accepted and are included in this Special Section.

In the first article, "Real-Time Estimation of Support Provision Capability for Poor-Observable Distribution Networks" by Jafarian et al., the authors evaluate the capability of a distribution network in providing active and reactive power support to the upstream transmission network in real-time, through coordinated control of DERs.

In the second article, "Deriving DERs VAR-Capability Curve at TSO-DSO Interface to Provide Grid Services" by Singhal et al., the authors discuss the implications of considering headroom while operating the DERs and its impact on the TSO's ability to utilize the DSO's reactive power (VAR) availability.

In the third article, "Coordinated Vertical Provision of Flexibility from Distribution Systems" by Früh et al., the authors propose a decentralized and hierarchical approach for the practical implementation of coordinated, vertical flexibility provision across multiple voltage levels.

In the fourth article, "Distributionally Robust Decentralized Scheduling between the Transmission Market and Local Energy Hubs" by Yin and Wang, the authors propose a multi-period scheduling framework that considers the coordination between the transmission network and distribution energy hubs.

In the fifth article, "On the Coordination of Transmission-Distribution Grids: A Dynamic Feasible Region Method" by Zhang et al., the authors propose a TSO-DSO coordination framework with temporal-coupled constraints embedded to achieve the effective interaction between the TSO and DSO with least information.

In the sixth article, "Pricing for TSO-DSO Coordination: A Decentralized Incentive Compatible Approach" by Sun et al., the authors propose a market-based approach with the consideration of individual rationalities, aiming at the coordination of TSO and DSOs.

In the seventh article, "TSO-DSO-Customer Coordination for Purchasing Flexibility System Services: Challenges and Lessons Learned from a Demonstration in Sweden" by Ruwaida et al., the authors present a real-word implementation of a TSO-DSO-customer coordination framework for the use of flexibility to support system operation.

In the eighth article, "Robust Coordinated Distribution System Planning Considering Transactive DSO's Market" by Kabiri-Renani et al., the authors propose a transactive distribution system expansion planning approach to investigate the profitability of the planning as the objective of investors.

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In the ninth article, "A Data-driven Approach to Estimate the Flexibility Maps in Multiple TSO-DSO Connections" by Silva et al., the authors propose a methodology to estimate flexibility existing on TSO-DSO borderline, for the cases where multiple TSO-DSO connections exist.

In the tenth article, "Grid Impact Aware TSO-DSO Market Models for Flexibility Procurement: Coordination, Pricing Efficiency, and Information Sharing" by Marques et al., the authors propose market models for flexibility procurement by TSO and DSOs, based on TSO-DSO coordination schemes.

In the eleventh article, "MILP Model for Optimal Day-Ahead PDS Scheduling considering TSO-DSO Interconnection Power Flow Commitment under Uncertainty" by Resener et al., the authors propose a mixed-integer linear programming (MILP) model for optimal day-ahead power distribution systems (PDS) scheduling considering the interaction of TSO and DSO.

In the twelfth article, "Asymmetrically Reciprocal Effects and Congestion Management in TSO-DSO Coordination through Feasibility Regularizer" by Weng, et al., the authors propose to formalize and quantify the asymmetrically reciprocal effects between the transmission and distribution systems.

In the thirteenth article, "Exploiting DERs' Flexibility Provision in Distribution and Transmission Systems Interface" by Pourghaderi et al., the authors propose a market-based framework to exploit DERs flexibility in distribution and transmission systems.

Finally, in the fourteenth article, "Transactive Energy Market Operation through Coordinated TSO-DSOs-DERs Interactions" by Ullah and Park, the authors propose a decentralized transactive energy market strategy integrating wholesale and local energy markets through coordinated interactions between TSO, DSOs, and DER owners.

We would like to thank the Authors for their innovative and valuable contributions, and the Reviewers for their excellent feedback and suggestions.

Special thanks go to the Guest Associate Editors who have handled the large number of submitted papers in the most effective way, namely ALEX PAPALEXOPOULOS, BABAK ENAYATI, FLORIN CAPITANESCU, IVANA KOCKAR, LUIS(NANDO) OCHOA, PENGWEI DU, and XIN FANG. We would also like to thank the current EiC, JOVICA MILANOVIĆ, for his endorsement.

Last but certainly not least, we would like to deeply thank BIKASH PAL for his constant support and guidance over the years.
We hope that you find this Special Section interesting and useful, serving as a reference for future work in the field.

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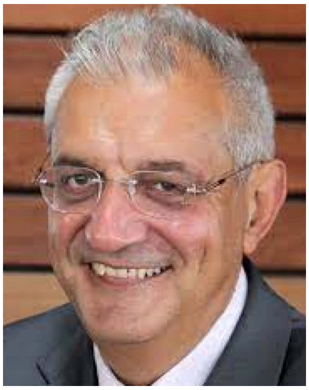

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