Guest Editorial Advanced Methods in Grid Operation and Planning With High Penetration of Distributed Energy Resources

FUTURE power grid will face tremendous challenges in operation and planning as a massive number of distributed energy resources (DER) are integrated into the system. Due to their limited visibility and controllability, it is imperative to study the impacts of a high penetration of DERs over the power grid, and to analyze and evaluate their reliability and economic benefits especially when they are enabled to provide essential reliability services in a large scale. The lack of DER modelling method is another barrier to the efficient integration of DERs into the existing operation, planning and market paradigm. This is also complicated by increasing complexities in the management systems developed to coordinate and control a large number of heterogeneous DERs.

The aim of this Special Section is to present the latest research efforts in modelling, control and value proposition of DERs. This issue also identifies issues that must be addressed for the adoption of DERs in a modern power system.

We were extremely impressed by the number of papers submitted in response to the Call for Papers and the spectrum of interests that the international community has for the integration of DERs into the power grid. This special section include 11 exceptional papers focusing on various topics from market operations, transmission operation planning and distribution system control. The final paper selection was made based on the quality of the papers and an attempt to balance a broad topic representation. The final papers were divided into four topical areas as follows.

I. Market Operations

"Scenario-based Economic Dispatch with Tunable Risk Levels in High-renewable Power Systems" introduced an empirical approach to dispatch resources in real-time power system operation with growing levels of uncertainties emerging from DERs. It does not require any knowledge of the underlying uncertainty distribution. By solving an uncertain economic dispatch problem, this approach limits the risk of potential reliability violations.

"Annual Optimized Bidding and Operation Strategy in Energy and Secondary Reserve Markets for Solar Plants with Storage Systems" presented an advanced market bidding and operation strategy for the joint participation of a solar power plant with storage in energy and reserve market. Evaluated with annual real market data, the most advanced strategy, which is a trade-off between market profits, battery cost and market technical fulfillment, can achieve additional 6.72% market gain compared to a base case.

"A Data-Driven Model of Virtual Power Plants in Day-Ahead Unit Commitment" presented a way to allow DERs to provide valuable services by aggregating them and participating in the wholesale market as a virtual power plant (VPP). The problem of dispatching DERs with an intermittent and variable output is solved through a distributionally robust optimization approach.

II. Transmission Operation and Planning

"Nonlinear Control for DC MicroGrids Enabling Efficient Renewable Power Integration and Ancillary Services for AC Grids" proposed a nonlinear control for direction current (DC) microgrids in order to provide frequency support to the main alternating current (AC) grid. The introduced controllers are shown to ensure grid stability, both by a poof using Lyapunov techniques and by simulations.

"Distributed Formal Analysis for Power Networks with Deep Integration of Distributed Energy Resources" presented a scalable distributed formal analysis to efficiently evaluate the stability of a large-scale interconnected power grid under heterogeneous disturbances induced by a high penetration of DERs. This provides an invaluable tool for designing and operating a future power grid, which features the deep integration of DERs.

"Transmission Network Investment with Distributed Energy Resources and Distributionally Robust Security" recognizes that DERs have the potential to significantly contribute to network security and hence release latent capacity of existing transmission assets. It developed a two stage optimization model to determine the optimal portfolio of DER services necessary to displace, in a secure fashion, inefficient network investment.

III. Transmission and Distribution Coordination

"Generalized Master-Slave-Splitting Method and Application to Transmission-Distribution Coordinated Energy Management" proposed a new model based on a generalized

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master-slave-splitting (G-MSS) method to study the interdependency between transmission networks and distribution systems when a large number of DERs are present.

IV. Distribution System Control

"A Fully Distributed Hierarchical Control Framework for Coordinated Operation of DERs in Active Distribution Power Networks" introduced a hierarchical framework to economically manage multiple DERs within three layers in an active distribution power network while ensuring a satisfactory frequency response.

"Distribution System State Estimation to Support Coordinated Voltage-Control Strategies by Using Smart Meters" proposed a novel distribution system state estimation method based on the information provided by smart meters to support coordinated voltage control strategies. The test results show that the proposed method is effective in the case of loss of communication between smart meters and the control system, which allows a central voltage control strategy in real time.

"Distribution System Voltage Control under Uncertainties using Tractable Chance Constraints" adopted a chance constraint approach to account for correlations between renewable resources for better reactive power compensation so as to control voltage in the presence of uncertainties.

"Two-Stage Distribution Circuit Design Framework for High Levels of Photovoltaic Generation" examined the design of modern distribution circuit topologies for accommodating high photovoltaic (PV) generation, while addressing power quality concerns. The proposed approach can increase the PV hosting capacity of the IEEE 123-bus test feeder system by 53%.

As guest editors of this volume, we thank all of the authors for their innovative works in this important area. We are also grateful to our many colleagues who reviewed the submitted papers and assisted greatly in improving the quality of those manuscripts. Special thanks are owed to the Editor-in-Chief of the IEEE Transactions on Power Systems, Dr. Nikos Hatziargyriou, for providing us this great opportunity.

T. Zheng, *Guest Editor*
ISO New England
Holyoke, MA 01040 USA

P. Du, *Guest Editor*
The Electric Reliability
Council of Texas
Austin, TX 78744 USA

J. Tong, *Guest Editor*
PJM Interconnection
Norristown, PA 19403 USA