Guest Editorial: Special Section on Battery Energy Storage Systems for Net-zero Power Systems and Markets

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BATTERY energy storage technologies have witnessed both dramatic cost reduction and technical evolution in recent years. This is leading to widespread deployment of battery energy storage systems (BESSs) worldwide, particularly to support operation of power grids with already deep penetration of renewables. Considering the development of new battery technologies with different power-to-energy ratios and for various engineering applications, BESSs could play a strategic role towards a net-zero energy future. New opportunities are emerging for BESSs to participate in several markets, provide different grid services, and perform "value stacking", eventually allowing development of new business cases and improved BESS economics. BESS configurations that are "behind the meter", "in front of the meter", hybrid plants co-located with renewables, and so forth, are only some of the exciting propositions that are being seen in different countries and at different scales, from highly distributed (virtual power plants), to neighbourhood-level (community batteries), to utility scale.

This Special Section aims to address technical, economic, commercial, regulatory, and environmental aspects of the most recent developments in BESSs, with particular interest in real-world applications. It includes 15 papers that cover different broad topics, namely, "value", "operation", "market", and "planning".

The crucially important issue of "value" is dealt with by the three opening papers of the Special Section. The paper "Storing Freshwater Versus Storing Electricity in Power Systems with High Freshwater Electric Demand" discusses the complementary use of BESS and other forms of storage, looking at economic and reliability perspectives and considering different renewables scenarios. The paper "Co-optimization of Behind-the-meter and Front-of-meter Value Streams in Community Batteries" proposes new techno-economic arrangements and business models for value stacking different grid and market services for neighbourhood BESSs. The paper "Low-carbon Dispatching for Virtual Power Plant with Aggregated Distributed Energy Storage Considering Spatiotemporal Distribution of Cleanness Value" presents a model aimed at internalising the environmental benefits and creating relevant value from distributed storage aggregated in virtual power plants.

"Operation" of BESSs is addressed under different perspectives in five papers. The paper "Optimal Operation with Dynamic Partitioning Strategy for Centralized Shared Energy Storage Station with Integration of Large-scale Renewable Energy" discusses optimal energy trading among multiple distributed entities that interact with and through a centralized shared BESS. In the same vein, the paper "Real-time Energy Management for Net-zero Power Systems Based on Shared Energy Storage" presents two shared energy storage models, referred to as "energy storage sale model" and "power line lease model", also suitable for community peer-to-peer trading. Focusing on building-level energy systems, the paper "Improved Energy Management Strategy for Prosumer Buildings with Renewable Energy Sources and Battery Energy Storage Systems" looks into a new operational optimization approach for a combined renewables-BESS scheme, including consideration of battery performance degradation and loss of technical life. The paper "Distributed Stochastic Scheduling of Massive Backup Batteries in Cellular Networks for Operational Reserve and Frequency Support Ancillary Services" takes a system-level perspective to demonstrate how backup BESSs could be efficiently adopted as demand-side resources to provide reserve and frequency response services to the grid. The paper "Multi-scale Fusion Model Based on Gated Recurrent Unit for Enhancing Prediction Accuracy of State-of-charge in Battery Energy Storage Systems" finally deals with forecasting aspects of storage operation, through an approach specifically designed for complex multi-step state-of-charge prediction in practical BESS applications.

Four papers focus on "market" aspects of BESS. The paper "Optimal Offering of Energy Storage in UK Day-ahead

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Energy and Frequency Response Markets" introduces a new modelling method for optimal storage bidding across multiple markets considering uncertainty in the utilization factor of frequency response products. The issue of optimal bidding across energy and frequency control markets is also addressed in the paper "Optimal Bidding Strategy for PV and BESSs in Joint Energy and Frequency Regulation Markets Considering Carbon Reduction Benefits", with additional consideration of positive environmental outcomes through participation in carbon markets, too. The paper "Distributed Source – Load – Storage Cooperative Low-carbon Scheduling Strategy Considering Vehicle-to-grid Aggregators" deals with market participation of distributed storage in the form of electric vehicles, by proposing a cooperative scheduling model that brings together a distribution system operator and electric vehicle and load aggregation entities. Aligned with several papers above on shared energy storage, but focusing more on market and commercial aspects, the paper "Multi-time-scale Resource Allocation Based on Long-term Contracts and Real-time Rental Business Models for Shared Energy Storage Systems" introduces a modelling framework to design various long-term energy and capacity contracts with associated real-time rental models.

The last part of the Special Section is dedicated to "planning" and consists of three papers. The industry-led paper "Virtual Transmission Solution Based on Battery Energy Storage Systems to Boost Transmission Capacity" discusses the two-BESS scheme that has been proposed in Chile to provide $N-1$ transmission capacity enhancement via post-contingency operation ("grid booster" functionality), thus improving system stability while increasing the share of renewables that could be integrated under normal conditions. The paper "An Analytical Method for Delineating Feasible Region for PV Integration Capacities in Net-zero Distribution Systems Considering Battery Energy Storage System Flexibility" provides an analytical model and discussion to assess the benefits that BESS can bring to enhance the hosting capacity of a distribution network with solar PV. Finally, the paper "Optimal Design of Hybrid Microgrid in Isolated Communities of Ecuador" analyses optimal system operation and design of a rural microgrid for different scenarios and considering the role that a BESS could play in the context of a renewables-based community.

We are grateful to all the participating authors for considering submitting their works to this Special Section, all the Guest Editors who have competently and promptly taken care of assigning the paper reviews, and of course all the reviewers without whom no research journal enterprise could succeed. We would also like to thank Prof. Antonio Gómez-Expósito for suggesting this Special Section and following closely its development, and all the MPCE editorial office staff for their impressive administrative and editorial support.

Hopefully the readers will enjoy this Special Section at least as much as we did in putting it together!