Guest Editorial
Special Section on Sustainable Energy for Enhancing Grid Resiliency

EXTREME weather threatens lives, disables communities, and devastates energy generation, transmission, and distribution systems. These extreme events are likely to become more frequent or more intense due to climate change. Energy networks have shown significant vulnerability during record hurricanes, deadly heat waves, destructive wildfires, and winter storms in the past few years. Because of the energy transition process, modern power grids will feature a high penetration level of the use of renewable resources. The adoption of renewable energy and the rise of omnidirectional power delivery mean that our energy network is more decentralized than ever. In this new environment, grid operation becomes more complex, and achieving resiliency is more difficult than in the past. Many utilities are seeking the latest technologies to improve energy security and responsiveness to severe events. On the one hand, sustainable energy resources can provide emergency power and assist grid restoration in disastrous events. On the other hand, their volatility, susceptibility, interdependency, and other unique features must be carefully considered when being used for grid resilience enhancement.

This special section brings together 22 papers that range from innovative research advances tackling fundamental challenges of achieving more resilient grids to real-world demonstrations of leveraging sustainable energy resources to enhance grid resiliency. These papers can be categorized into three groups.

I. Service Restoration and Blackstart Using Sustainable Energy

"Utilizing Aggregated Distributed Renewable Energy Sources with Control Coordination for Resilient Distribution System Restoration" by Liu et al. proposes a critical load restoration method with a two-step distribution system operator - distributed energy resource management systems interaction paradigm to coordinate the control of renewable energy resources.

"A Secure and Adaptive Hierarchical Multi-timescale Framework for Resilient Load Restoration Using a Community Microgrid" by Shirsat et al. presents a secure and adaptive three-stage hierarchical multi-timescale framework for proactive and resilient scheduling and dispatch of community microgrids during emergency conditions.

"Autonomous Restoration of Grid-Forming Inverter-based Networked Microgrids" by Banerjee et al. proposes and evaluates an autonomous microgrid restoration concept using grid-forming inverter-based resources and smart circuit breakers.

"Hierarchical Combination of Deep Reinforcement Learning and Quadratic Programming for Distribution System Restoration" by Mehdi et al. proposes a model for hierarchical coupling of deep reinforcement learning (DRL) with integer optimization, where optimal power dispatch within integrated hybrid resources is determined by a DRL-trained controller, while a grid-level optimization model checks grid constraints and performs critical operations.

"An Integrated Situational Awareness Tool for Resilience-Driven Restoration with Sustainable Energy Resources" by Qin et al. proposes a resilience-driven restoration scheme using the most updated information from an integrated and enhanced situational awareness tool based on kernelized Bayesian state-space inference with Markov Chain Monte Carlo and multiple optimization algorithms.

"Power System Restoration with Renewable Participation" by Qiu et al. explores the potential benefits of renewable energy in restoration and potential ways for variable renewable energy to participate in system restoration.

"Model Predictive Control Based Voltage Regulation Strategy Using Wind Farm as Black-Start Source" by Liu et al. develops a coordinated voltage regulation method based on model predictive control for utilizing wind farms as a black-start source to start up thermal generating units.

"A Post-Event Generator Start-Up Strategy for Renewable Penetrated Transmission System Considering Dynamic Frequency Regulation" by Jiang et al. proposes a deterministic post-event generator start-up strategy where the conventional and renewable units are co-operated.

"Distribution Service Restoration with Renewable Energy Sources: A Review" by Alobaidi et al. reviews the state-of-the-art frameworks proposed for service restoration in distribution networks with renewable generation technologies.

II. Resilience-Oriented Planning With Sustainable Energy

"Grid Resilience With High Renewable Penetration: A PJM Approach" by Chen et al. describes a PJM approach to evaluate and analyze the impact of high renewable penetration on grid

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resilience, formulate plans to be prepared for such impact, and use market mechanisms to improve grid resilience.

"Risk-based Active Distribution System Planning for Resilience against Extreme Weather Events" by Poudyal et al. presents a risk-based planning framework for active power distribution systems to improve their resilience to extreme weather events.

"A Resilience-Oriented Multi-Stage Adaptive Distribution System Planning Considering Multiple Extreme Weather Events" by Wang et al. develops a multi-stage hybrid stochastic-and-robust formulation to model decisions not only for initial investments, but also for adaptive investments and emergent operations in response to particular extreme events, while considering both long-term and short-term uncertainties.

"Optimal Energy Storage System and Smart Switch Placement in Dynamic Microgrids with Applications to Marine Energy Integration" by Wu et al. proposes a dynamic microgrid planning methodology that optimally places energy storage systems and smart switches so that a dynamic microgrid with marine renewable energy is warranted with proper resource adequacy and topological flexibility in both contingency and normal operations.

"Coordinated Planning Strategies of Power Systems and Energy Transportation Networks for Resilience Enhancement" by Xu et al. proposes a two-stage planning model to coordinate the expansion strategies of power systems and energy transportation networks considering the resilience constraint.

"On Machine Learning-Based Techniques for Future Sustainable and Resilient Energy Systems" by Wang et al. reviews multi-energy system resilience quantification methods and the application of machine learning-based techniques to assess the resilience level of future sustainable energy systems.

III. Optimal Control and Management of Sustainable Energy for Resilience Enhancement

"Quantitative Metrics for Grid Resilience Evaluation and Optimization" by Yao et al. develops a new set of quantitative metrics with clear physical interpretation to comprehensively evaluate power system resilience. Using microgrids as an example, an event-based corrective scheduling model and an online model predictive control model are developed to integrate the proposed quantitative resilience metrics into power system optimization models for resilience enhancement.

"Inertia and Frequency Support from Britain's AC Powered Trains" by Henderson et al. assesses the resource and analyzes the impact of using already existing AC electric multiple-units in Great Britain to provide inertia support and frequency support during large frequency events.

"Resilience Constrained Scheduling of Mobile Emergency Resources in Electricity-Hydrogen Distribution Network" by Cao et al. proposes a tri-level risk-constrained mixed-integer programming formulation for resilient scheduling of electricity-hydrogen distribution network under disastrous situations.

"Multi-segment Decentralized Control Strategies for Renewables-rich Microgrids in Extreme Conditions" by Yan et al. proposes a fully decentralized control strategy without the need of communication for islanded microgrids with a high penetration level of renewables, which can be used in extreme cases where communication links are unavailable and DER statues are unknown.

"Resilience-based Coordinated Scheduling of Cascaded Hydro Power with Sequential Heavy Precipitation" by Wang et al. investigates thermal units and cascaded hydro units in consideration of sequential heavy precipitation to improve power source resilience.

"Controlled Islanding Resilience with High Penetration of Renewable Energy Resources" by Ma et al. develops a stochastic cascading failure model to assess the resilience of islands against cascading failures under a high penetration level of renewables.

"Photovoltaic System Control for Power System Frequency Support in Case of Cascading Events" by Baskarad et al. presents a novel control algorithm to enable rapid recovery of PV power reserve, which makes the PV system capable of providing support to the cascading disturbance events.

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