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A Two-Stage Framework for Power System Resilience Assessment: Process Design and a Case Study in Kinmen

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Abstract

This study proposes a two-stage power system analysis framework to assess the resilience of power systems in a practical decarbonization pathway when facing high-impact, low-frequency (HILF) events. The first stage utilizes integrated resource planning (IRP) models and power system simulation tools to design cost-minimized and practical decarbonization pathways from development and operational perspectives. Based on the optimal decarbonization pathway, the second stage conducts resilience analysis for HILF events, including HILF event selection, equipment damage probability assessment, system impact analysis, and resilience performance assessment based on generalized resilience metrics.

The case study examines the Kinmen region with a 2030 carbon intensity target of 0.4 kg CO2e/ kWh. This study explores its power system resilience under a HILF event (in this study, tsunami) and potential improvement strategies. In the first stage, simulation results indicate that substantial solar PV deployment and the introduction of energy storage systems are essential to increase renewable energy penetration and reduce thermal power generation reliance. In addition, based on the power system's grid structure, the locations of future solar PVs should be carefully planned to avoid bottlenecks in the substations due to the potential reverse power. In the second stage, this study examines 48 scenarios featuring different outcomes of substations and decentralized levels/ advanced functions of battery storage systems. It assesses their resilience performance using a set of generalized resilience metrics developed in this study. The generalized resilience metrics effectively quantify system resilience across different scenarios, providing actionable insights for system enhancement. The findings suggest dispersed energy storage systems with auxiliary service capabilities significantly enhance the power system's resilience.