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## **Integrated Risk Assessment for Enhancing Power System Resilience against Large-Scale Natural Disasters**

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### **Abstract**

The frequency and severity of large-scale natural hazards have increased in recent years, heightening concerns over their impacts on electric power infrastructure and operations. In parallel, the transition toward a 2050 carbon-neutral power sector—characterized by higher renewable penetration, grid decentralization, and new transmission development—introduces additional complexity and interdependencies. These trends underscore the need for integrated risk assessment frameworks that incorporate disaster resilience from the earliest stages of system planning, facility design, and operational strategy.

This presentation introduces a practical approach to resilience enhancement centered on power supply–demand simulation under extreme events. We introduce a framework that couples models of asset damage, restoration processes, generation capacity constraints, transmission limitations, and dynamic demand recovery to estimate the magnitude and duration of potential supply–demand imbalances. While our case study focuses on long-term power shortage risks following large-scale earthquakes and associated cascading impacts, the methodology is designed to be hazard-agnostic and extensible to typhoons, floods, storm surges, wildfires, heatwaves, and compound or sequential events. By parameterizing hazard footprints, outage mechanisms, restoration pathways, and demand profiles, the framework supports consistent scenario analysis across diverse risk contexts.

The simulation outputs quantify risk in operationally meaningful terms (e.g., unserved energy over time, regional deficits, critical bottlenecks), enabling the evaluation of countermeasures such as targeted hardening, redundancy enhancement, strategic spares and mobile resources, flexible demand measures, and coordinated restoration strategies. We further discuss how the results can inform prioritization, resource allocation, and resilience investment planning under uncertainty, including the use of sensitivity and stress testing to reveal tipping points and no-regret actions. Overall, the study aims to provide actionable insights for operators, planners, and policymakers seeking to build robust, adaptable, and sustainable power systems capable of withstanding and rapidly recovering from large-scale natural disasters within a multi-hazard risk management paradigm.