Multi-Timescale Nuclear-Renewable Hybrid Energy Systems Operations to Improve Electricity System Resilience, Reliability, and Economic Efficiency

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Program: NE-2.3: Systems Control

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ABSTRACT:

Nuclear and renewable energy sources are important to consider in the U.S. economy's evolution because both are clean, non-carbon-emitting energy sources. Advanced nuclear-renewable hybrid energy systems (N-R HESs) composed of nuclear and renewable energy sources, industrial energy users, and energy storage systems are being evaluated for their economic benefit and technical feasibility. N-R HESs have been proposed as a technology that can generate very low-carbon, dispatchable electricity and provide very low-carbon energy to industry at a lower cost than many other options.

Beyond classic energy-shifting services, N-R HESs may be able to provide a suite of services at finer time-scales to promote a safer and more reliable integration of renewable energy resources. ***The overarching objective of this project is to develop a multi-timescale N-R HESs operations framework to provide different types of grid products.*** The benefits of two N-R HESs will be evaluated: (i) one with a nuclear reactor, wind power plant, an industry thermal user, and energy storage; and (ii) one with a nuclear reactor, solar power plant, an industry thermal user, and energy storage. We aim to model and analyze the capabilities of N-R HESs to provide power grid services at different operation timescales ranging from seconds to days, such as day-ahead unit commitment, flexible ramping (5-45 minutes), regulation reserves (1-5 minutes), and frequency response (less than seconds). This innovative holistic multi-timescale N-R HESs operations strategy is expected to improve electricity system resilience, reliability, and economic efficiency by exploring more benefits that accrue to both N-R HESs and other grid assets. The following four research thrusts will be investigated in this project:

- **Data-Driven Short-term Load and Renewable Generation Forecasting:** This research thrust will pursue research activities to model and forecast the wind/solar power generation, load/netload (at different levels of aggregation) with high penetrations of renewables and distributed energy resources, and extreme ramping events in renewables and load/netload.
- **Short-term Multi-Timescale N-R HES Operation:** The team will explore the market opportunities available for N-R HES to participate in energy and ancillary markets and develop optimal strategies for bidding N-R HES into the bulk grid or for industry thermal users.
- **N-R HES and Electricity Grid Resilience:** The team will develop a power system disruption management framework (PODIM) for enhanced resilience of N-R HESs, which utilizes smart operational enhancement strategies such as N-R HES control, storage, or curtail strategy, to minimize the negative impacts due to disruptive events, thereby improving the overall energy system reliability and resilience.
- **Hardware-in-the-loop (HIL) Test:** The team will conduct the thermal-electrical HIL simulation and laboratory demonstration for the developed multi-timescale N-R HES operations control and disruption management platform in improving electricity system resilience, reliability, and economic efficiency.