Dynamic Modeling, Optimization and Techno-economic Analysis of Integrated Energy Systems for S odium Fast Reactors

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Program: CT-2: Integrated Energy Systems Design and Modeling

ABSTRACT:

Given the growing penetration of solar and wind, nuclear energy is increasingly being seen as complementary to solar and wind energy. In achieving a carbon pollution-free power sector by 2035, nuclear energy is expected to play an instrumental role. Natrium is designed to seize this opportunity serving as both baseload and fast burst resource. As the first of its kind, the Natrium system is an advanced nuclear energy system directly coupled to energy storage based on sodium fast reactor (SFR) technology. With the molten salt thermal energy storage, it features a 345 MWe nominal power with the potential of peak power output of 500 MWe for more than 5.5 hours when needed. This enables nuclear power plants to follow daily electric load changes and helps customers capitalize on peaking opportunities driven by renewable energy fluctuations.

While Natrium provides higher energy efficiency and flexible power output compared to existing nuclear power plants based on light-water reactor technology, additional design improvement and optimization from current Natrium system can further improve its economic potential. Integrated with other energy systems, Natrium can become more versatile and be expanded to diverse energy markets where significant penetration of wind and solar are experienced and/or expected, including ERCOT (Electric Reliability Council of Texas), APS (Arizona Public Service), and MISO (Midcontinent Independent System Operator).

In this project, the university and national lab teams will work closely with the Natrium team to explore greater design space for Natrium's Energy Island and other innovative IES design options including hydrogen production and storage, water desalination to meet various deregulated markets in the U.S. High-fidelity, Modelica process models will be developed to evaluate various innovative IES designs. Meanwhile, the project is expected to enrich the existing open-source library of IES modeling tools for advanced nuclear reactors. Two-layer optimization and stochastic techno-economic analysis (TEA) will be performed using the Risk Analysis and Virtual ENviroment (RAVEN) and Holistic Energy Resource Optimization Network (HERON) platform. The IES designs and associated TEA will help inform future design decisions for Natrium and similar advanced reactor systems. In addition, this work will demonstrate the importance of integrating nuclear energy with other renewable energies (e.g., solar and wind) in achieving carbon pollution-free power sector by 2035.