
Proactive Hybrid Nuclear with Load Forecasting

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ABSTRACT:

The main objective of the project is to improve the design and optimize the dispatch of nuclear hybrid energy systems (NHES) coupled with energy storage and to evaluate those systems for economic benefit and technical feasibility. To do this, we propose an extension of the capabilities of RAVEN to include improved forecasting, dispatch optimization, and design optimization with a combination of new and proven methods. A new method is improved forecasting with blended machine learning that combines the latest advancements in data-driven modeling with physics-based elements. Inaccurate forecasts lead to sub-optimal dispatch solutions and in some cases, produce an outcome that is worse than using no forecast. The improved forecasting attempts to improve upon Autoregressive Moving Average (ARMA) models that are used in the existing workflow. Another innovation of this project is the integration of two new tools with RAVEN. The first is the GEKKO Optimization Suite that is designed for efficient dispatch of large-scale hybrid energy systems. GEKKO is proposed to replace the existing dispatch optimization method in RAVEN. GEKKO offers an interface to large-scale gradient-based optimizers that use warm-start methods, forecasts, and dynamic models to efficiently achieve a minimized effective levelized cost of electricity (eLCoE). The evaluation of optimized eLCoE is performed many times as new unit capacities are generated by RAVEN so it is important that this inner step is efficient and effective at finding the best solution. A second innovation is to determine novel nuclear designs that further improve the eLCoE. The integration of the nuclear design package OPTIONS is proposed as another extension of RAVEN capabilities. Two experimental studies will validate the software innovations. The first is a lab-scale energy storage system that emulates temperatures within the primary and secondary containment loops of a nuclear reactor. This experimental study is proposed to validate the models with phase changing materials to enable large energy thermal storage. Industrial instrumentation and controls will be used to regulate the small-scale system. The hardware control system will be documented, and a data repository created as a benchmark test case for further development. The second experimental validation is proposed with a full-scale district energy system that includes thermal and electrical generation, energy storage, and demand profiles for campus-wide users. The RAVEN-enhanced tools will be tested over a one-year period to determine the improved eLCoE and validate the software for real-time use. As a final step, the improved RAVEN capabilities will be generalized for optimal dispatch and design of other NHES concepts that may include nuclear integration with petroleum oil refining, natural gas reforming to produce hydrogen, ammonia/ammonia-based products, methanol, olefins, synthetic fuels, biomass conversion to biofuels, and reverse osmosis (RO) desalination. This project is critical to the nuclear energy program because it will provide an improved workflow for design and operation of NHES. As a baseload power and heat source, nuclear is made adaptable to load changes through coupling with other systems. The proposed methods will allow reactor development teams to quickly run different scenarios, discovering improved options, and optimize the dispatch control of hybrid systems.