Modeling and Experimental Verification of Thermal Energy Storage Systems to Enable Load Following Capability for Nuclear Reactors

PI: Dr. Richard N. Christensen, University of Idaho

Collaborators: Dr. Matthew J. Memmott, Brigham Young University
Dr. Piyush Sabharwall, Idaho National Laboratory

Program: NE-2: Hybrid Energy Systems Design and Modeling

ABSTRACT:

The proposed work aims at integrating new thermal energy storage (TES) models developed in Modelica with ongoing nuclear-renewable hybrid energy systems (NRHES) modeling efforts, and perform optimization in RAVEN, to evaluate the economic potential and advantages of the new process designs over baseload electricity production. It also aims to scale, design, test and optimize the TES systems to be later integrated with the Idaho National Laboratory's Dynamic Energy Transport And Integration Laboratory (DETAIL) for integrated systems testing.

Renewable energy penetration has increased over past few years and with the current DOE programs and SunShot efforts, the penetration would further increase. However, due to the intermittent nature of these energy sources, caused due to their dependence on geographical and weather conditions, instabilities in the grid and price fluctuations in the electricity market have also increased. Such instabilities can be overcome by implementing a NRHES. The NRHES is an integrated system comprised of nuclear reactor, renewable energy source, and industrial processes that can simultaneously address the need for grid flexibility, greenhouse gas emission reductions, and optimal use of investment capital. In order to make the NRHES technology more attractive, it is herein proposed to couple the NRHES with a thermal energy storage (TES) system, to which excess heat not demanded by the grid for electricity production can be allocated to, for later use when there is high demand or low renewable energy contribution.

The objective of this work is to evaluate the potential and economic benefits of advanced NRHES systems integrated with TES systems. The computational phase of this project will include the development of mathematical and physics based models of TES systems, which could later be translated to Modelica and integrated with some of the existing NRHES components. The testing and optimization of these models will be conducted using RAVEN. A techno-economic analysis will be performed to evaluate the compatibility of the newly formed integration of TES and NRHES, as well as to quantify its feasibility and economic benefits. The experimental aspect is more focused on the development of scaled TES systems, which will not only serve as verification for the models generated in Modelica, but also allow for integrated systems testing upon being integrated with the INL DETAIL.

The following deliverables are to be developed to quantify the potential of the integrated NRHES - TES system: (i)Development of mathematical and physics based models of TES systems (ii) Acquire thermophysical characteristics of molten salts (iii) Scale, design and test TES systems (iv) Perform comparative analysis and verification based on experimental and modeling results (v) Integrate developed models into existing NRHES models (vi) Evaluate results and perform optimization of integrated systems.

The proposed study involves two universities and one national laboratory, and will have significant impact on undergraduate and graduate education, and training of post-doctoral researchers. This research will help develop future workforce for the U.S. nuclear industry