HERON: A New Code for Optimal Dispatch of Nuclear Power

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Flexible Plant Operation and Generation Pathway

The LWRS Program is developing a computer code that will help utilities evaluate future operating options for nuclear power plants. With electricity grid operations undergoing rapid but far-reaching changes, nuclear power plant owners and utility companies need to understand the lifetime financial benefits of LWR plant operations that involve switching between electricity production for the grid or directly providing thermal and electrical energy to an industrial. For example, the nuclear plant could apportion electricity between the grid and an electrolysis plant that produces hydrogen or a water desalination plant that produces fresh water.

Due to the expansion of wind and solar energy and the rapid growth of natural gas power plants, nuclear power plants in some regions may not always operate as baseload plants, but may need to dispatch power to the grid to make up the difference between electricity grid demand and supply provided by other sources, including renewable energy. With flexible operation and generation, nuclear power plants may distribute energy to an industrial process in a dynamic manner that optimizes the revenue of nuclear power plant owners. Some type of energy storage may be required to satisfy the time-of-day needs of the electricity grid and the industry user. A computational code that is capable of projecting and analyzing the integrated system capital and operating costs and cash flow is needed to help optimize the revenue to each of the partners.

A new code, named HERON for Holistic Energy Resource Optimization Network, is being developed as a plugin to RAVEN (Risk Analysis Virtual ENvironment)—a model that was developed to optimize the performance of a complex system. Together, HERON and RAVEN make it possible to account for the increasing random behavior of electricity markets when evaluating key nuclear power plant operating decisions or capital projects. The code characterizes key stochastic trends that account for variables such as solar cycle and weather correlations with variable renewable energy generation, electricity demand, and market pricing. The code creates synthetic time histories for grid hourly pricing for the projected life of a given LWR flexible plant operation and generation system, which may be up to 30 or 40 years. This allows meaningful decisions to be made relative to the economic viability of hybrid LWR configurations and operations under conditions specific to a region and grid.

A detailed technical description of the joint RAVEN/HERON code can be found at the LWRS Program reports webpage for Flexible Plant Operation and Generation [1]. The iterative workflow is represented in Figure 3. The inner loop generates stochastic behaviors and synthetic time histories for dispatch schedules relative to capacity additions and LWR hybrid plant operating boundaries and response limits. The outer loop manages the physical size of the flexible plant operation and generation system components. This can be executed by two modes: sweep mode and optimization mode. In sweep mode, various combinations of component capacities are sampled in order to obtain an understanding of how economic metrics change with respect to changes in the component capacities. This can yield differential economic proforma or sensitivity results. In optimization mode, the outer loop seeks the cost-minimizing or profit-maximizing component capacities by exploring the variable space made up of the component capacities.

As an example, HERON/RAVEN was recently employed in a Cooperative Research and Development Agreement (CRADA) [2] study with Exelon and FuelCell Energy to analyze an integrated LWR electrical power and hydrogen

production facility in the Midwest. The code was used to assess the NPV of the systems as a function of the size of the hydrogen plant, the optimal schedule for producing hydrogen or sending electricity to the grid, and the size of hydrogen storage that is needed to ensure a constant supply of hydrogen to industrial users. This optimized system was used to identify attributes of profitability for the affiliated partners under a range of market conditions.

LWRS Program researchers are currently testing the RAVEN/HERON code for regulated and deregulated market conditions. The goal is to make this computer code available to LWR owners and utilities interested in evaluating flexible plant operation and generation alternatives early in 2021. New integrated system configurations will be added to the code to expand the capability of the model beyond hydrogen production. Future capabilities may include new electrochemical processes for polymers or chemicals production, wastewater treatment, or plastics recycling. The code will help evaluate these alternatives to help guide nuclear plant owners in making strategic decisions relative to the best markets and optimal modes of plant operations.

References

1. Flexible Plant Operations Reports: https://lwrs.inl.gov/SitePages/GroupedReports.aspx?ReportCategory=Flexible%20Plant%20Operation%20and%20Generation.
2. The CRADA was cost shared among the industrial partners and Department of Energy Office of Nuclear Energy Crosscutting Technology Development Integrated Energy Systems program and DOE office of Energy efficiency and Renewable Energy Fuel Cell Technology Office.

Figure 3. RAVEN/HERON model workflow.