HERON: A New Tool for Assessment of LWR Operations in Future Grid Markets


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The LWRS Program recently completed the demonstration of a new analysis tool that can be used to investigate options for enhancing the economic performance of existing nuclear power plants in current and future grid markets by diversifying the usage of the steam and electricity produced by these plants. This computation program, named HERON (for Holistic Energy Optimization Network), performs robust stochastic techno-economic analyses of LWR operations under both regulated and deregulated grid market conditions that progressively change over time. With the advancement of natural gas power plants and the subsidized buildup of solar and wind energy in many regions of the country, it is becoming increasingly important for owners of traditionally baseload power plants to develop strategies to operate in grid markets tending toward hour-ahead, and even minute-ahead, market decisions. HERON was specifically developed to evaluate the economic performance of flexible plant operations that include electricity production for the grid market plus energy storage or the production of other non-electrical products during specific periods of time to help raise the revenue of the nuclear plant. This mode of operation allows the nuclear plant to continue operating at its fullest capacity.

HERON's primary strength, in comparison to other grid economics analysis tools, is its focus on the capability to optimize the scale and dispatch of flexible plant operations and generation, considering multiple markets and their performance over the long-term. By predicting grid market changes over time and applying condition-dependent payments for dispatchable electricity and grid services that may become available, HERON provides insights into how the design and flexible operation of nuclear power plants can be optimized. An evaluation of case-by-case alternatives can then be made and used to develop strategies for operating nuclear power plants into the future.

The latest advancements to HERON were made in collaboration with the Electric Power Research Institute (EPRI). EPRI and LWRS Program researchers identified several policies, markets, and scenarios that LWR owners and operators may face in the next 30 years. A set of case scenarios and parameters were then developed for future markets that include 100% renewable portfolio standards, carbon tax policies, and alternate capital cost assumptions. HERON was advanced to meet the analysis demands of these scenarios. The EPRI team then applied US-REGEN (a deterministic capacity expansion model developed by EPRI, [1]) to project the marginal cost and dispatch order of generator capacity outputs. These outputs were then used by HERON to complete an analysis of the potential economic benefits of introducing hydrogen generation as an Integrated Energy System under the various market conditions. [2]

Figure 13 illustrates the concept of how a LWR may intermittently switch between the electricity market and the hydrogen market throughout a year. This is one of the scenarios of flexible operation of a nuclear plant being considered. With the goal of maximizing the revenue of the nuclear power plant, a simple "switch-over" selling price of electricity was determined for hourly scheduling of the nuclear power plant to sell power to the grid. Anytime the projected marginal electricity price exceeds the switch-over price, the plant will rapidly turn down hydrogen production and dispatch power to the grid. Conversely, when the price of electricity is projected to be low, the plant will ramp up hydrogen production. The switch-over price may vary throughout the life of the project as a function of the change in the mix of power generation capacity. With the ability to rapidly ramp hydrogen production up and down, flexible plant operations could help regulate the grid. The value of such services may become valuable in future grid markets as recognition of systems that can help stabilize and provide

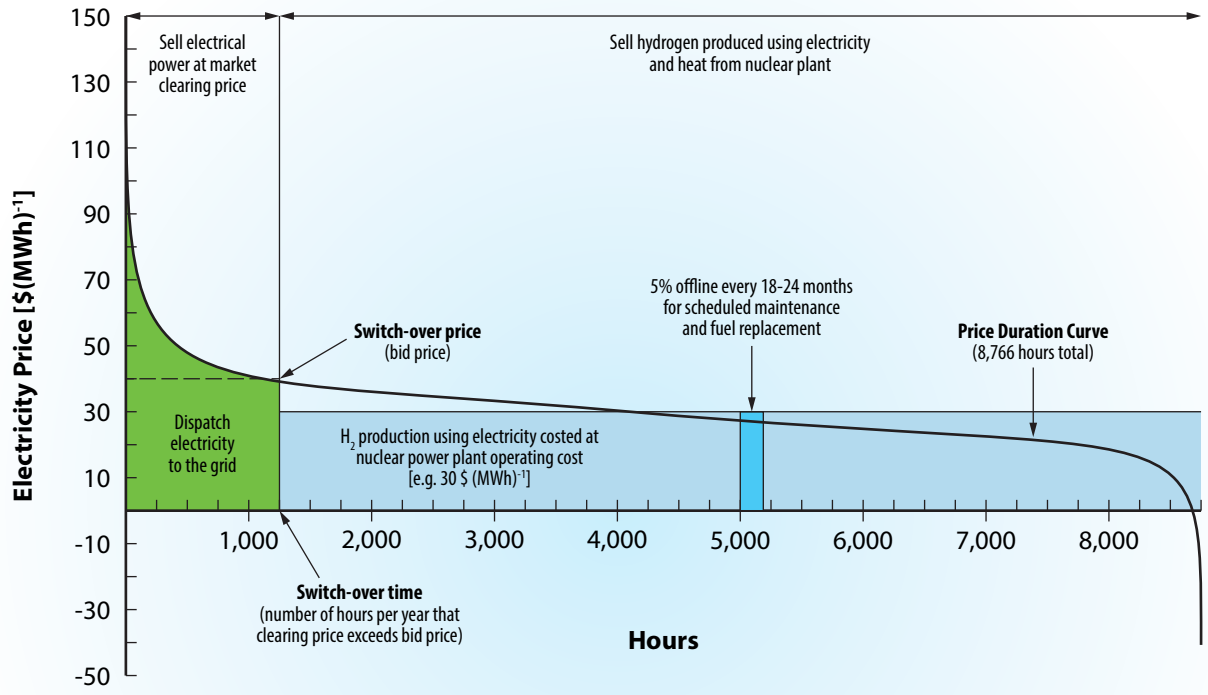

Figure 13. A sample light water reactor nuclear power plant apportionment of power to the grid and hydrogen production.

a more resilient grid is becoming evident with extreme weather events throughout the county and almost all places around the globe.

The HERON analysis of regulated and deregulated market scenarios demonstrated economic benefit to introducing hydrogen generation via flexible plant operations. In particular, if nuclear and renewable energy technology costs are expected to maintain current trajectories, substantial benefits are likely from introducing hydrogen generation as an Integrated Energy System to an existing LWR. Further, in the event of low nuclear technology costs and high variable renewable costs, and in the presence of carbon tax or 100% renewable portfolio standard policies, significant benefits are also likely from introducing hydrogen generation as an Integrated Energy System to existing LWRs.

Public release of HERON has been initiated to enable academic and commercial users to begin using this tool to evaluate new markets for LWRs. These latest improvements to HERON make it possible to evaluate various LWR plant operation options such as hydrogen production as well as the direct use of thermal energy by process industries. HERON uses data for grid market forecasts that are often available from utilities or which can be generated by capacity expansion models such as US-REGEN. The LWRS Program report for this activity provides guidance on how this is done.

References

1. U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) Model. Available at https://www.epri.com/research/products/000000003002016601
2. Talbot, P.W., et al. 2020. Evaluation of Hybrid Flexible Plant Operation and Generation Applications in Regulated and Deregulated Markets Using HERON. INL/EXT-20-60968, Revision 0.