Hybrid renewable energy projects

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For a 60-minute period in January 2023, a power plant like no other existed in the U.S. Mountain West. It contained a solar array, lithium-ion battery, hydrogen electrolyzers, and a nuclear reactor, all coordinating with each other to provide reliable power. Even more unusual, the plant combined real and simulated technologies hundreds of miles apart.

This unique power plant was part of a national research and development project to remotely connect energy assets in real time using the Department of Energy"s (DOE"s) Energy Sciences Network (ESnet). By linking capabilities at the National Renewable Energy Laboratory (NREL) and the Idaho National Laboratory (INL), the researchers created a collaborative "SuperLab," which allowed them to study energy systems currently not in existence. In this case, they demonstrated that renewable and nuclear energy, combined within a hybrid system, can complement each other well to support the grid.

"Integrating nuclear assets deployed at INL and connecting them with renewable energy assets at NREL showcases the power of energy hybridization technology and underscores the importance of connectivity in achieving sustainable energy solutions," said Rob Hovsapian, ARIES research lead in hybrid energy systems at NREL. "Innovation without implementation is merely an idea, but at-scale validation is the bridge that makes ideas a reality. The Advanced Research on Integrated Energy Systems (ARIES) platform at NREL is the engine that powers this evolution, connecting multiple assets and de-risking complex energy systems for faster adoption of novel clean energy technologies."

The SuperLab demonstration successfully linked energy grid and power production simulations from two laboratories:

ESnet-operated fiber-optic cabling provided high-speed, low-latency, and low-jitter data connections between the two laboratories. This connection synchronized simulations and control signals, providing "virtual proximity" of the assets.

This SuperLab demonstration followed months of preparation by several dozen researchers at INL, NREL, and ESnet. The demonstration was attended by over 60 energy experts, including representatives from other national laboratories and DOE representatives from the Office of Science, the Office of Nuclear Energy, the Office of Electricity, and the Office of Energy Efficiency and Renewable Energy.

The SuperLab demonstration showed that nuclear power and renewables could be used in combination for the electric grid. Nuclear reactors operate best in a steady state as a source of baseload power but cannot respond

quickly to changes in demand. Wind and solar power can provide intermittent power but are not always dispatchable. Together, they provide stable power during abrupt changes in demand or weather conditions. And for an extra-functional design, the researchers added hydrogen electrolyzers and thermal batteries to store excess power.

"A hybrid plant that incorporates both nuclear and renewable assets allows us to leverage the unique benefits offered by each of these clean energy technologies," said Shannon Bragg-Sitton, Integrated Energy & Storage Systems Division director at INL. "It ensures that grid demands are met reliably and affordably at all times while taking advantage of the heat provided by a nuclear thermal generator to produce clean hydrogen and support the decarbonization of industry."

During the demonstration, the researchers found that their hybrid plant performed as desired. First, they simulated a sudden loss in solar power from a passing cloud, and the nuclear reactor stepped in to support grid demand. Then, when they simulated a storm knocking out neighborhood power lines, the nuclear reactor ramped down its power to the grid and redirected it to increasing hydrogen production and storage. These scenarios provide developers a baseline and high-quality operational data for how hybrid renewables-nuclear designs might operate together for a reliable power grid.

"Demonstrating integrated use of diverse generation assets in a controlled experimental facility allows us to better understand how these systems can mutually support a varying energy demand before major investments are decided," Bragg-Sitton said. "These demonstrations can emulate performance under both expected and off-nominal conditions to gain confidence in their operations. Through this SuperLab, each laboratory in the DOE complex brings unique expertise to the challenge of clean energy systems of the future."

The January demonstration was not just an achievement for hybrid power plants, as it also made strides for the network backbone supporting SuperLab: ESnet. This demonstration was one of several, with more ahead, to connect megawatts of power hardware using ESnet. In 2017, eight laboratories connected for the first demo using virtual private network connections, shown in the video below. It was a successful proof of concept, but varying latency made it difficult to cosimulate power signals requiring millisecond sensitivity.