OAK RIDGE NATIONAL LABORATORY

Modernizing US Hydropower: The Digital Twin for Hydropower Systems Project



The Challenge: Aging US Hydropower Infrastructure

The US hydropower fleet, with an average machine age of 64 years, represents the nation's longest-serving renewable energy technology. However, to sustain and enhance its value and reliability, this aging infrastructure requires significant modernization. As the energy grid evolves to prioritize efficiency and resilience, and with the increasing integration of variable renewable energy sources like wind and solar, hydropower must adapt to successfully support new energy generation paradigms. The challenge lies in integrating recent technologies such as advanced control systems, analytics, simulation, and optimization software to ensure hydropower can continue its critical role in the US energy grid.

The Solution: Digital Twin for Hydropower Systems (DTHS)

To address these challenges, the US Department of Energy's Water Power Technologies Office has launched the Digital Twin for Hydropower Systems–Open Platform Framework (DTHS-OPF) project, jointly executed by Oak Ridge National Laboratory (ORNL) and Pacific Northwest National Laboratory (PNNL). As shown in Figure 1, a digital twin (DT) is a virtual representation of a physical entity, created using data from sensors, simulations, and historical records. In hydropower, DTs provide a dynamic, real-time virtual model of a facility, enabling operators to monitor and optimize performance, predict maintenance needs, and optimize energy production.

The DTHS-OPF initiative aims to develop an open platform framework that integrates data from legacy systems and recent technologies, making it accessible and interoperable across the hydropower industry. This platform is designed to be affordable, user-friendly, and capable of advancing with future technological developments. By adopting DT technology, the US hydropower fleet can reduce operating costs, improve reliability, and enhance grid resilience.

ADVANTAGES OF DIGITAL TWINS

- OPTIMIZED ENERGY PRODUCTION
- PERFORMANCE MODELING AND PREDICTIVE MAINTENANCE
- IMPROVED RESOURCE MANAGEMENT AND ENVIRONMENTAL STEWARDSHIP



R.C. Thomas Hydroelectric Project, Polk County, Texas (image courtesy of Simpson Gumpertz & Heger)

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Impact and Vision: Transforming Hydropower with Digital Twins

The DTHS-OPF project is a critical first step in a long-term vision to modernize the US hydropower fleet through digitalization. By creating a standardized, extensible platform, the project aims to make DT technology a best practice for hydropower design, operation, and management. The benefits of this technology include the following:

- **Optimized Energy Production:** Through simulations and data analysis, DTs help operators adjust turbine settings, manage water reservoirs, and align energy generation with demand, maximizing efficiency and output.
- **Improved Performance Monitoring and Predictive Maintenance:** DTs enable operators to monitor facilities in real time, identify deviations from optimal conditions, and predict equipment failures before they occur, reducing downtime and unplanned outages.
- **Enhanced Resource Management and Environmental Stewardship:** DTs model water flows, reservoir levels, and environmental factors, allowing operators to make informed decisions that minimize water use and environmental impact.

Integrating Real-World Applications: A Glimpse into the Field

The potential of DTs in hydropower technology is already being explored in real-world settings. For example, ORNL and PNNL collaborated with Tacoma Public Utilities and Chelan County Public Utilities District to implement a DT at the Alder Hydroelectric and Rocky Reach Dam Developments in Washington State. By collecting data on water levels, flow rates, and other critical parameters, the DT was trained and validated against real data. This allowed operators to monitor and optimize the facility's performance, demonstrating the practical benefits of DT technology in hydropower. In addition, a DT provides a platform for research communities to further their general research activities on a wide spectrum of hydropower systems topics.

Norris Dam, Anderson County, Tennessee (image courtesy of Brennan Smith)



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