Penstock Performance Monitoring Digital Twin

- Gain understanding of the negative impacts that primary, secondary frequency control and starts and stops have on penstock structural integrity
- Conduct real-time transient pressures monitoring throughout the penstock and water conduits
- Enhance hydropower critical infrastructure through advanced monitoring

Background, Objectives, and New Learnings

Hydropower is the largest source of low-carbon electricity generation, surpassing nuclear and all other renewable energy sources combined[1]. The prevalence and attributes of hydropower make it a key enabler of Variable Renewable Energy (VRE) sources and an instrumental part of the clean energy transition. As the worldwide hydropower fleet ages, proper approaches to monitoring the condition and health of mechanical components are needed to avoid unplanned outages or possible failures and support the resource's role in a low-carbon energy future.

Today hydropower is evolving, as changes in electricity markets and new requirements by transmission system operators are altering facility operation. While extensive research has been conducted on the negative impacts these changes may have on turbine components, few studies have focused on the penstock and water conduit system. This project aims to address this gap by enabling real-time monitoring of hydraulic transients caused by changes in hydropower operation.

Monitoring of the hydraulic circuit, compared to the power-unit, is limited. Therefore, this project intends to offer new learnings in the real-time monitoring of critical parameters in the penstock and water conduits, such as stress-time history throughout the water conveyance system without the physical installation of sensors in-situ. Real- time monitoring may offer an enhanced understanding of the negative impacts that primary and secondary frequency control and starts and stops have on penstocks water conduit structural integrity.

Benefits

This project aims to increase hydropower plant reliability and safety through advanced monitoring. Researchers intend to better understand the negative impacts of primary and secondary frequency control and start/stop on the structural integrity of penstocks. The analysis of results from different hydropower plants may provide the ability to evaluate penstock levels of stress of the host site. In addition, the findings may help identify the most critical points along the penstock with respect to fatigue to help avoid unplanned outages or possible catastrophic failures.

Project Approach and Summary

A physically based digital twin will be implemented in one (1) hydroelectric power plant featuring low or medium head Francis turbines or reversible pump-turbines, to monitor penstock fatigue resulting from normal operation over a 12-month period. To this end, a tested solution on other hydroelectric power plants will be used to achieve a real-time simulation of the one-dimensional hydraulic system, including the water conduits and the hydraulic machines

[1] IEA (2021), Hydropower Special Market Report, IEA, Paris
https://www.iea.org/reports/hydropower-special-market-report

transient behavior [2,3]. The deployment of the penstock performance monitoring digital twin requires remote access to a workstation located within the plant to run the real-time simulation. The simulation will be performed on the basis of the boundary conditions measured on site and to allow an efficient system maintenance. The numerical model will be calibrated and validated during the first phase of the project through comparison with site measurements. The immediate benefit of this digitalization is that it allows the non-measured/non-measurable quantities, such as pressures throughout the water conduits, to be monitored at all times without the physical installation of additional sensors. Using the appropriate penstock structural mode, these pressures can be related to the stress-time history. The fatigue assessment of each penstock segment can then be performed by tallying the cumulative damage resulting from the different ancillary services and operating sequences. The approach yields the penstock level of structural stresses as a function of the operating mode. The analysis of the results obtained from chosen hydroelectric power plant intends to draw conclusions and recommendations with respect to the impact that primary and secondary frequency control and starts and stops have on penstocks' water conduit structural integrity.

Deliverables

- Hydropower plant digital twin operational at host power plant to collect pressure and stress time histories
- Bi-annual webcasts—and an in-person meeting at the end of the project—to provide updates and lessons learned
- Final report on contribution from primary and secondary frequency control and starts-stops to penstock structural integrity. The report will include the penstock fatigue results from chosen hydroelectric power plant based on digital twin outcomes.

Price of Project

The price to join the project as a host will be determined by the host site characteristics. The price can be paid over two years. This project is eligible for Self-Directed Funds, Tailored Collaboration, and co-funding.

Project Status and Schedule

The project is expected to take approximately two (2) years.

Who Should Join

The outcomes from the project are critical to all stakeholders in the hydropower sector. The results obtained may provide the basis to more broadly understand the negative impacts that primary and secondary frequency control and starts and stops have on penstocks and water conduits' structural integrity in hydropower plants. The risk of failure is generally greater in older plants or in equipment subjected to cyclic operation; therefore, members who operate hydropower assets (Francis, Kaplan, propeller, pump-turbines, and Pelton) and who have recently experienced an increased in changing loads to support electric grid reliability are encouraged to participate in this project.

Contact Information

For more information, contact the EPRI Customer Assistance Center at 800.313.3774 (askepri@epri.com).

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[2] Dreyer, M., Nicolet, C., Gaspoz, A., Gonçalves, N., Rey-Mermet, S., Boulicaut, B., *Monitoring 4.0 of penstocks: digital twin for fatigue assessment*, Proc. of the 30th IAHR Symposium on Hydraulic Machinery and Systems, Lausanne, Switzerland, March 21-26, 2021, Virtual conference.

[3] Dreyer, M., Nicolet, C., Gaspoz, A., Biner, D., Rey-Mermet, S., Saillen, C., Boulicaut B., *Digital clone for penstock fatigue monitoring*, Proc. 8th IAHR International Meeting of the Workgroup on Cavitation and Dynamic Problems in Hydraulic Machinery and Systems, October 9-11, 2019, Stuttgart, Germany.

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