Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

IN SITU TURBINE STARTUP OPTIMISATION USING VIRTUAL SENSORS AND ACTIVE LEARNING

Martin Gagnon[1*], Vincent Mai[1], Quang Hung Pham[1], Arthur Favrel[1], Jean-Philippe Gauthier[1]
[1]Institut de recherche d'Hydro-Québec (IREQ), Varennes, Québec, Canada
*gagnon.martin11@hydroquebec.com

ABSTRACT

Hydroelectric turbine startup optimization is more and more used to maximize remaining useful life (RUL) of the runner blades. Given that turbine startups tend to generate high amplitude strains on the runner blades leading to eventual fatigue cracking, optimizing the turbine startup control parameters can minimize the generated strain amplitudes dynamic range. However, using trial and error during a dedicated measurement campaign can be costly and does not guarantee finding an optimal set of control parameters.

We propose using virtual sensors, simulation models and active learning to accelerate the startup optimization process during the blade strains measurement made as part of the turbine commissioning. Virtual sensors leverage the use of machine learning to estimate the turbine blade strain using inputs obtained from numerical simulations. By coupling virtual sensors and the numerical model to a black-box optimization technique, optimal control parameters can be obtained by focusing on overall strain ranges, startup time and uncertainty estimate. With the active learning approach, new control parameters can be tried after each optimization iteration and the new strain data used to retrain the virtual sensor. The optimization loop is then run again to provide the next optimal control parameters set to test. This is repeated until convergence, ensuring that an optimal set of parameters is obtained with a minimal budget of trials.

The approach was implemented on a medium head turbine at one of Hydro-Quebec facilities. The results showed fast convergence to optimal control parameters, while enabling constraints like startup time requirements. The algorithm successfully identified an optimal startup sequence using only seven measured sequences, resulting in a 42% reduction in the maximum strain range compared to the initial startup sequence. This paves the way for more efficient HGU startup optimization and RUL maximization.