HARMONIC MODAL ANALYSIS USING SIMULATED HYDROELECTRIC RUNNER STEADY-STATE STRAIN GAUGE MEASUREMENTS

Nicolas Morin¹, Quentin Dollon², Jérôme Antoni³, Antoine Tahan¹, Christine Monette⁴, Martin Gagnon²

¹ Mechanical Engineering Department, ÉTS Montréal, Montréal, Canada
² Institut de Recherche d’Hydro-Québec (IREQ), Varennes, Canada
³ Lab. Vibration Acoustique, Univ. Lyon, INSA-Lyon, Villeurbanne, France
⁴ Andritz Hydro Ltd, Pointe-Claire, Canada

ABSTRACT

Integrating wind and solar energy sources to the power grid has the effect of stretching the operating range of hydroelectric turbine-generator units. Off-peak operations of turbines result in new loadings accentuating fatigue degradation of the runner, entailing the need for a better understanding of its dynamic behaviour. This knowledge would enable the reduction of uncertainties on physical properties and increase confidence in the predicted modal characteristics. It can result in an improvement of fatigue analysis tools, life estimation and diagnosis tools, and allows the better-suited design of turbines to the fluctuating demand.

It has been recently shown that the interaction of synchronous vibrations generated by casing non-uniformities and natural modes of the runner can give rise to resonance. Those non-trivial rotor-casing interactions (NTRCI) can be of lower periodicity than typical rotor-stator interactions (RSI). The wide harmonic content of NTRCI brings an opportunity for a new, nodal diameter-specific, steady-state harmonic-based modal analysis method of the runner. The research project aims to evaluate, from strain gauge measurements, Francis runner modal parameters in steady-state conditions using harmonics generated by the interaction between natural modes and runner-casing interactions. The method is developed near the best efficiency point (BEP), a regime with dominant harmonic excitations and marginal stochastic excitations.

Under a Bayesian inference-based methodology, using a harmonic forced response model of the runner and simulated strain gauge measurements, a probabilistic identification tool is developed to evaluate the modal parameters of the runner and the associated uncertainties. The harmonic forced response model implies that each NTRCI-generated harmonic observed in the measured response is modulated according to its proximity to specific natural modes. The excitation roots are defined as periodic and independent of those modes. Hence, the excitation’s Fourier coefficients, the modal parameters of the runner and a homoscedastic error can be inferred using a Metropolis-Within-Gibbs algorithm. The approach is built on a prediction error model using a physical model-based likelihood. The probabilistic identification algorithm’s robustness is evaluated, in the first stage, on a virtual two-degrees-of-freedom model with a one-per-revolution periodic excitation and varying noise intensities. Then, in the second stage, the algorithm is evaluated on a more complete model simulating prototype runner strain measurement which includes RSI periodicity.