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”SYSID#2 - Harmonic Modal Analysis Using Hydroelectric Runner Steady-State Strain Gauge Measurements”

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Hydroelectric turbine runners’ fatigue life is reduced by more recurrent off-peak operations induced by the integration of wind and solar energy sources to the power grid. This increase in fatigue degradation entails the need for a better comprehension of runners’ dynamic loadings and responses. This needed knowledge includes a more accurate prediction of runners’ modal characteristics and solicitations. It allows better-suited design of turbines to the fluctuating demand and improves fatigue analysis tools, life estimation and diagnosis tools. Analysis of Francis runners’ operational vibrations has recently shown that non-trivial rotor-casing interactions (NTRCI) can give rise to resonance. Those NTRCI, induced by the interaction of turbine casing non-uniformities and natural modes of the runner, generate a richer harmonic response than typical rotor-stator interactions (RSI). It is proposed in the literature that the amplitude of each harmonic observed in the runner’s forced response resulting from NTRCI, and RSI, is modulated according to its proximity to specific natural modes. The synchronous excitation from the casing is defined as periodic and independent of those modes, allowing the decomposition of the excitation in distinct Fourier coefficients. This brings an opportunity for a new, nodal diameter-specific, steady-state harmonic-based modal analysis method of the runner. This paper proposes a method to be best suited near the best efficiency point of operation, where harmonic excitations dominate stochastic excitations, non-ideal conditions for usual operational modal analysis algorithms. The proposed Bayesian inference-based methodology uses Francis runner strain gauge measurements and a harmonic forced response model to evaluate the modal parameters of the runner and the associated uncertainties. The probabilistic identification tool relies on a prediction error model using a Metropolis-Within-Gibbs sampling algorithm and a physical model-based likelihood to infer the excitation’s Fourier coefficients, the modal parameters of the runner and a homoscedastic error. The modal identification method was implemented on a model simulating NTRCI and RSI harmonics observed in steady-state strain gauge measurements. The method was shown efficient to identify the modal parameters and the harmonic excitation of the model. In this paper, the algorithm’s robustness is evaluated on real Francis runner prototype strain gauge measurements in steady-state operating conditions.

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